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Extended Abstracts

(listed in alphabetical order, by presenting author)

The Development of Benoa Port as Bali Maritime Tourism Hub (BMTH)

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Summary
Port of Benoa-Bali is among major port destination for cruiseships in Indonesia. During the last five years, Port of Benoa has been upgraded and transformed into Bali Maritime Tourism Hub (BMTH) in order to cater more cruiseship calls, thus generate multiplier benefits from the cruise tourism. The paper highlight the project challenges, from the point of views of Indonesia's central government, Bali's regional authorities and port operator (PELINDO) and the local communities. Various government policies and regulation have been implemented in order to accelerate BMTH development. Technical and environmental aspects during the construction are also described in this paper.
Keywords: Bali Maritime Tourism Hub, cruise terminal, dredging, working with nature

1. Introduction

Known as the Island of the Gods, Bali is an island paradise that attracts many foreign tourists to visit. Ancient temples, magical sunsets, traditional villages, beautiful beaches and traditional crafts are some of the island's most remarkable attractions. Bali's uniqueness also contribute to its status as popular cruise destination in the Asia-Pacific region. The Port of Benoa is the major cruise terminal in Bali as well as in Indonesia.

In order to accommodate more and larger cruise ships to visit Benoa Port, longer berth and deeper channel are needed. This paper describes the recent development of Benoa Port as Bali Maritime Tourism Hub (BMTH). The BMTH project is one of the national strategic projects stipulated based on Presidential Regulation Number 109 of 2020 regarding the Acceleration of the National Strategic Projects Implementation.

The paper will cover on how the government of Indonesia supports the project, from the preparation stage, construction stage, until the final stage. The role of the Coordinating Ministry for Maritime Affairs and Investments (CMMAI) in coordinating the line ministries to de-bottleneck some issues needing strategic decisions during project execution will be highlited. The prominent issues, among others are: the removal of dead ships and fishing-shipwrecks, acceleration of permits, review of existing Port Masterplan, etc.

2. Area and Project Descriptions

Port of Benoa is strategically located on the eastern side of the southern part of Bali, sharing close proximity to many tourist attractions, beautiful beaches, and other marine-related activities (See Figure 1). As one of major commercial port operate by PELINDO (Indonesia Port Company) Port of Benoa by regulation is among 10 Indonesia Main Ports that has cabotage relaxation so that foreign flag cruise ship may embark and disembark passengers. Figure 2 shows the number of cruise ships visiting Benoa in 2018 and 2019.

Figure 1 Aerial Photo of Benoa Area

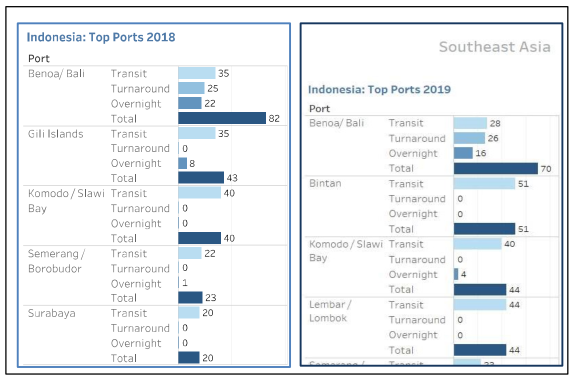

Figure 2 Cruise ship Calls to Benoa is #1 among Indonesia's Top Ports in 2018-2019 (Source: [1], [2]).

Since 2019, construction, dredging and reclamation activities have been done to transform and upgrade Benoa port. The aim is to make Benoa as a Home Port thus able to accommodate more cruise calls, yachts visits, also to serve as tourists destination with parks and beautiful landmarks in the surrounding area. The project's main activities consist of dredging of the harbour basin and channels, dumping and reclamation areas, beautification of terminals, as well as construction of port's supporting areas.

The ultimate development of Port Benoa (BMTH) is to accommodate the 350m-length-cruiseships could enter and berth in Benoa Port. The access channel depth is -12 meter. The berth is 500 meter length, to allow two cruiseship berthing paralelly in the same time. Based on the Port Master Plan, the port the ultimate design development will be done in stages from 2021 to 2040.

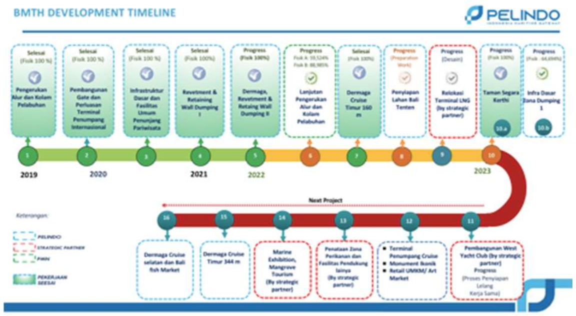

Figure 3 BMTH's Project Timeline (Source: [3]).

Benoa port is a multipurpose port. As a Maritime Hub, the Bali Maritime Tourism Hub will provide berthing facilities for yachts on the west side, with facilities such as wet berth, dry berth, yacht club, sport facility, Lounge & Bar, as well as other supporting facilities such as the Bali Fish Market and local-small enterprise retail. Apart from being the focus of the tourism sector, Benoa Port also provides facilities for the Liquid Bulk Terminal and Container Terminal, also area for fishing vessels and state vessels. Access to those terminals will be different from access to tourism facilities.

3. Challenges and Discussion

3.1 Removal (Salvage) of Rotten Fishing Ships

Within the Benoa harbor, there is a fishing port area. Generally, the ships that anchor there are traditional fishing boats of small to medium size. At the initial stage of BMTH project, there were a lot of unflag/unregistered fishing vessels that were no longer functioning. In total there were 74 rotten fishing ships that need to be relocated, which 35 were unknowns (no ownership) or ships wreck. The removal and scrapping of the ships were not simple, it was involving ships owners, Pelindo as the BMTH's project executor, salvage company, port authority, local government, and the navy. It required strategic decision for the execution, related to: budgets, procedures/regulations, technical, environmental issues, etc. With the lead and coordination of CMMAI, the relocation and removal of the ships wrecks were resolved well. In total, it took about eight months to finish.

3.2 Dredging Works

Dredging work includes dredging of the access channel, turning basin and port basins up to the target depths (see Table 1). The total dredging volume is about 5 million cubic metres.

Table 1 Dredging requirements

Feature	Depth (m LWS)
Access channel	-12 m
Turning basin, Cruise pier basin, LNG pier basin	-12 m
Fisheries basin Yacht basin	- 4 m - 4 and -6 m

The challenges include: Environmental Impact Assessment (EIA) and permits, selection of dumping areas, dredging permits, socials issue (community rejection), and so on.

3.3 Dumping and Reclamation Area

In the early days, this project received a lot of opposition and criticism from the local community and Bali provincial government. Wider reclamation development disrupted sacred areas, mangrove forest and the bay natural beauty, giving rise to protests and reactions from the community. This happened because technical work had not been built on retaining wall and silt screens in accordance with the environmental management permit in the AMDAL (EIA)'s document. But, later on retaining wall and silt screens are in place during the construction works.

3.4 Relocation of the LNG Terminal

Based on the Master Plan, the Benoa port consists of three blocks, the first is the oil and gas terminal block, the cruise terminal block and the marina block. The existing LNG terminal (in the southern part) currently is bellow the landing path of I Gusti Ngurah Rai Airport, thus it will be relocated to the northern part,as indicated in the Master Plan (Figure 4).

Figure 4 Port of Benoa (BMTH) Master Plan (Source: [3])

4. Conclusion

The development of Benoa port as a Bali Maritime Tourism Hub has many challenges and opportunities. The success of this project requires synergy and support from various related parties: relevant ministries, contractors, Bali Provincial Government, Denpasar City Government, security forces and the community. Working with nature is one of the key success factors for development projects in Bali.

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Relevant UN SDGs (*https://sdgs.un.org/goals*): 8, 9, 11, 14.

Upgrade for the Maritime Police Wharf (MPW) on Betio Island

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Summary
This paper outlines the upgrades to the Maritime Police Wharf (MPW) on Betio Island to improve its capacity to support Guardian Class Patrol Boat (GCPB) vessels. It identifies problems including the need for dredging a deeper berth pocket and limited data for as-constructed details. The approach involves remote data collection challenges, analysis and detailed design. The proposed upgrades included the installation of submerged sheet piles and scour protection to future proof the wharf apron.
Keywords: Port Planning and Engineering, Dredging, Sheet-piling, Scour Protection, Betio Island, Kiribati.

Introduction
The Maritime Police Wharf (MPW) on Betio Island, Tarawa Atoll needs to accommodate Guardian Class Patrol Boat (GCPB) vessels as part of the the Australian Department of Defence's Pacific Maritime Security Program. The existing MPW Wharf comprises a bulkhead sheet-piled wall with a concrete facing capping beam, anchored by H piles and connecting tie rods.
This paper outlines the design approach for upgrades to enable the MPW to provide safe and efficient berthing and mooring facilities for the new GCPB.

Problem
A number of issues needed to be addressed as part of the wharf upgrade including:
a) Berthing pocket dredge depth - the berthing pocket required dredging to a minimum depth of -3.4 meters (LAT). However, the new depth impact the overall stability, deflections, and internal forces of the quay wall.
b) As – built details and condition of buried elements - the existing wharf's details and condition of tie rods and anchors was unknown.
c) Future scour - the possibility of scouring occurring due to the vessel's propellers, which could affect the quay wall's stability.

Approach
The approach for detailed design generally included four main steps: 1) Data gathering 2) Early analysis and concept solutions 3) Detailed geotechnical and structural modelling and analysis 4) Safety in design and Detailed Design. The design flowchart of this process is provided in Figure 1.

Data Gathering
Our inspection of the MPW wharf included the unearthing of a select tie rod and anchor pile section to allow direct measurement. The inspection noted that whilst all elements were in very good condition and without visible evidence of corrosion or defects, the diameter of the rods and the distance between the anchor piles and the sheet-piled wall are less than what was expected from the available documentation. Additionally, during the geotechnical investigation, three (3) boreholes were drilled along the quay wall to a depth of 28 meters. These boreholes indicated that the ground consisted of approximately 5 to 6 meters of fill, followed by very loose to medium-dense coral sand and gravel (with a thickness of 7 to 15 meters). This layer overlies a late Quaternary coral reef, which is characterized as medium-dense to dense coral sand and gravel down to the borehole termination depth.

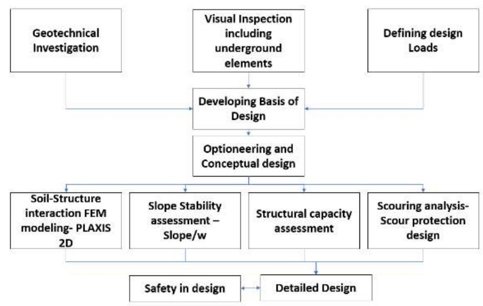

Figure 5 Design Flowchart

Conceptual Design
Preliminary analysis of the wharf was competed using WALLAP and Slope/w software. The analysis indicated that the factor of safety (FOS) for the quay wall, after dredging to -3.4 meters (LAT), would be under the minimum FOS requirements (1.3 for static condition and 1 for seismic condition), and consequently, any further dredging, over-dredging, or scouring could compromise the integrity of the quay wall. Further analysis also noted that, under seismic conditions, the toe of the sheet pile would be at risk of failure.
The available options for improving the FOS were:
a) Install a row of sheet piles with the top level at the seabed to enhance the toe capacity of the existing wall.
b) Install a new sheet piled wall designed to work in conjunction with the existing structure.
c) Install a completely new sheet piled wall, rendering the existing structure redundant.

Based on the preliminary modelling, the first option was selected as this would meet the capacity requirements for the wharf, could be built safely, and could reduce the cost impost on the project.

Geometry and Loading
The designed geometry at the quay wall Section is shown in Figure 2. The design considers the following:
- Top of the submerged sheet-piled wall to be at -2.0 m (LAT) and the toe at -14 m (LAT).

- The gap between the existing wall and the submerged sheet-piled wall from -2.0 m (LAT) to -3.4 m (LAT) is filled with concrete to provide a rigid bearing connection between the walls.

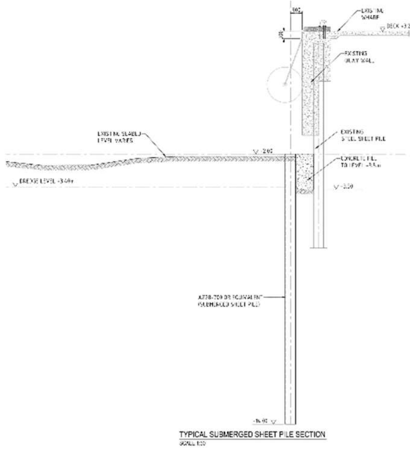

Figure 6 Geometry at wall section

In accordance with AS 4997 [1], load combinations across four categories (Serviceability, Stability, Strength, and Seismic) were considered for geotechnical and structural analysis.
The load cases encompassed various factors including dead load, soil pressure, surcharge, mooring loads, tidal lag, and seismic effects.

Soil-Structure interaction analysis

The FEM based program PLAXIS 2D [2] was used to carry out the soil-structure-interaction assessment.
The results indicated that the global stability factor of the system varied between 1.27 and 1.67 for different load combinations after the installation of a new submerged sheet pile. Figure 3 illustrates the geometry and total displacement results.

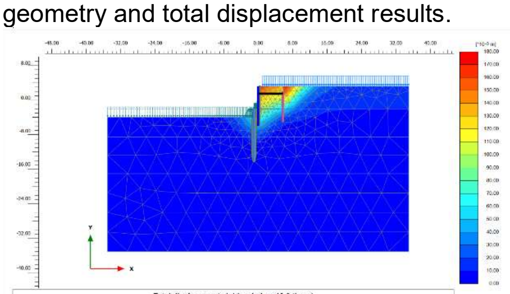

Figure 7 PLAXIS 2D model

Slope Stability Assessment

The Slope/W module of GeoStudio program [3] was used to carry out the slope stability assessment.
The Morgenstern-Price method was adopted to compute the safety factor of the slope with and without submerged sheet piles.
The results demonstrated that the FOS improved from 1.04 without submerged sheet-pile to 3.324 with the installation of submerged sheet-pile. Figure 4 shows the critical slip surface of the quay wall with submerged sheet-pile.

Structural Assessment

The capacities of submerged sheet piles, existing sheet piles, anchor piles, and tie rods were checked in accordance with AS 4100 [4]. The sheet pile capacities were found to be greater than the internally mobilized forces resulting from the soil-structure interaction model.

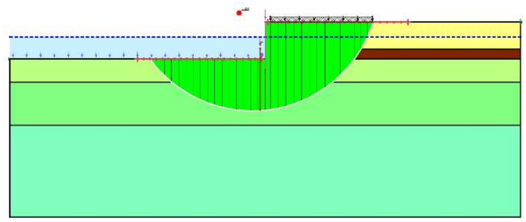

Figure 8 Critical slip surface

Scour protection design

A scour protection system was designed on considering the potential scouring caused by vessel propellers, which could lead to seabed erosion in front of the sheet-piled wall and subsequently impact the quay wall's stability.
Based on PIANC Report n° 180 – 2015 [5], the Dutch method was utilized for the protection design. Table 1 summarizes the input parameters and resulting velocities obtained through the Dutch method.

Table 2 Flow velocities

Parameter	Value
maximum engine power (PD)	2X2000 W
percentage of power used (fp)	40%
propeller diameter (Dp)	1.6 m
outflow velocity (Vo)	9.85 m/s
maximum velocity near the bed caused by Two propeller (Vb,max)	2.40 m/s

The minimum thickness of the concrete mattress calculated as 250mm using the method was determined using the Pilarczyk formula.
In addition, to ensure that this upward force remains smaller than the submerged weight of the bottom protection, Bernoulli's Law is utilized.

Discussion and Conclusion

In conclusion, this paper shows how to upgrade the MPW wharf effectively. Based on a site investigation, detailed analysis and designing solutions, we can address challenges like dredging and unknown construction details. The proposed upgrades, including submerged sheet piles and scour protection, significantly enhance the wharf's stability and safety.

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Field Measurement and Numerical Modelling of Resuspended Sediment due to Tugs

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Summary
The study aimed to assess the risk of resuspended sediment due to tugs reaching seawater intakes and impacting nearby seagrass areas. Field measurements for vessel movement at an existing facility informed hydrodynamic modelling of sediment concentration and plume dispersion. Key findings included the identification of tug-induced turbidity as a project risk and the establishment of a model to predict suspended sediment concentrations at points of interest. The study's outcomes are crucial for future planning and environmental compliance.

Keywords: sediment resuspension, field measurements, TUFLOW FV modelling, environmental risk, Alcoa Jetty, Western Australia.

Introduction

The study addressed the potential risks associated with sediment resuspension due to tug propeller-induced current (prop wash). The study objective was to assess the risk of sediment reaching seawater intakes and impacting nearby seagrass areas. Several seawater intakes for existing power plant cooling and the Perth Seawater Desalination Plant (PSDP) are located close to the Alcoa Jetty.

Potential risks were identified that tug-induced turbidity from vessel movements could elevate the total suspended sediment (TSS) concentration at the intakes and increase light attenuation impacting nearby seagrass habitats (Figure 9). The study area shown in Figure 9 includes the area between Alcoa Jetty and the PSDP intakes. The seagrass area of interest is approximately 900m west of the end of Alcoa Jetty.

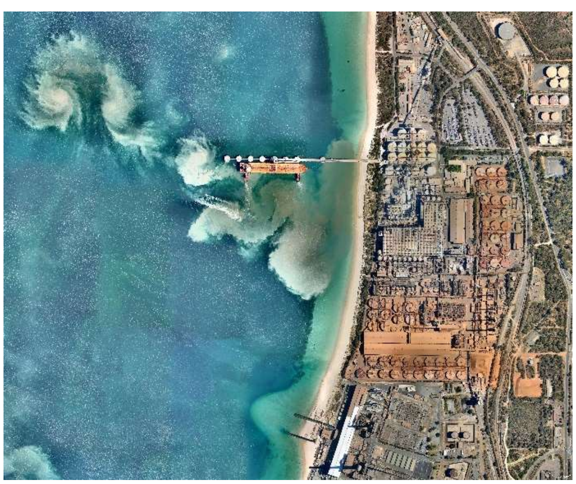

Figure 9: Identification of potentially elevated concentrations of TSS at PSDP due to tug prop wash (Nearmap, 10 December 2013)

Method

To evaluate potential for resuspended sediment entrainment at points of interest due to tug prop wash, the following tasks were undertaken:

- Preliminary drone flight to determine timing and sequencing of a vessel berthing manoeuvre and tug induced turbid plume evolution and extent;
- Estimation of tug prop wash speed profile determined in accordance with design standards [1];
- Review and characterisation of seabed sediment particle size distribution (PSD) and turbidity profiles;
- Assessment of settlement and advection processes due to currents simulated using the TUFLOW FV model and Sediment Transport (ST) Module, compared to results derived from the field measurement campaign;
- Mapping the extent and concentration of suspended sediment and assessing the frequency of occurrence for TSS concentrations at the PSDP intake and seagrass area.

Field Measurements

The purpose of the field measurements was to inform and validate the numerical model by quantifying the resuspended sediment concentration and plume extent at Alcoa Jetty, resulting from tug prop wash during vessel manoeuvres. Field measurements included:

- Drone aerial imagery of tug activity during vessel turning and berthing manoeuvres informing sampling locations, Figure 10;
- Collection of water samples in the area of tug activity for analysis of PSD and TSS, to inform modelled sediment fractions and settling velocities and develop a site-specific relationship between turbidity and TSS;
- Turbidity profiles from surface to 0.5m above seabed to determine resuspended sediment concentrations within the water column.

Figure 10 Alcoa Jetty during the berthing manoeuvre of KULJAK ARROW at No.2 berth (south) during the field measurement campaign, showing resuspended sediment plume due to tugs (BMT 25/08/2023).

The recorded GPS track for the sampling vessel and sampling waypoints, including sample type per site is shown in Figure 11.

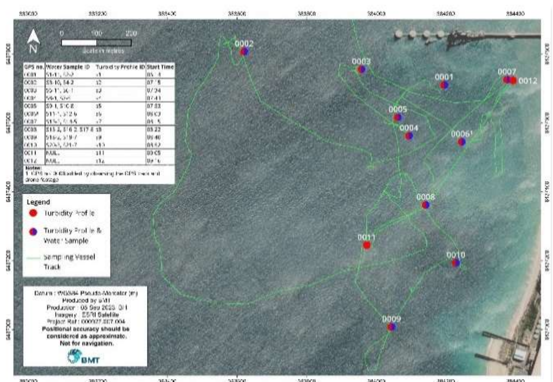

Figure 11 Sampling sites and type of measurements (Alcoa Jetty top right).

Hydrodynamic and Sediment Fate Modelling

TUFLOW FV (calibrated) and ST Module (uncalibrated) were used to simulate sediment resuspension and plume dispersion. Three 1-month periods were modelled, capturing seasonality and variability of currents. Simulations tracked silt and clay sediment fractions to represent material resuspended by tug prop wash.

Drone observations captured the significant contribution of prop wash momentum to driving water circulation within ~1km of the jetty. Motivated by these observations a momentum source boundary condition was calculated based on the tug prop thrust and applied to the plume model in conjunction with the plume source. With the addition of the momentum source, the model was more realistically able to capture local circulation and plume advection generated by tug operations.

Samples derived from field measurements were used to post-calibrate model results. The modelled TSS concentration results were scaled to represent the observed data.

Risk at seawater intakes

Model outputs were analysed to produce 98th-percentile maps (~14.8hours over the 1-month periods) of depth averaged TSS showing extent and concentration of the turbid plume, Figure 12.

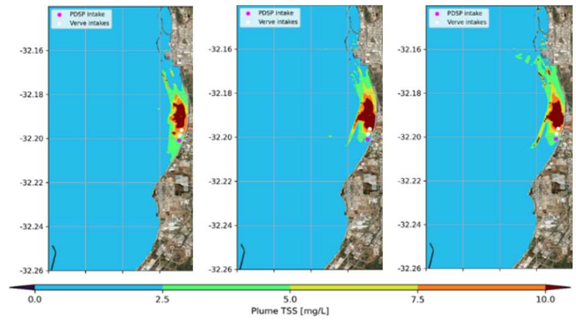

Figure 12 98th-percentile plume TSS for January, May and July 2013 simulations respectively.

The zone of influence defined for this assessment as 98th-percentile tug plume where the TSS>2.5mg/L, which encompassed the PSDP intakes in all three 1-month simulation periods.

Risk at Seagrass Location of Interest

The timeseries of tug resuspension plume TSS (at 2-3m above the seabed) were extracted from the model at a point of interest within an area of seagrass, approximately 900m west of the end of Alcoa Jetty. The results showed low levels of TSS and therefore poses potentially low risk of environmental impact to the seagrass area.

Conclusion and Discussion

Study timing required early model development. Field measurement results were only available near the end of the study, allowing comparison with uncalibrated model results. Modelling indicated a low risk of sediment entrainment at the intake locations due to tug prop wash, and a low risk of impacting the seagrass. Results of depth averaged TSS from the uncalibrated numerical simulation were scaled to represent the TSS levels from field sampling. Further model refinements are possible using or collecting additional field data. The study demonstrates the capability of the proposed modelling and measurement framework for accurately assessing the risk associated with tug propeller sediment resuspension.

References

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Geraldton Port: New Berth Selection

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Summary
The Geraldton Port Maximisation Plan (PMaxP) is a major infrastructure project at the Geraldton Port in Western Australia. BG&E Resources (BGER) has been awarded the Engineering, Procurement, Construction and Management (EPCM) contract for the PMaxP project. The project includes several port layout changes, including addition of a new dry bulk export berth, extension and upgrade of the existing Berth 6 and relocation of the tug harbour to a new facility adjacent to the main western breakwater. This paper presents a high-level overview of the work completed to date to inform the location selection for the new berth.

Keywords: Port Planning, Coastal Modelling, Long Period Waves, Geraldton Western Australia

Introduction
The Geraldton Port Maximisation Plan (PMaxP) is a major infrastructure project at the Geraldton Port in response to a significant projected throughput increase from 15MT to around 25MT per annum over the next 10 years. In May 2022 the Western Australian Government announced major funding approval for Mid-West Ports Authority (MWPA) to initiate the PmaxP project [1]. BG&E Resources (BGER) has been awarded the Engineering, Procurement, Construction and Management (EPCM) contract for the PMaxP project.

The project includes several port layout changes, including addition of a new dry bulk export berth, extension and upgrade of the existing Berth 6 and relocation of the tug harbour to a new facility adjacent to the main western breakwater.

This paper presents a high-level overview of the work completed to date to inform the location selection for the new berth and tug harbour.

Figure 13 Geraldton Port (Source: [1]).

Background
Geraldton Port is impacted by both swell and long period waves (LPW) resulting in broken mooring lines, berthing constraints, and operational downtime. Functional criteria were developed for the proposed new berth to achieve a berth operability equal to or better than the existing berths (Berths 4 to 7) and have no adverse impact on existing berths operability.

The new berth locations assessed are summarised in Table 1 and shown in Figure 4.

Table 3 New Berth Options Assessed

Option 1	Description
New Berth 2	Demolition of existing structure, dredging of SE corner of harbour to lengthen berth pocket. Installation of new piled deck structure above existing revetment.
New Berth 1	New piled deck structure with reclamation north of existing tug harbour required and dredging of a new berth pocket.

The port has been the subject of many previous studies to improve the harbour tranquillity and operability of the port. These have included moored ship modelling exercises that have highlighted the contributions from both swell and LPW's to moored vessel movements and resulting increased line tensions. To quantify the impact of any harbour layout modifications further studies to quantify the wave climate in the harbour were required.

Wave Modelling
BGER engaged Oceanum Ltd to undertake numerical wave model studies of the existing and proposed new berth layouts under a range of offshore wave conditions. A FUNWAVE phase resolving Boussinesq model was used to adequately resolve the complex wave transformation processes that occur over the shallow reef platforms and port entrance region. A 6.6km x 6.1km domain up to about 22m water depth was used, which built on an existing wave model established and validated in 2014 with improved bathymetry under the wharf areas [4].

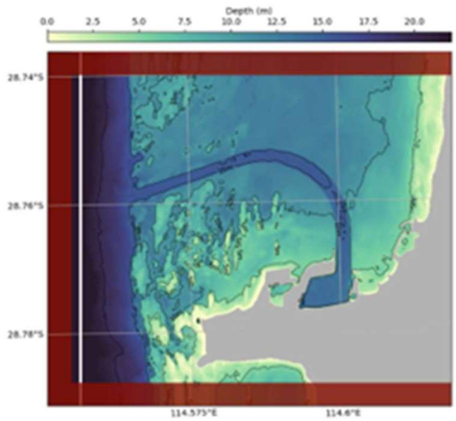

Figure 14 OCEANUM FUNWAVE domain with red patches showing location of sponge layers and the white line indicating the central cross-shore position of the wave maker source function (Source: [3]).

The model was forced with 20 representative events selected using a maximum dissimilarity algorithm to yield a good representation of the range of conditions from the limited set of recorded events.

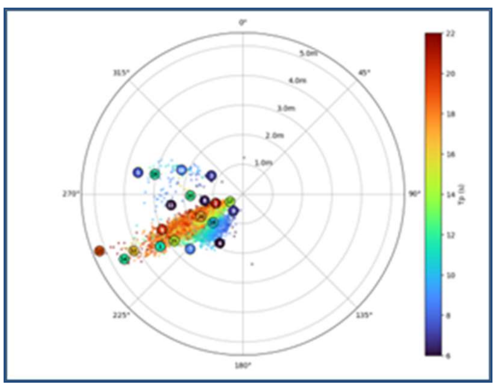

Figure 15 Polar scatter plot showing spread of measured data and the 20 selected events from the MDA. (Source: [3]).

Dynamic Mooring Analysis

BGER engaged Baird Australia Pty. Ltd. (Baird) to conduct a Dynamic Mooring Analysis (DMA) of both Berth 1 and Berth 2. The full FUNWAVE model output (surface elevations and velocities) at each berth was used to determine wave forces on the vessel. This approach was verified against vessel movement measurements at Berth 3.

DMA results found that the required dredging in the southeast corner of the basin for the Berth 2 option resulted in an amplification of LPW waves. This resulted in increased yaw motions in a vessel at Berth 2 compared to Berth 1. Berth 1 was found to be the preferred location based on berth availability.

New Berth Selection

A multi-criteria assessment (MCA) was undertaken to determine the preferred berth location. Criteria were developed in collaboration with MWPA and other stakeholders and included Berth availability (both mooring and berthing), impact on availability of other existing berths, overall functionality, capital cost and environmental impact. The outcome of the MCA was that Berth 1 was the best for Port solution and was recommended to be taken forward to Detailed Design phase.

New Tug Harbour

To increase the ports available space for future berths as well as providing safer tug pens a new facility will be constructed as part of an extension to the Western Breakwater. Additional benefits from this new facility include the creation of an additional reclamation area that can be used for the disposal of dredge spoil and future laydown areas; and a reduction in wave energy entering the Harbour and consequently reduction in the number of port closures.

Figure 16 Ultimate Harbour Layout (Source: [5]).

Conclusion

Initial modelling of this ultimate layout (Figure 4) has shown a significant reduction in LPW energy within the harbour which will result in an increased berth availability at all berths above current levels. Further modelling work and layout optimisation is currently underway as part of the detailed design of the new tug harbour and breakwater extension.

Acknowledgements

BGER acknowledges MWPA for their significant contribution and collaboration on the PMaxP project.

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Engaging the Next Generation of PIANC

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Summary
Engaging the next generation is crucial for PIANC to address key challenges in waterborne transport infrastructure, such as decarbonization and sea level rise. PIANC Young Professionals in Australia and New Zealand have been undertaking student outreach through a variety of methods with mixed success. Moving forward, PIANC aims to broaden engagement across various disciplines to foster diversity and innovation. By involving young professionals, PIANC ensures its continued relevance and effectiveness in solving global maritime infrastructure challenges.
Keywords: PIANC, Young Professionals, Student Engagement, Diversity

Why PIANC needs the next generation
PIANC has a rich history dating back to its founding in 1885. As an organization dedicated to providing expert guidance on inland and maritime navigation, PIANC has been instrumental in the development and maintenance of waterborne transport infrastructure worldwide and has enabled significant global changes. However, to ensure its continued relevance and effectiveness, PIANC must actively engage the next generation of professionals, fostering a sense of ownership and commitment among young engineers and related professionals.

Engaging young professionals is crucial for PIANC to address the significant long-term challenges facing society, particularly those related to waterborne transport infrastructure. Key issues include the global energy transition, decarbonization of waterborne transport, development of maritime renewable infrastructure, and adaptation to global sea level rise. By involving young professionals, PIANC can harness fresh perspectives and innovative solutions essential for tackling these complex problems.

Recent Attempts in Australia and New Zealand
In Australia and New Zealand, each regional chapter of PIANC has a Young Professionals (YPs) representative. This group collaborates across the region to organize events that facilitate ongoing collaboration and networking among YPs in the PIANC network. In recent years, there has been a focussed effort by YPs to reach out to undergraduate students, aiming to communicate the significance of PIANC, the exciting and important challenges the association faces, and the crucial role of the next generation in addressing these challenges.

Several initiatives have been undertaken to engage students:

- **UWA Oceans Institute PIANC Careers Fair:** This event has been a success, effectively engaging students and connecting them with industry. Included pizza helped draw a crowd.
- **UNSW Pizza Drop-in:** This initiative did not meet expectations with poor attendance.
- **Engineers Australia COPEP Collaboration in Victoria:** Despite the potential, this collaboration failed. The event site was off campus in the CBD and too few student registrations despite marketing efforts meant the event was cancelled.
- **Student Societies:** In the wake of the failed event above, a networking night with the RMIT student society was easily and effectively organised.
- **Australian Maritime College Careers Fairs:** These fairs are successful in reaching students already studying a maritime career and exposing them to PIANC.
- **Guest Lectures:** These have been done on a couple of occasions with moderate success, indicating that while they are beneficial, there is room for improvement.
- **Student Careers Fairs:** These were found to be cost-prohibitive for PIANC, particularly because PIANC does not directly offer jobs, making it challenging to attract students primarily looking for employment opportunities.
- **UWA Indian Ocean Marine Research Centre PhD Seminars:** A very effective event where PhD students working on maritime issues presented to industry representatives.

Lesson Learned
One of the key lessons learned from these efforts is that students will not come to us; we need to go to them. Success has been more pronounced when engaging with students who already have an interest in maritime and coastal subjects. However, there is a struggle to communicate effectively with a broader range of emerging professionals.

Framework Moving Forward
To ensure ongoing engagement with the next generation, the following strategies are underway:

- **Targeted Engagement:** Continue to focus on students undertaking maritime and coastal undergraduate degrees, ensuring they are well-informed about PIANC and the opportunities it offers.
- **Broader Outreach:** Reach out to student societies across various disciplines, including

engineering, science, environmental studies, policy, and arts. This approach will help attract a range of students, which is essential for fostering the innovation, diversity and creativity needed to solve global challenges.

- **Enhanced Communication:** Develop tailored communication strategies to effectively convey the value of PIANC and the significant impact students can have by being part of this international association.

Our Message

PIANC offers a truly collegiate and engaged international association with exceptional networking opportunities, great events, and accessible and relevant international working groups.

The problems PIANC addresses, such as the energy transition, decarbonization, and adaptation to global sea level rise, have profound impacts on society at all levels. By becoming involved with PIANC, young professionals can contribute to meaningful solutions that benefit both the industry and society as a whole.

In conclusion, engaging the full diversity of the next generation is vital for the sustainability and growth of PIANC. By implementing targeted strategies and effectively communicating our message, we can inspire and involve young professionals, ensuring that PIANC continues to thrive and lead in the field of waterborne transport infrastructure.

Relevant UN SDGs

4, 5, 7, 8, 9, 10, 11, 13, 14, 16, 17

Using WG205 Design and Construction of Breakwaters on Soft Seabeds

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Summary
PIANC MarCom Working Group 205 (WG205) has prepared a new report on the design and construction of breakwaters on soft sediments. This report represents current industry practice and aims to provide a valuable source of information with a blend of technical information and practical know how. At the time of writing this abstract it was in the final stages of preparation for publication. This presentation explores the content of this report and how it may be useful for professionals working with these difficult conditions, particularly in the planning and concept development for works over soft seabeds, moving through design, construction and finally onto monitoring and maintenance.

Keywords: Soft Seabed, Mud, Settlement, Geotechnical Failure, Breakwater, Soil Improvement

WG205 Overview
The PIANC MarCom Working Group 205 (WG205) was formed in 2019 to prepare a report into the design and construction of breakwaters on soft seabeds. The report is now written and will be available to PIANC members free of charge shortly.

This presentation will explore the contents and how the report can be used by professionals to assist in the planning and design of works on soft seabeds.

Scope of Report
The report explores the geotechnical issues planning, design, construction and maintaining of breakwaters on soft seabeds such as unconsolidated silts or clays, and loose sand. It is intended that the report be used by professionals responsible for the planning, design or maintenance of these structures.

A quick overview for of the report by looking at the contents of each chapter is provided below.

1. ***General Aspects*** - This is an overview chapter setting out scope of the report and contents.

2. ***Geotechnical Characterisation of Site*** - This chapter addresses physical settings where soft seabeds occur (sediment rich and low energy). Further it explores the data collection and characterisation of sediments.

3. ***Design considerations on breakwater types*** Explores failure modes (collapse and settlement) and how different types of breakwaters respond to these issues. The chapter also looks at the various loads impacting breakwaters.

4. ***Construction considerations on breakwater types*** - Construction is discussed with an overview of how soft sediments impact the works with risks identified. Materials, equipment, and logistics are addressed.

5. ***Existing codes, standards, and guidelines*** - Relevant codes, standards or internationally recognised guidelines are identified.

6. ***Stability and settlement analysis*** - Response of soft sediments to the loading are explored. This includes theories for the assessment and modes of analysing the responses.

7. ***Ground conditions improvement and reinforcement*** - This chapter examines various techniques utilised to improve foundations and consideration in selecting the most appropriate.

8. ***Monitoring*** - Ongoing settlement in the structures are maintenance concerns. This chapter discusses methods used for monitoring movements and impacts over time.

9. ***Conclusion*** - Provides a summary and draws together the findings of the report.

10. ***Case Studies*** – Learn by example:

- Southern Breakwater in the Port of Barcelona
- Port of Brisbane Expansion (FPE)
- Cowes Outer Harbour Project
- Breakwater of the Port of Ishinomaki
- Susaki Port Breakwater a Caisson-Type with Crushed Stone Embankment

Areas of Application
The methods and understandings in the report can also be applied to breakwaters, seawalls, bunds and reclamations over soft seabed material.

Use in Site Selection and Project Planning
Potentially the most valuable contribution this report can make is as a guide when planning works. Decisions made early have the greatest impacts on projects.

A common issue in the siting of infrastructure is a lack of awareness of the implication of soft seabeds on project costs, timelines or viability. Initially this report can be used to assist in ensuring site selection is not made in ignorance. The report provides an explanation of the met ocean and geographic conditions that are linked to the presence of problematic deep soft seabeds.

The report sets out the construction methodology and ground improvement effort required to address the soft seabed issue. This should make it clear to decision makers the difficulties and expense the proposed site is likely to experience. It also details how to forecast settlement and the significantly impact this can have on both costs and timelines.

Data Collection Programs
The report sets out data needed for different stages of design and suggests appropriate methods to collect this data. Guidance on analysis and use of data allows appropriate planning and timelines to be incorporated into the project planning.

Assistance with Design
The bulk of the report addresses various elements to be considered in design. The design effort for structures over soft seabeds is complicated with a myriad of solutions and failure modes.

Critically what breakwater type should be adopted is explored for consideration at the preliminary design phase:

- Conventional rubble mound breakwaters;
- Caissons and composite breakwaters;
- Berm breakwater or RMB with extended toe;
- Pile-type breakwaters;
- Breakwaters with wide bottom slab on piles;
- Suction caissons; and
- Floating breakwaters.

Loading examined including static loads (structure weight) and dynamic loads such as waves, currents, seismic, tsunami, ship loads and construction loads. Further to assist in design Standards and codes applied across the globe are are described to ensure appropriate design approaches are adopted.

The varied failure and settlement issues are described and quantified. The guidance on geotechnical issues in the report addresses the revetment stability and settlement issues is significant detail.

When developing designs, the practicalities of construction need to be considered. This is explored in a detailed review of construction methodology.

Use for Construction
The range of methods available to deliver a suitable outcome are explored. Further an appreciation of variability in dealing with soft sediments provides more insight of the risks contractors face. This report provides a valuable refence for contractors when considering how to minimise commercial and personnel risk during construction.

Use in Ongoing Management
The ongoing settlement issues that structures built over soft seabeds is a concern for asset managers. The report sets out some useful monitoring techniques that asset managers can use to assess the behaviour of structures. An example of measured ongoing settlement at Port of Brisbane expansion is provided in Figure 17.

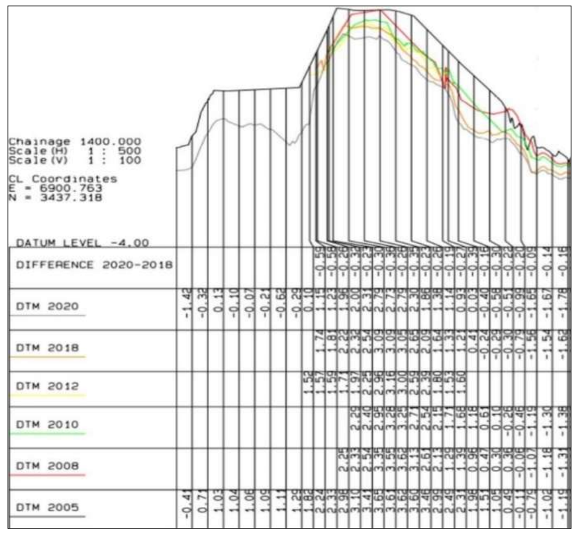

Figure 17 Survey revealing ongoing settlement from the Brisbane Port Case Study (Source: [1]). Note the typical measured settlement of 1 to 2 m and changes in profile shape over the 15 years since construction.

The report also provides guidance on the soil behaviours that can be anticipated, exploring methods used to accelerate settlement and resolve issues in a timely manner.

Conclusion
The WG205 Report "Design and Construction of Breakwaters on Soft Seabeds" is now complete and draws together industry practices from across the globe. It provides a valuable tool for anyone involved in planning, site selection, design, construction or maintenance of breakwaters and reclamations on soft seabeds.

References
[1] PIANC Working Group 205 (2024). Design and Construction of Breakwaters on Soft Seabeds.

Relevant UN SDGs (*https://sdgs.un.org/goals*)
PIANC WG205 report addresses UN SDGs for Quality Education (4), Industry and Infrastructure Innovation (9), and Reducing Inequality (10).

Design and Constructability Issues of Driven Piles in Yarra Delta Region

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Summary
The Yarra Delta Region presents several design and construction problems for driven piles. This is largely borne out of the geological complexity and variability of the region. This paper discusses the geotechnical challenge of piles encountering rock flows at shallow depths, and as a result not being able to achieve adequate penetration to develop their required tension capacity. Several design solutions are proposed to tackle this problem. Implementing measures discussed will avoid the need to relocate, downrate or re-design piles during construction and ensure that changing pile conditions are well considered within the overall design of maritime structures.

Keywords: Driven Piles, Structural Design, Geotechnical Design, Pile Design, Melbourne

Introduction

Driven precast concrete and steel piles have been widely used within Melbourne's Yarra Delta. This can be put down to the ground in which the piles are founding in. Coode Island Silt (CIS) is encountered over much of the Yarra Delta area. It is soft and compressible but provides easy driving conditions. Underlying the CIS are Quaternary Deposits such as Fishermens Bend Silt (FBS), characterised by consistent, stiff clays and silts. Piles could be founded in the FBS or the underlying Moray Street Gravel or Older Volcanics.

However, the geology of the Yarra Delta Region is quite complex and can present several design and construction problems for driven piles. It is highly complex as it has resulted from a sequence of Quaternary deposition and erosion. Older Volcanic flows vary in thickness and can be present at shallow depths depending on historical patterns. Thin, highly resistant layers may impede upon pile penetration to the depth required to suit the design (Neilson, 2017).

Piles founding at a shallow depth is a concern for the following reasons:

The pile may not have adequate lateral ground support, leading to instability of the structure.
Piles may need to be founded into a deeper rock unit to achieve adequate tension capacity.

This work proposes solutions to solve the problem of suddenly changing pile driving conditions. This might cause the scenario where driven piles encounter high pile driving resistance in rock at a shallow depth, which is not in line with the overall pile design.

Yarra Delta Geology

The Engineering Geology of Melbourne (Neilson, 2017) includes sections through the West Melbourne Precinct. The section below (refer Figure 18) shows the region to be underlain by Quaternary aged deposits of Port Melbourne Sand, CIS, FBS and Moray Street Gravels. Pre-quaternary deposits are shown to comprise layers of Older Volcanics and Werribee Formation overlying the Melbourne Formation basement rock.

A thin layer of Older Volcanics flow is evident underlying the Maribyrnong River and Coode Island Hill (represented by Tov in the figure). This Upper Older Volcanic flow has been truncated below the western edge of Swanson Dock by erosion prior to quaternary deposition. The upper flow may vary in thickness or be absent in parts of the dock depending on the historical patterns of deposition and erosion. The variability and complexity of this sequence can result in piles unpredictably hitting refusal where they are unable to penetrate the Upper Volcanic flow.

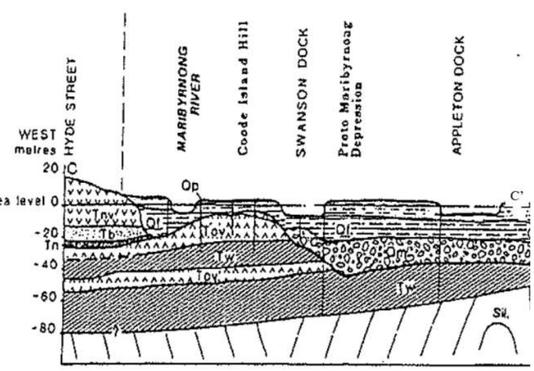

Figure 18 Geological Section through West Melbourne (Neilson, 2017).

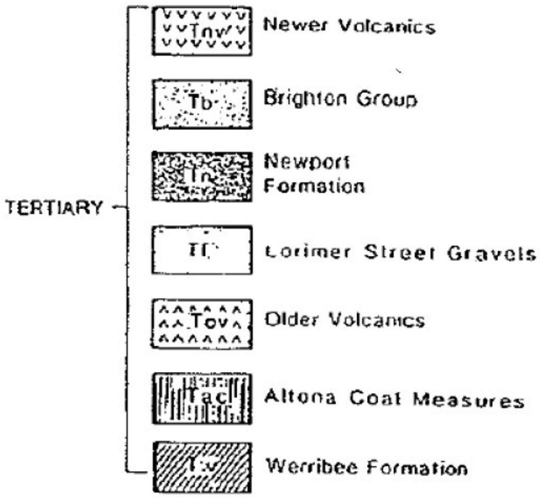

Figure 19 Legend for Geological Section through West Melbourne (Neilson, 2017).

Recommendations for Pile Design

The variability of the ground conditions can cause significant problems for driving piles, particularly when unaccounted for. Where piles unpredictability hit refusal above the pile toe depth required by the design, this can result in piles not achieving the pile tension capacity required by the design. This is because above the Upper Volcanic flow, CIS and FBS provide little shaft capacity in tension.

Potential solutions are listed below:

- At times, borehole investigations alone will not pick up the geotechnical variability at a given site, especially in the Yarra Delta Region. Geophysical survey could be conducted between boreholes to capture critical data on rock strength prior to design so that variability can be accounted for.
- Piles can be designed to ensure highly resistant layers at shallow depths are considered within the overall pile design. For example, piles could be designed as compression-only members. Whilst in compression, members would act with axial, flexural, torsional and shear capacity. However, if they go into tension, they would be removed from analytical models. Analytical software is capable such as *SpaceGass* can perform an iterative process to disable compression-only members that are found to have gone into tension.
- Adopt a shorter pile with passive tension bar, grouted into lower rock unit. This passive tension bar would involve an anchor hole driven beyond the toe of the pile. A high-strength steel rod placed inside corrugated sheaths to be grout-filled. The driven piles could be designed to have sufficient compression capacity whilst the anchor would provide additional tension capacity.
- Pre-bored/ Bored piles drilled through sequence of variable weathered rock to a required founding depth. It should be noted that to pre bore tubular piles on an incline will require specialised equipment not readily available.
- Piles could be fitted with steel toes or rock punching ends with high penetrating capability.

A risk-based approach shall be adopted when attempting to resolve design and construction issues of high pile driving resistance at shallow depths. Upon the consideration of the solutions described in this paper, the positives should be balanced against the cons to determine which is appropriate given project specific requirements.

Discussion & Conclusion

With vessel sizes increasing and greater load bearing capacity needing to be accommodated by our wharf infrastructure, there is a need for deeper and larger piles. Furthermore, with Australia facing challenges around skilled labour shortage, reduction in construction timeframes is critical to minimise labour costs, driving piles to be larger, deeper, and less numbered.

As a result, in the Yarra Delta Region, piles are generally required to be embedded into the competent lower flow of the Older Volcanics which directly underly much of the region. In contrast, historically piles in the region have generally been embedded in the upper flow of the Older Volcanics or Quaternary Deposits. This required piles to be in some instances, cored a small distance into rock to achieve the minimum required toe level in some instances. Now, minimum pile toe levels presented in designs are far deeper than in the past.

Recommendations for pile design outlined in this paper should be implemented during the feasibility design to derive potential solutions to the construction and design challenges of high pile driving resistance at shallow depths. It is most applicable within the Yarra Delta, which clearly introduces geological complexity into design and construction with generally poor founding conditions and highly complex and variable conditions. However, the lessons learnt can be applied more broadly across different contexts.

References

Neilson, J. L. (2017). *Engineering Geology of Melbourne.* London: Taylor and Francis.

Relevant UN SDGs (*https://sdgs.un.org/goals*)

4, 9, 11, 13

Optimisation of Sedimentation Basins' Return Water: Enhancing Dredging Environmental and Operational Outcomes

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Summary
Return water quality from sedimentation basins is crucial for environmental conservation and operational efficiency, and is governed by stringent turbidity requirements. Exceeding these values can disrupt dredging operations and environmental balance. Monitoring return water quality involves various factors like soil properties, basin dimensions, and flowrates. Data analytics offers opportunities to optimise water quality management. This paper introduces a methodology that integrates real-time data and predictive models to ensure compliance with turbidity requirements. By integrating this approach into dredging operations, potential breaches can be mitigated, ensuring both environmental protection and operational efficiency, which highlights the synergy between technology and environmental conservation.

Keywords: return water, sedimentation, basin, settlement, reclamation

Introduction

In pristine water systems, return water must meet stringent quality requirements, which can be met by storing return water in sedimentation basins to settle practically all the fines.

A unique engineering model is available that estimates settlement times and basin sizes required to meet return water quality requirements. This model uses site-specific data and dredger specifications to create accurate designs of sedimentation basins.

Hydraulic Mixture Properties

Hydraulic dredgers create a mixture of water and soil while dredging. The process water volume, which is pumped ashore, cannot be stored in sedimentation basins. Therefore, the water used as the transportation medium must return to the environment.

The soil mixture's particle sizes, particularly of the fines portion, need to be known to design sedimentation basins. This should be accurately measured using a hydrometer. If clay is present, then undrained shear strength, in situ density and Atterberg Limits are also required to be able to perform clay slurrification assessments [1].

Liquified clay has a relative slow settling velocity. However, in salt water natural flocculation occurs [3], which significantly accelerates settlement rates. Therefore, to determine any increase in settling velocity, settlement rates should be measured over a period of days.

A software tool is available that uses image recognition to measure settling velocity. Figure 1 provides settlement test results, as produced by this tool, for three samples.

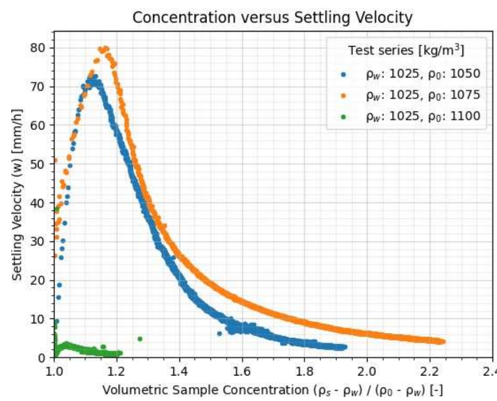

Figure 20 Volumetric sample concentration versus settling velocity.

The individual particles theoretically settle at 2 to 10 mm/h. However, flocs are found to settle at 70 to 80 mm/h, as shown in the above graph.

The sample with the highest initial density (ρ_0) of 1,100 kg/m^3 (shown in green in the above graph), was not settling. Rather it was consolidating, hence the low settling velocity.

Bulking Factor

Dredged material has an in situ density (ρ_{is}) that typically decreases to the mixture's density and then increases again when it settles and consolidates in the sedimentation basin.

In situ material typically increases in volume once it is dredged by a factor known as the bulking factor (BF), as the material's settled density (ρ_{sd}) is larger than the in situ density. However, the dredged material will consolidate over time and again reduce in volume.

$$BF = \frac{\rho_{is} - \rho_w}{\rho_{sd} - \rho_w} \tag{1}$$

In the case of clay, the BF can be in the range of 2 to 5, which makes it an important soil parameter to consider as it affects the sedimentation basin's storage capacity, where these particles settle.

Reclamation Areas

Any dredging project, where soil is transported hydraulically and placed onshore, requires a reclamation area where most of the bulked dredged material can be stored and settled before the water and fines are allowed to runoff into a sedimentation basin.

Reclamation areas are relatively small areas in which to spread the flow and reduce the mixture's velocity. However, as most material settles near the pipe outlet, large areas are not required. Only the fines, clay and silt leave reclamation areas and are considered in return water quality assessments.

Sedimentation Basin

These are usually large areas, spanning from a few to tens of hectares. Typically, the flow path in these basins is extended between the inlet and outlet by using internal bunds.

Sedimentation basins' designs should consider the end of the dredging project when the reclamation area contains all the bulked material, and the sedimentation basin stores all the fines.

Figure 2 depicts an ideal sedimentation basin where the width and depth are constant along the basin's flow path. However, in reality sedimentation basins are undulated, and the width typically varies to fit within existing infrastructure. To accurately measure a basin's undulations and available area, topographic survey data is required.

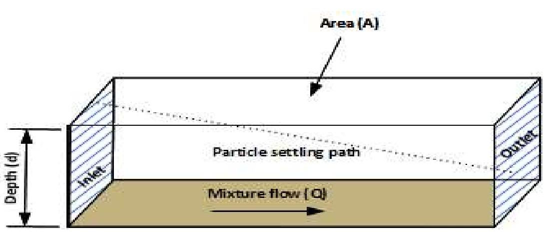

Figure 2 Ideal sedimentation basin.

With ideal sedimentation basins, the required Residence Time (RT) and Settling Time (ST) are easily determined using the following equations:

$$RT = \frac{Ad}{Q} \tag{2}$$

$$ST = \frac{d}{w} \tag{3}$$

where RT is area (A) times depth (d) divided by flow (Q), and ST is depth (d) divided by settling velocity (w).

The required residence and settling times in real-life sedimentation basins are a little harder to calculate. Nonetheless, it is just a matter of keeping track of width and depth variations along the mixture flow path and how the flow adjusts to these variations.

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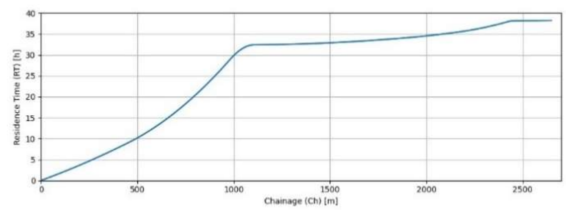

Figure 3 Residence time along a sedimentation basin's flow path with obstructions at Ch 1,100 and 2,450.

As the above graph shows, narrowing the flow path with obstructions at chainage 1,100 and 2,450 causes the flow to spread more slowly and increases residence time after the obstruction. This shows the detrimental effect of obstructions in sedimentation basins.

Figure 21 graphs the mixture's concentration along the basin's flow path. In this instance, all fines settled within 500 m of entering the basin. Furthermore, this basin was found to be oversized as the original design did not allow for natural flocculation.

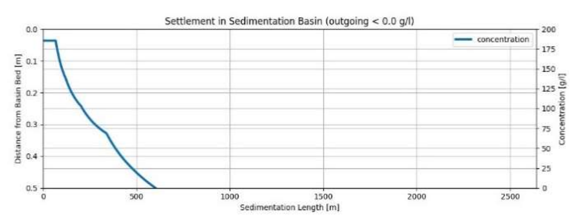

Figure 21 Concentration along the sedimentation basin's flow path.

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Relevant UN SDGs (*https://sdgs.un.org/goals*)

6, 9, 12, 14

3D Snapback Visualisation Models for Improved Port Safety

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Summary
Through computational methods described in previous papers (Butler, 2024), WGA have developed the capability to accurately predict the path and velocity of parted mooring lines. The datasets derived from these models typically take many weeks to calculate and contain 10 – 20 TB of data for an ordinary berth. In this abstract we present our novel solutions for visualising this data. We demonstrate that we can reduce datasets by 99.97% without the loss of information required for visualisation. We also demonstrate how such visualisations work and can be used for real-time viewing of expected Snapback paths based on known mooring arrangements and vessels. We demonstrate our latest model that contains 248,832 different parted line simulations and renders in real-time. We show that the application of this technology takes Snapback Path Analysis (SPA) results out of the realm of so-called "Big Data" and allows it to be used as a real-time end user tool for risk management.

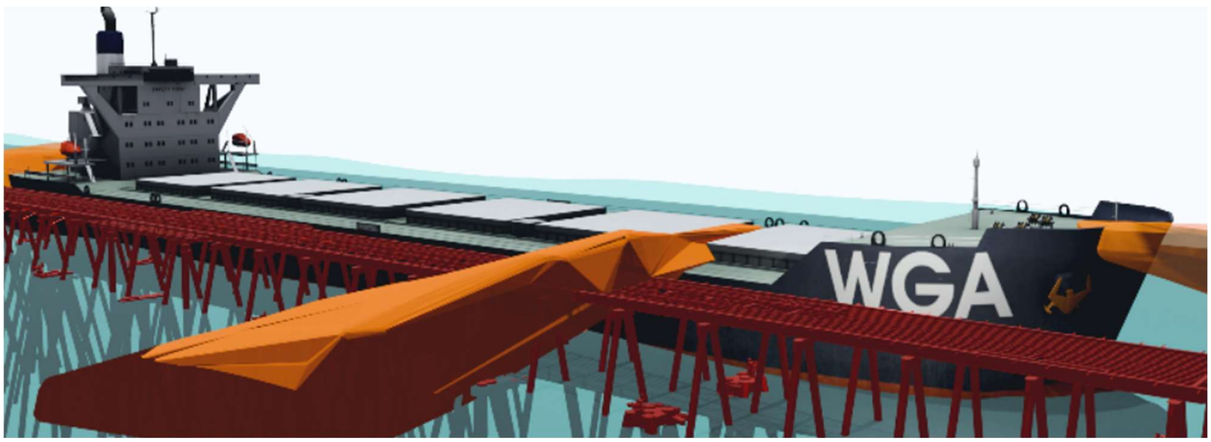

Figure 22 A visualisation of the envelope of snapback paths arising from vessel motion for a winch failure of a forward spring line at high tide.

Keywords: Digital Engineering, 3D Visualisation, Snapback Analysis, New Technology

Introduction
Snapback describes the recoil of a parted mooring line at high velocity; a catastrophic event that is often fatal in cases of line-human interactions. It is estimated that snapback events occur every 7 to 52 minutes worldwide, totalling between 10,000 and 68,400 events each year (Butler, 2024), though due to the poor availability of data, the number of events may be much greater than this. Though the accurate analysis of snapback path and velocity through computational methods is presently becoming reality, both through the work of WGA and, more generally, PIANC WG 251, the datasets to describe such events are still massive. For example, a 4-berth export facility, with vessels ranging from 180k to 250k DWT, with an average of 13 different mooring configurations per vessel, results in a data set of 248,832 different line simulations, each containing approximately 60 x 10^6 unique values describing velocity and displacement. Such models are approximately 20 TB in size, or 1280 to 2560 times what the average modern laptop can render simultaneously.

This presents a significant challenge to consultants and asset owners/operators alike, namely:

"What good is all that data if you cannot see it?"

Through our Maritime and Data and Analytics teams, WGA have developed novel methods for the rasterisation of the large arrays that describe snapback paths without the loss of the spatial information describing the battery limits of the snapback paths. Through the application of these methods, we show that a 99.97% reduction in data size is possible. Such reductions take snapback data out of the realm of so-called "Big Data". This, as will be shown in our presentation arising from this abstract, allows for the creation of standalone Snapback Models that can be rendered and filtered in real-time by end users, based on their vessel, mooring configuration, berth furniture, and ambient conditions.

We propose that the adoption of these rasterised models will inform snapback risk in real time and better inform decision making for port operators.

Methodology
WGA's methodology involves running parametric kinematic models for Snapback Path Analysis. As the displacement and velocity data of these models is calculated, a two-dimensional array of cartesian coordinates can be used to describe the transit of the line. Because velocity information is also encoded, it is possible to filter subsets of the data to provide an array of cartesian coordinates that only describe "high velocity" regions; such regions could be defined as velocities exceeding an acceptable threshold deemed to be a significant risk to personnel, though guidance on what these thresholds might look like does not yet exist.

Generally, each two-dimensional array contains sets of coordinates in the order of 10^5 to 10^6 per simulation. When saved as .csv or .txt, file sizes are in the order of 5 to 500 MB per simulation. By passing the minima and maxima values for each dimension within the array, an n by m by o rectangular prism can be described that by definition inscribes the set of coordinates described by the array. A mesh of desired coarseness can be generated over the rectangular prism. Through Bound Volume Hierarchies (BVH) and projection vectors, each node on the surface of the rectangular prism can be mapped to the *surface* of the snapback array. These projections are then rasterised to produce wavefront files.

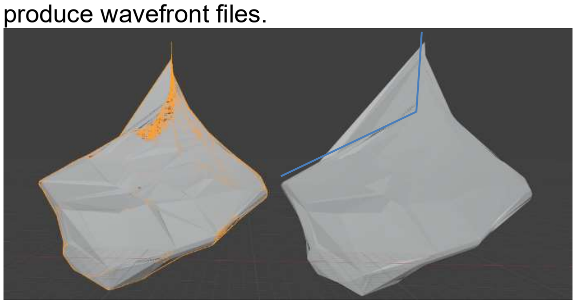

Figure 23 A visualisation of the rectangular prism mapped to the array of cartesian points describing a single breast line failure. The reduction in file size was 99.7%. The left and right renders show the difference in result from changing the rectangular prism. The blue line shows the initial mooring line configuration.

Applications
Through the application of our methodology, A render of the snapback paths for a given mooring configuration can reduced from 10 to 100 GB to 9.6 MB, or around a 1000-fold decrease in data size at a minimum. On recent WGA projects, the average reduction was 3,333-fold, or 99.97%.

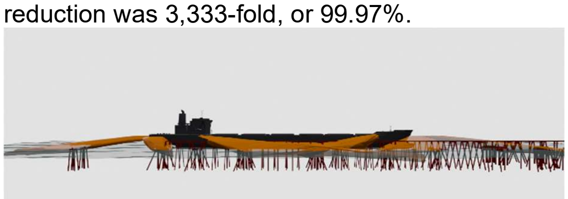

Figure 24 A visualisation of the envelope snapback paths for a capsize vessel in ballast high-tide conditions.

Because of these massive reductions in file size, we show that the resultant models can be run in real-time on standard hardware. Furthermore, WGA have integrated these models with standard BIM and packages, such as Revit and Navisworks.

Further, because filtering based on velocity, position within the line, or cartesian space is possible before rasterisation, we show the application of clash detection algorithms for snapback path to voxels that describe the spatial coordinates of the target infrastructure. Using this approach, the output visualisations can show the overall expected snapback path without collision, whilst also including truncated paths that highlight the points of expected first impact. This information is critical to understanding both the overall risk area for the facility and the high-risk expected impact regions.

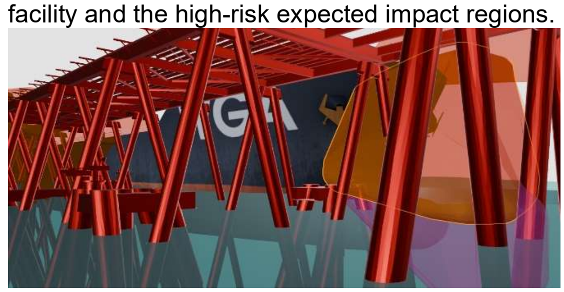

Figure 25 A visualisation of the snapback path of a forward breast line that has parted near the winch. Though the snapback barriers on the dolphin were modelled, the orange path (which is a truncated wavefront based on time to clash detection with the structure) shows a line that was able to effectively whip sideways around the barrier and get halfway under the deck before hitting the water level. The untruncated path is shown in purple.

Discussion and Conclusion
WGA believe that through both the development of this technology, and the free dissemination of our methodology to our peers in industry through this abstract, increased port safety can be achieved by giving port operators and asset owners access to real-time usable tools that can inform the specifics of snapback risk on a per vessel and per mooring arrangement basis. Whilst such models are unlikely to ever be able to fully account for the risk of ricochet after impact, or interactions with the vessels themselves, they serve to provide much clearer pictures of snapback risk than the historically adopted 2-D *"Snapback Cones".* Accordingly, we see this technology as an important first step towards tangible tools that can be used to improve port safety for snapback, ultimately saving lives.

References
[1] Butler, Jordan (01.05.2024). Snapback To The Future: New Methods for Parted Mooring Line Analysis, PIANC 35th World Congress, Cape Town.

Port Master Planning 2.0

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Summary
Traditional master planning typically relies on static and iterative processes to project future outcomes from limited and sometimes disconnected data sets. In contrast, Master Planning 2.0 is founded on a digital strategy that connects all port levels, providing a comprehensive suite of tools for informed decision-making through the analysis of a wide data set. By taking advantage of the wealth of internal and external data that modern digital systems capture, the system empowers the port to navigate and analyse vastly expanded data sets and make informed decisions.

Keywords: master planning 2.0, strategic planning, data management, digital twin

Introduction
Master Planning 2.0 empowers ports to make holistic, well-informed decisions by gaining a holistic understanding of their functional reality. This abstract aims to outline the path to Master Planning 2.0, highlighting three crucial elements: strategic planning, data management, and digital and dynamic innovation.

Preparing the way to Master Planning 2.0
Traditional master planning faces the dual challenge of balancing the need for a clearly defined plan with the requirement to be flexible, all while being a static and iterative process using limited data. This limitation often stems from the port being inwardly focused, neglecting the integration of upstream and downstream data, and undervaluing stakeholder input. Consequently, hampering accurate forecasting and hindering the port's ability to adapt to dynamic market conditions and global trade developments.

Figure 1 shows how industry has moved away from traditional master planning into a transitional phase. By recognising the above-mentioned limitations, ports have begun to address the limitations by embracing collaborative planning, fostering increased stakeholder engagement, including local communities and First Nation Peoples, to align with broader regional development and Environment, Social and Governance (ESG) goals. This transformation is increasingly leveraging digital tools to enhance collaboration during the planning process and ensure the accessibility of plans thereafter.

Moreover, ports are now playing an active role in advancing the UN SDGs by generating economic opportunities, fostering job creation, and stimulating economic growth, ultimately contributing to the stability and well-being of both the country and the region.

While the industry is moving in the right direction, the journey towards Master Planning 2.0 continues. This evolution entails expanding data collection and integration efforts and developing analytical tools to leverage this data effectively.

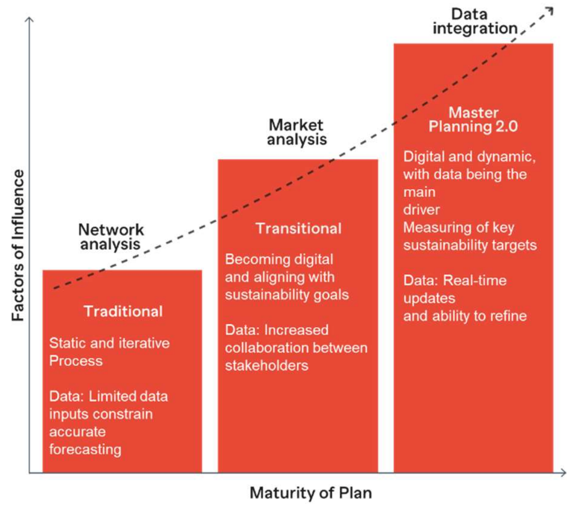

Figure 26 The journey to Master Planning 2.0; data management ensures the maturity of each phase; the dynamic master plan relies on real-time data updates, enabling continuous refinement and adaptation of the plan.

Strategic Planning
It's essential to view the port within its unique context, considering both macro and micro players and understanding their interconnectedness with the port itself. This requires ongoing collaboration among stakeholders to ensure that the port's development aligns harmoniously with the goals of the city, state, and federal entities. Effective partnerships rely on continuous data and insights exchange, fostering regular communication beyond just the planning cycle.

UN SDGs, decarbonisation roadmaps and ESG criteria increasingly form part of the strategic planning processes. Consideration of these elements in dynamic scenario modelling allows for fidelity of future outcomes and a more accurate understanding of past performance. Integration of these elements into dynamic scenario modelling enhances the accuracy of future projections and allows for retrospective analysis and reporting. Evaluation of these goals should extend beyond the initial master planning stages.

Data Management
Strategic planning hinges on enhanced data management, linking previously siloed data from all stakeholders to unlock greater value. By fostering more integrated and holistic approaches to port development, the port can harness the power of data to anticipate future challenges proactively.

This proactive stance enables the port to remain resilient and responsive amidst the ever-changing maritime landscape. Leveraging predictive analytics allows for the anticipation and mitigation of potential challenges, ranging from optimising cargo handling operations to predicting maintenance requirements.

Digital and Dynamic
Modern master plans increasingly integrate digital features like live dashboards, gamification of concepts, simulations, etc. Despite their digital nature, these plans are still not dynamic. Dynamism allows planning to progress from the most recent known point and be immediately responsive to changed conditions. The port itself can be dynamically captured as a ”digital twin”, frequently synchronising with reality, and providing a source of truth that models can update and correct against. This dynamic linkage delivers more accurate future forecasting, and contemporary visibility of progress toward strategic objectives.

Conclusion
Traditional master planning constrains the port from realising its full potential. To chart the course towards the future of master planning, leveraging data from all systems and players within the port's reality as foundational elements is essential. Data serve as building blocks upon which digital tools can be developed, empowering ports to finely tailor their spatial layout for optimal efficiency and effectiveness.

Relevant UN SDGs (*https://sdgs.un.org/goals*)
8, 9, 11, 17

Environmental drivers in Port Selection MCA and avoidance outcomes in sensitive ecosystems

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Summary
The **Westport Program** will deliver a new container port terminal and integrated transport infrastructure in the **Kwinana Industrial Area Outer Harbour**, located in the Perth metropolitan region, that strategically address the efficiency, transport access and urban amenity issues facing the existing Port of Fremantle Inner Harbour. Westport's Stage 3 **Multi Criteria Assessment** (MCA) was underpinned by substantial weighting of environmental criteria, technical studies, and expert advice informing the final site selection of the Port consistent with **mitigation hierarchy** and **working with nature** principles. In recognition of the importance of Cockburn Sound to the community, Westport funded the WAMSI-Westport Marine Science Program (WWMSP). The program will provide an understanding of the current condition of key environmental and social factors within Cockburn Sound. Westport has fundamentally integrated environmental opportunities into its planning and development.

Keywords: Working with Nature, Kwinana Industrial Area Outer Harbour, Mitigation Hierarchy, Fremantle Ports, Westport.

Introduction
Westport is a program that will deliver a new container port, integrated transport infrastructure, and provide Western Australia with a competitive, efficient, and world-class supply chain network, to contribute to the future prosperity of the State and Australia. The program will strategically address the efficiency, transport access, and urban amenity issues facing the Port of Fremantle Inner Harbour, which is Western Australia's sole container port. A key goal of the Westport Program is to 'plan, build and operate the most sustainable port in Australia', which has underpinned the option selection and design process. This aligns with the United Nations Sustainable Development Goals (SDG) 8, 9, 11,13 and 14.

The proposed port in the Outer Harbour of Kwinana will be a multimodal facility that will handle container trade, with connections to road and rail networks. The port will be located on reclaimed land, using dredged material from the construction of a second main channel, access channels, turning basins and berthing areas. The port will also include an offshore breakwater, which will provide protection from wind and waves, and potentially offer environmental and social benefits, such as habitat enhancement and recreational opportunities.

The preferred port location and design have been informed by a staged multi-criteria analysis that included significant weighting towards alternatives that avoid or minimise environmental impacts and maximise opportunities to enhance environmental and community values.

The multi-criteria analysis proposed various options with the preferred option being selected based on its lower environmental impacts and performance in other delivery, commercial, and operational aspects.

Main body
The Westport Project Office tasked a Supply Chain Integrated Design (SCID) consultant to produce an initial long list of potential design outcomes and associated logistics chain components using inputs from trade forecasts, planning status of key road corridors, key rail constraints, land use planning, environmental analysis of the Cockburn Sound, and analysis of the social amenity. These matters informed the weighting utilised in the MCA process and the final site selection and 15% design informing the Business Case and State and Commonwealth environmental referrals.

The Kwinana Industrial Area and Cockburn Sound were selected over Bunbury due to the costs associated with duplicating the southwest main drain and cost of road enhancements between Perth and Bunbury. All 5 shortlisted options from the MCA stage 1 were located within Kwinana. The MCA stage 2 further developed these shortlisted options to determine an overarching logistics design in the location selected. It was decided that a land backed port option was strongest option from a variety of cost benefit analyses. Stage 3 of the MCA focused on the associated infrastructure required based on the selected location and produced an analysis for required number of stevedores, dredging strategy, landside infrastructure, and additional decisions that supported the business case including refined analysis of environmental considerations [1].

The results of the Stage 3 MCA process were a consolidation of qualitative and quantitative scores measured against the Westport goals across three phases of MCA analysis. This process refined 30 options to seven and then seven to three. After the highest performing option was selected in each phase, a further interrogation of the top performing options and a rework including all high performing solutions was conducted.

The environmental selection elements measured direct and buffered impacts of seagrasses and overall benthic habitat impacts. These elements were weighted more than other impacts as they were crucial in producing a sustainable outcome that avoided the most sensitive environmental factors. These were produced using the following sustainability requirements:

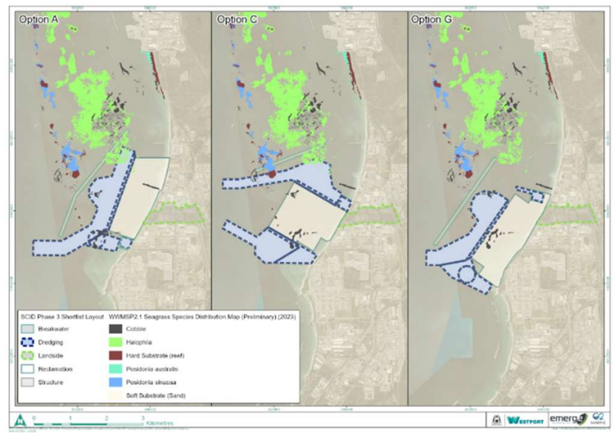
- Westport Goals and Criteria
- Westport ESG Strategy Commitments and Objectives
- Westport Port Planning Project Detailed Planning Rating (V2.1) – IS Management Plan
- PIANC Working with Nature Guidelines

The preferred option avoided direct impacts on perennial seagrass on the Kwinana Shelf by selecting a south shifted option and provided the highest performing hydrodynamic option with lower impacts on circulation in Cockburn Sound and commensurately low impacts on snapper spawning and egg/larval dispersion.

Additional Working with Nature opportunities aimed to regenerate benthic habitat and water quality aspects of Cockburn Sound were identified to facilitate better environment outcomes. The SCID consultant incorporated Working with Nature opportunities in the final concept design incorporating opportunities identified through stakeholder workshops. Identified opportunities included consideration of breakwater design, location and materials, beneficial re-use of dredge spoil, optimisation of the port terminal footprint and infrastructure to enhance biodiversity gains and energy efficiency measures associated with port operations. These proposals will be further explored throughout the detailed design process.

The Westport Project Office also produced a Mitigation Strategy [2] to support resilience building of the overall Cockburn Sound marine ecosystem. This strategy identified a mitigation hierarchy which was utilised to compliment the MCA process using three steps: 1. Avoid, 2. Mitigate, 3. Offset. The Mitigation Strategy is intended to support resilience building opportunities in Cockburn Sound beyond basic regulatory and project requirements that support Westport's overarching sustainability goals. Outputs from the WAMSI Westport Marine Science Program (WWMSP), the Mitigation Strategy, the MCA Preferred Option report and supporting documents, confirmed that the selected option performed highest based on environmental criteria.

Figure 27 Recommended Port Terminal Option G (WSP: [1]). A 3D visualisation of the recommended Option G layout of the Port Terminal and breakwater in



context.

Figure 2 WWMSP Project 2.1 habitat mapping with the final three shortlisted port options (WWMSP: [3]). The Shortlisted Port options and Seagrass distribution

Discussion and Conclusion

The Westport Project seeks to achieve beyond best practice environmental outcomes to construct and operate a sustainable port for the future of trade in Western Australia. Using a comprehensive staged MCA process to determine the location and design of the future port while utilising research-based scientific inputs and implementing Working with Nature guidelines, Westport seeks to become the most sustainable port development in Australia. The work undertaken to date demonstrates the impact that targeted research and a robust MCA processes can have on achieving positive economic, environmental and social outcomes for port developments.

References

[1] WSP. (2024), Preferred Option Selection Report Supply Chain Integrated Design.

[2] Westport Project Office; Environmental and Social. (2024). Westport Mitigation and Resilience Building Strategy.

[3] Emerge Associates and O2 Marine. (2024), Outer Harbour Port Development, Kwinana; *Environmental Protection Act 1986* Referral. Prepared for the Westport Project Office.

Relevant UN SDGs (*https://sdgs.un.org/goals*)

Goals; 8, 9, 11, 13, 14

Sustainable Marine Infrastructure: Design and Construction

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Introduction
What is sustainable marine infrastructure? There are so many applications today where sustainability ideals are noted as key pursuits. Indeed, we now have various ESG (environmental, social, and governance) initiatives that target improvement in sustainability. But not all are as readily applied to the design and construction of marine infrastructure.

For instance, the UN defines sustainable development as:

> *Sustainable development requires an integrated approach that takes into consideration environmental concerns along with economic development.*

This is not a terrible definition, but is very general in its nature and is difficult to apply to marine infrastructure.

There is an EnviCom PIANC working group document that relates to the subject: EnviCom Task Group 2 – Towards a sustainable waterborne transportation industry. The report is targeted at non-technical stakeholders, such as shippers, policymakers and non-governmental organisations who have an interest in the choices to be made as the global transportation system evolves. It assumes a limited knowledge of the industry and attempts to provide sufficient background material for a general understanding of the benefits, opportunities and challenges faced by the navigation industry – not so relevant for the design of marine infrastructure specifically.

Infrastructure Australia is perhaps more directly relevant. Infrastructure Australia uses an outcomes-focused understanding of sustainability as:

> *Meeting the needs of the present without compromising the ability of future generations to meet their own needs.*

Again, a very general statement that is not easily or directly applied to marine infrastructure. The definition proposed by Infrastructure Australia for 'sustainable infrastructure' is more useful in this instance:

> *Sustainable infrastructure refers to the network and system, equipment and assets designed to meet the population's essential service needs, while adhering to sustainability principles. This results in infrastructure that is planned, designed, procured, constructed and operated to optimise social, economic, environmental and governance outcomes over an asset's life.*
>
> *Sustainable infrastructure protects and preserves the ecological processes required to maintain human health, equity, diversity and the functioning of natural systems. It is not just about building new projects, but also about the rehabilitation, reuse or optimisation of existing infrastructure.*
>
> *Sustainable infrastructure enables economic development and the efficient use of financial resources, while enhancing quality-of-life and protecting natural resources. Sustainable infrastructure can reduce the life-cycle cost of infrastructure, while limiting negative effects on the environment.*

We are essentially trying to maximise performance and minimise waste. For this abstract and associated presentation, I will focus on three key themes connected to the three elements of this definition:

1. Good planning to optimise performance and outcomes over an asset's life.
2. Re-use and optimisation of existing infrastructure.
3. Value for money and maximum functionality.

Keywords: Maritime construction, marine infrastructure, sustainability, durability, port planning

Key Drivers for Sustainable Marine Infrastructure
Several projects and case studies from the author's own project history will be used as examples to explain these key themes and what it means for design and construction.

1. Good planning to optimise performance and outcomes over an asset's life:

What future uses might be coming? Do we even know? How can we build additional capacity into the asset at minimal cost? This is essentially future proofing. Can we consider construction techniques that provide additional capacity at nominal (or perhaps no) additional cost? What can we do with design so that further extensions of the design life will be relatively easy?

There are many examples of structures that we work on each year that are either at or beyond their original design lives - what are they being used for now vs what was the original design intent?

For this theme, I will use the following examples:

a. A berth deepening project in Port Adelaide where an underwater retaining wall was required to facilitate dredging (Flinders Ports, Outer Harbour Berth 4)
b. A wharf upgrade project in Geraldton where a shiploader was refurbished and required berth strengthening
c. A jetty in northern WA designed for a remote community (Wyndham) where availability of maintenance contractors is very limited.

2. Re-use and optimisation of existing infrastructure:

Can we make something of what's already there? Or perhaps, what can we do with design of greenfields infrastructure projects to give future engineers and designers the best chance of being able to find a future use. What information do we need to ensure is (and will be in the future!) available for this to be maximised? Should temporary structures still be looked after and protected more carefully (at modest expense) to ensure that there is adequate reserve for repurposing? Or can we simply achieve longer design lives than required with nominal changes?

For this theme, I will use the following examples:

a. A berthing caisson that was repurposed in South Australia (Klein Point) and will now be used for the third design vessel with significant increase in displacement
b. A historical study used for design of the Wyndham jetty
c. A geotechnical investigation with floating plant, required because pile records for an adjacent structure were not available (Rapid Bay jetty, South Australia)
d. A wharf in Port Hedland tug harbour (known as the 'John Holland Wharf') originally built as a temporary structure to facilitate construction of another project, still in daily use and fully refurbished decades later.

3. Value for money and maximum functionality:

How do we get the most our of infrastructure projects to ensure that maximum value is derived from a single project, reducing the need for another future project that will further impact the local environment?

For this theme, I will use the following examples:

a. A heavy lift project in Henderson, WA where larger cranes were accommodated at nominal cost.
b. A regional jetty in Monkey Mia, WA where the construction methodology led to bigger piles and a wider deck at no additional cost.
c. Esperance Berth 3 – iron ore export wharf designed for minimum CAPEX. Could there have been more value derived with a little extra budget?

References
While most of the content of this abstract and presentation is the authors own work, the following references have also been consulted.

1. United Nations - Sustainability
   www.un.org
   https://www.un.org/en/academic-impact/sustainability

2. Infrastructure Australia (Australian Government)
   Sustainability Principles
   Infrastructure Australia's approach to sustainability
   April 2021

About concrete caissons and floating docks

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Summary
The use of concrete caissons has been documented as far back as the Roman Empire yet compared to other structural typologies they remain relatively unknown and infrequently utilised in many regions around the world. Caissons can offer several advantages compare to other structural forms and can maximise the benefits associated with prefabrication. The use of floating docks to fabricate concrete caissons greatly enhances the speed and efficiency of the fabrication. And this paper will introduce the concrete caisson, presenting advantages over other alternative solutions as well as outlining the methodology for their fabrication utilising modern floating docks .

Keywords: Concrete caissons, floating docks, semisubmersible vessel.

Concrete caissons
Concrete caissons are typically used as either a quay wall a breakwater and in some instances they can act as both. Despite this versatility, the use of concrete caissons is not common in many regions and countries where sophisticated fabrication techniques are unavailable.

Caissons rely on their self-weight to resist loads and forces transmitted via wave actions or vessel berthing and mooring operations. Whilst an increase in the weight of the caisson will improve its ability to resist these forces, the increase will also result in a greater transmission of vertical forces to the underlying ground. This makes geotechnical conditions a key factor when considering caissons as a viable option.

Environmental and sustainability considerations can also play a key role in the decision-making process during early planning stages. Caissons avoid issues such as underwater noise and vibration typically associated with piling works and offer a more efficient use of resources and materials compared to rubble-mound breakwaters due to their smaller footprints. Reductions in turbidity when installing are also notable advantages

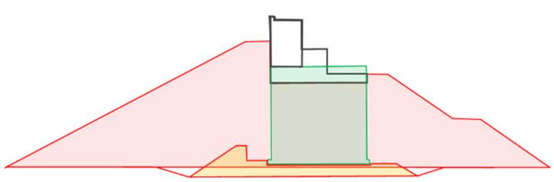

Figure 28 Volume and footprint comparison (Source: developed by the Authors).

Significant improvements to the structures durability and whole of life cost are also key features when compared to structural typologies which rely upon the regular maintenance of protective paint and cathodic protection systems.

Finally, the use of slip form technologies inside floating docks significantly reduces fabrication time and cost and when combined with further reductions in onsite resources levels and installation times, the use of concrete caissons can in many cases offer a lower overall cost solution.

Advantages over other solutions
This presentation will outline the main advantages of caissons compared to other structural typologies when acting as a quay wall and/or as a breakwater.

A main advantage is the structures efficiency in providing protection against waves and berthing forces using a single element (caissons).

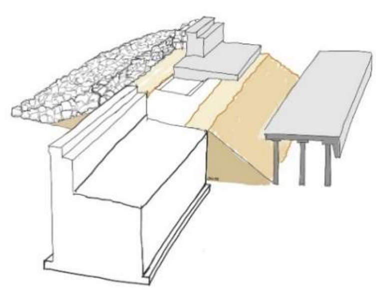

Figure 29 Protection and berthing structure (Source: developed by the Authors).

Advantages from a point of view of logistics can be explained through the example of TX2 of Port of Açu (Brazil), where a temporary auxiliary port was created and later dismantled reusing the caissons.

Figure 30 Auxiliary temporary port at Açu.
(Source: ACCIONA).

Caissons fabrication
Typically, the fabrication of Caissons is undertaken using the following methodologies

- Onshore fabrication.
- Fabrication in dry dock.
- Fabrication in special facilities.
- Fabrication with floating dock.

Onshore fabrication, and fabrication with a floating dock, are the two most common strategies however onshore fabrication strategies require large laydown and working areas to support construction activities.

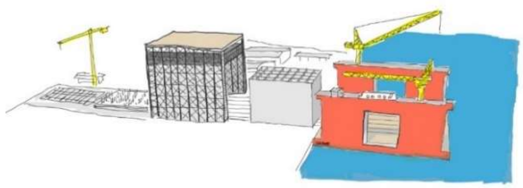

Figure 31 Onshore fabrication
(Source: developed by the Authors).

This presentation will explain the phases of the fabrication sequence with a floating dock.

Figure 32 Fabrication with floating dock
(Source: ACCIONA).

Phase 1. Prefabrication of bottom slab reinforcement matts and wall starter bars outside of the floating dock.

Phase 2. Transfer and installation of the prefabricated steel reinforcement base matt to inside the floating dock and casting of the bottom slab.

Phase 3. Slip forming of the caisson wall supplying the concrete from the quay and using concrete pumping and distribution arms inside the top of the floating dock.

Phase 4: Completion of concrete slip forming process for walls before floating of caisson units out of Dock.

The duration of the process directly depends on the height of the caissons however fabrication rates of of 4 m/day is typically achieved, meaning that a caisson 20 m height can be fabricated in 5 days.

Construction with concrete caissons
This presentation will outline the phases once the caissons are fabricated, explaining how they are transported to the site and installed.

Figure 33 Installation of caissons
(Source: ACCIONA).

Phase 1: Depending on the quantity of caissons to be fabricated, the floating dock may be shipped using semi-submersible vessels to the site or caissons may be manufactured at the floating docks homebase and later shipped to the project site.

Figure 7 Installation of caissons
(Source: www.puentedemando.com).

Phase 2: Preparation of seabed areas and placement of bedding layers

Phase 3: Positioning and sinking of caissons in position using flooding techniques.

Phase 4: Filling of caissons using suitable materials as well as the potential reuse of dredge spoil from project site areas (where possible).

Phase 5: Topside construction including construction of capping beams, pavements and berthing and mooring systems.

Webb Dock East Berth Capacity Expansion

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Summary
This paper describes recent increases in capacity at Webb Dock East in the Port of Melbourne. The paper discusses extensions to the quayline, and increases in the ship to shore crane capacity.

The former includes a northward extension to Berth 4, requiring removal of a projecting area known as "the knuckle". An additional mooring dolphin has also been constructed at the south end of the quay line. Various options were considered to improve crane capacity; the selected option was to limit concurrent wharf loadings during crane operation.

The project demonstrates the sustainable upgrading and optimisation of existing port assets.

Keywords: Webb Dock; containers, extension, loading, sustainable upgrading and optimisation.

Introduction

This paper describes recent improvements at Webb Dock East in the Port of Melbourne to service larger container ships. This work follows on from previous projects in the mid-2010s. Figure 1 shows this area in relation to the overall port and city of Melbourne.

Figure 34 Webb Dock East 4 & 5, showing layout and context to the overall Port and City of Melbourne.

Background

Commercial ships (particularly container vessels) have been steadily increasing in size over time.

Webb Dock East Berths 4 & 5 were constructed in the early 1970s and 1980s respectively to service 2nd and 3rd generation container ships (2,000 – 3,000 TEU and 200-250m LOA). However, by the early 2000s, lift on-lift-off container operations had decreased and the berths were also being used for the automotive trade.

By 2010 the Port of Melbourne had determined that projected growth in container trade volumes warranted converting the facility back to a dedicated container terminal but that the berths needed to be refurbished and upgraded. Therefore in the mid-2010s the wharves underwent a major upgrade involving extension, deepening and restoration as part of the then Port Capacity Project (PCP). Jacobs was the maritime engineer for the project.

By the late 2010s, there was already a demand to accommodate multiple vessels of greater length than the PCP design criteria. Furthermore cranes with greater outreach and hence wheel loads were desired. Note that further increases in vessel drafts were not proposed due to dredge depth limitations of the existing structures.

Berth extension

The current requirement is for a combination of two vessels of 366 m and 350 m respectively to be able to use the berths concurrently. This required a 70 m extension of Berth 4 to the north, together with an additional mooring dolphin to the south of Berth 5.

In order to extend the wharf to the north, an area projecting out from the quay line needed to be removed. This area was the remnant of a former stern ramp facility and was already retained on several sides by a large retaining wall built during the PCP to retain differential berth pocket depths. In order to remove these retaining walls, the construction works needed to be planned to enable controlled release of loading.

A further transition structure was also needed so the extended berth pockets could batter up to the adjacent berth depths without the need of another transverse wall which may then also be required to be removed at a future date.

A number of options for the structure form were considered. Although the original wharves were all suspended deck over piles seaward of a central retaining wall, the immediately adjacent area had the newer PCP retaining walls and were fully land-backed. Ease and speed of construction were the main factors in determining that continuing a land-backed / fully retaining design from the PCP works would be the most cost-effective solution.

The final overall arrangement is shown in Figure 2.

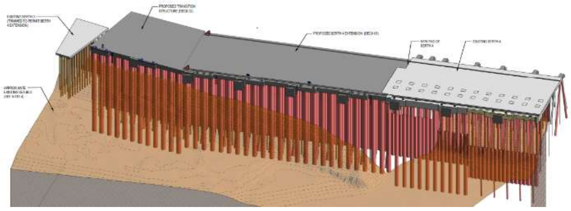

Figure 2 Berth 4 Northern Extension showing construction arrangement.

A second mooring dolphin (in addition to one built at PCP) was also constructed to the south of Berth 5. As this second dolphin was now too far from the wharf to be braced laterally to the wharf, it was constructed as a fully independent structure of concrete cap on steel tube piles.

Upgraded Crane Loading

To complement the ability to service longer container ships, the end user of the facility, Victoria International Container Terminal (VICT), was also seeking to service wider ships – up to 20 containers across. In order to achieve this greater outreach, it was necessary to increase the permitted crane wheel loads on the wharf.

Unfortunately, there is very little spare capacity of the structure to increase overall loading due to the limitations of the original design and extent of upgrading for the PCP. VICT commissioned Jacobs to investigate options which centred around maximising useable loading from the existing structure. This included looking at load and dynamic factors and load combinations with other deck usage.

The final solution was a combination of operating procedures including limiting other nearby deck loading whilst container cranes are in operation.

Discussion and Conclusion

Recent upgrades to Webb Dock East Berths 4 & 5 in recent years have permitted an increase in maximum ship LoA from 300 to 366 m. It was found that a fully retained structure was the fastest and most cost effective to construct.

A 10% increase to quay crane wheel loading was made possible by considering all relevant load factors and limiting adjacent concurrent loading.

Figure 3 shows the completed wharf extension and new quay cranes.

Figure 3 Webb Dock East 4 completed works, showing new cranes installed.

References

[1] Jacobs Report IS303800-SM-RPT-0005

[2] Jacobs Drawings P1304-WEB-S1000 to 1271

Relevant UN SDGs 8,9,11

Subaqueous capping remediation of Kendall Bay

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Summary
The sediments at Kendall Bay, Sydney were severely contaminated due to the operation of a gasworks facility that was active from 1886 until the 1980s. The site was polluted with a range of contaminants, including polycyclic aromatic hydrocarbons (PAHs), and petroleum hydrocarbons (TRHs), among others. To remediate the sediments, a subaqueous cap was constructed, which involved the installation of an active geocomposite called Tektoseal Active Activated Carbon (TAAC). This state-of-the-art technology has been proven to effectively contain and treat contaminated sediments in aquatic environments.

Keywords: Contaminated sediments, polycyclic aromatic hydrocarbons (PAHs), active geocomposite, Tektoseal active activated carbon (TAAC)

Introduction

The concentration of contaminants in marine environments has been a crucial topic in various fields for a long time. In recent decades, the number of available measures to remediate these contaminated sites has increased dramatically. However, choosing the right measure is imperative for decision-makers. In-situ capping, dredging and dewatering with geotextile tubes are the top remediation measures that can be applied to different boundary conditions to achieve the best results.

Contaminated sedimentary deposits in water bodies pose a significant problem for the environment, affecting the entire food chain. The primary cause of the problem is the discharge of industrial and commercial waste, which enters the water bodies during the operating processes and adheres to sediments. This paper proposes a definitive solution to this problem, advocating the use of in-situ capping with active geocomposites.

Capping systems can be designed in various ways using clean sand/sediment as diffusion barrier for the contaminants. However, its important to note that the thickness of the required capping layer decreases the hydraulic capacity and navigational depth of waterbodies [1]. It's recommended that the sand layer range from 100 to 250cm to achieve a minimum design life of 100 years [2]. To increase the effectiveness of capping, its recommended to integrate active medias such as activated carbon or organophilic clay as encapsulating element. These active material helps to chemically isolate the cap by binding the pollutants to themselves. However, installing such a layer can be challenging, especially of the active material that has a low density, leading to slow sinking behaviour. Additionally, combined with underwater currents, this can result in a thin and inconsistent layer distributed over a large area [3]. Using an active geocomposite material warrants consideration as a sustainable and pragmatic approach to resolving the issue at hand.

Active capping is a highly effective in-situ remedial approach that involves securing contaminated sediments at their current location by placing a layer of geocomposite and sand or clean sediment above them. The geotextile layer acts as a robust filter preventing any mixing between different cap layers. Additionally, it guarantees the stability of the cap. The active media within the geocomposite is the key component that binds the upwelling of contaminants by adsorption, thereby allowing the remediation process.

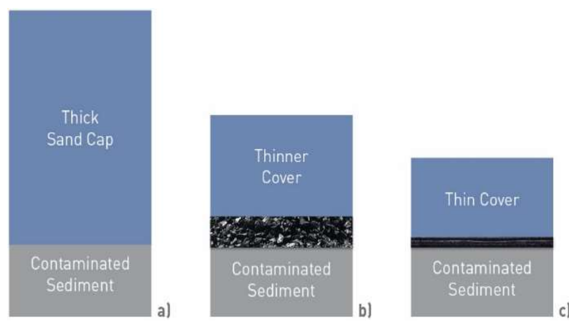

Figure 35 Different capping design (a) sand cap; (b) active cap with a thinner protection layer; (c) active geocomposite.

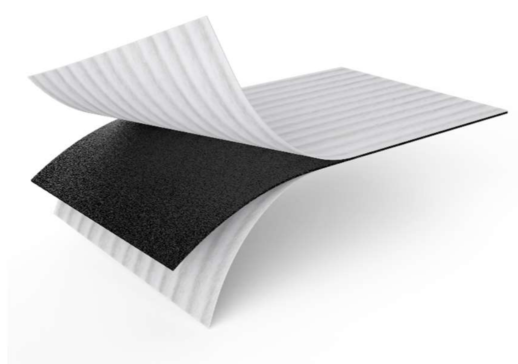

Figure 2 Tektoseal® Active Activated Carbon (AC)

Project Background
Kendall Bay, located 10km west of Sydney's Central Business District, was severely contaminated due to operation of a gasworks facility from 1886 until the 1980s. The sediments on the shore were black, oily and had a distinct tar, hydrocarbon, or naphthalene odour that is a clear indication of gasworks contamination. The level of polycyclic aromatic hydrocarbons (PAHs) and petroleum hydrocarbons (TRHs) were significantly higher than the quality guidelines. The contamination was extensive and highly concentrated, with sediment present to a maximum depth of over 4m in the northwest area of the bay and almost 8m in some parts of the southern end of the bay where a former stream had cut into the sandstone bedrock. The situation demanded immediate attention and remediation measures to ensure the safety and well-being of the local community and the environment.

Investigation
The NSW-EPA issued a clear declaration that the vicinity around the former gasworks facility necessitates remediation where sediments contained PAH concentrations averaging over 25 mg/kg and a maximum above 60 mg/kg (normalized to 1% total organic carbon), in addition to TRH concentrations averaging more than 4000 mg/kg and a maximum above 5500 mg/kg.

The site investigation indicated that the threshold limits were breached at multiple locations. The accessible foreshore areas and the western end of the mangrove area recorded total PAH concentrations greater than 1 mg/kg, while the remaining mangrove area recorded total PAH concentrations greater than 120 mg/kg. Even the wading areas showed total PAH concentrations greater than 60 mg/kg. The Site Auditor and NSW-EPA approved the remediation method, which include in-situ stabilisation, an activated-carbon geocomposite, and a ballast layer. To prevent any potential low-level dissolved phase impacts that could leach out of the ISS layer, HUESKER's geocomposite with activated carbon, Tektoseal Active AC, was installed above an in-situ stabilisation layer. Stringent protective measures were taken to preserve the marine environment before commencing the works, including silt curtains and sheet piles. The active geocomposite was prepared for the capping by removing larger debris and other materials that could cause damages to its fabrics.

Solution
Through extensive collaboration with designers and relevant authorities, Tektoseal Active AC 3400 has been chosen as the superior solution for this project. The material contains a high density of 3400 g/m² of engineered activated carbon, that has been customised to meet site conditions. This ensures maximum absorption of contaminants for several decades.

The installation of Tektoseal Active AC 3400 involved unrolling the material from a barge, while divers provided assistance. Additionally, a frame was used to sink the geocomposite and ensure controlled a ballasting with cobble and sand.

A thin cover layer was then carefully placed above Tektoseal Active AC to provide unsurpassed mechanical protection and a surface for benthic recolonisation. The meticulously planned installation of Tektoseal Active AC 3400 and the careful placement of the cover layer have ensured that the shoreline remains protected from contamination, thus safeguarding the environment for years to come.

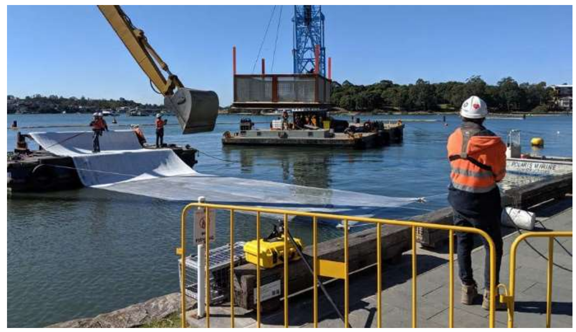

Figure 2 Remediation works on Parramatta River at Kendall Bay

Figure 3 Ballasting of the geocomposite with a thin cobble and sand layer with the help of a sinking frame

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Relevant UN SDGs: 6,9

Working with Nature – Ideation to Realisation in Sediment Management

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Summary
This paper explores the "Working with Nature" approach in sediment management. Key lessons include the importance of baseline understanding, community engagement, risk sharing, and alignment with sustainable development goals. These projects highlight the potential for achieving long-term, cost-effective, and environmentally friendly outcomes in coastal engineering. By working with natural processes, these initiatives not only protect coastal areas but also enhance biodiversity, provide recreational opportunities, and promote community well-being. The "Working with Nature" approach represents a paradigm shift in sediment management, offering a sustainable and resilient solution to the challenges posed by coastal erosion and climate change.

Keywords: Working with Nature, Sediment Management, Sand Bypassing, Zand Motor, Coastal Engineering

Introduction

The concept of "Working with Nature" involves designing and implementing projects that align with natural processes to achieve sustainable outcomes. Traditional beach nourishment methods which involve regular and frequent campaigns often disrupt coastal processes, affect marine flora and fauna systems, and incur high costs due to the extensive mobilisation and demobilisation of plants and equipment. In contrast, the "Working with Nature" approach seeks to harness and leverage natural forces in coastal and marine environments to achieve the desired outcomes. This paper examines the application of this concept through various projects, emphasising the benefits and lessons learned from these initiatives during actual implementation.

The concept

The Zand Motor project, where construction began in 2011 in the Netherlands, is a large-scale implementation of the "Working with Nature" principles in beach nourishment. Historically, beach nourishment campaign at the project location takes place in an interval of 4~5 years, with each campaign requiring some 5 million m^3 of sand. In contrast, the Zand Motor project involved placing 21.5 million m^3 of sand in a single location along the coast of Kijkduin, Zuid Holland, with a target design life of 20 years. During this period, natural forces such as waves, tides, and winds are relied upon to redistribute the placed sediment and promote the gradual build-up of beaches and dune systems along the coastline [1].

Several key benefits were resulted directly and indirectly from this approach:

- Reduced Ecosystem Disturbance: By eliminating the disturbance at both sediment extraction and placement locations every five years, this approach allows the ecosystem to rehabilitate, adapt, and rebuild in a longer period of time.
- Cost Savings: The large-volume, one-time placement of sediment reduces the need to regularly mobilise and demobilise construction plants and equipment. Additionally, it minimises the need for mechanically spreading the placed sediment along the beach, which contributes to the reduction of greenhouse gas emissions.
- New Habitats: As the ecosystem adapts and rehabilitates to reach the new equilibrium, the newly created shoals provide habitats for various flora and fauna to establish, enhancing biodiversity.
- Recreational Opportunities: The new landforms created by the project offer recreational spaces for the community, promoting well-being and tourism. It is also a demonstration of the harmony that humans can achieve with Nature in projects such as this.

Figure 36 The Zand Motor (Source: [1]). The width of the reclamation at completion was approximately 1 km in width and 2 km in length, with an average nourishment thickness of 5 m. Note the human-made habitat lagoon in the centre of the Zand Motor

Application in GHD projects

GHD delivered a number of sediment management projects incorporating the Working with Nature concept. Below is a summary of the three most recent examples.

Mandurah Sand Bypassing Concept Design: The natural littoral drift process at the project site has been interrupted since the completion of the training walls at the Mandurah Marina Entrance Channel. The project involved an annual bypassing campaign of 100,000 m^3 of sediment to maintain safe navigation and beach conditions. A sand trap is formed at the upstream side of the training wall to capture the littoral drift. When it is full, a mobile screening and pumping plant is mobilised to transport the sediment to the downstream side of the training wall through a series of submerged and buried pipelines, to allow the distribution of the sediment by the local tide, wave, and wind patterns.

Mini Sand Engine: This project involved the bypassing of sediment from upstream of a built coastal structure to downstream, with a deliberate positioning of the discharge pipe to enable the forming of three small sand spits, similar to Zand Motor. Historical campaigns saw mechanical excavation and transportation of around 80,000 m^3 of sediment every 3~4 years, where the sediment was then dumped and spread on the beach by dull dozers over a 6-week period. The latest campaign, which adopted the concept of Zand Motor and created three small sand spits, leveraged the natural force to mimic sediment distribution patterns under the influence of local wind, tide, and waves. The project was able to reduce the onshore stockpile footprint that would otherwise be required historically and reduce environmental impacts such as noise, dust, air quality, and greenhouse gas emissions through the elimination of trucking and spreading operations.

Resort Island in Southeast Asia: This project demonstrates the importance of establishing the characteristics of the site environment to enable further consideration of the implementation of the Working with Nature concept. The project site has experienced beach erosion. A root-cause analysis was carried out with the use of DHI MIKE 21 numerical models. It was established from the analysis that the seasonal variation of wave patterns around the Island contributed to the movement of sediment, exacerbated by the rising sea level. Following the finding, a series of mitigation options that leverage such a natural pattern were developed and examined in the model.

Lessons learnt

Implementation of “Working with Nature” in sediment management projects requires deliberate consideration during the planning and execution phases. A few lessons learnt are provided below:

- Work with Nature: Nature has been shaping the environment that we live in since the existence of the Earth. To achieve the desired outcome, human intervention should avoid working against Nature.
- Baseline Understanding: It is imperative that a comprehensive understanding of the baseline and characteristics of the site environment and its surrounding areas that may be impacted by the implementation of Working with Nature is established. This includes, for example, local geology, contamination, coastal processes, marine ecosystems, and habitats.
- Certainty: In practice, the project owner – usually a government entity, would like certainty on the outcome of the Working with Nature implementation. Considerations shall be given to the required scope of work to achieve a risk level that is acceptable to all stakeholders impacted. A contingency/response plan may also be required for “what if” scenarios during sediment management.
- Environmental Impact: It should be accepted that the implementation of Working with Nature in sediment management will have impacts on the environment. An honest and transparent evaluation of both positive and negative impacts shall be conducted, for consideration by the stakeholders.
- Community Engagement and Consultation: Recognising the influences of implementing the concept and the level of certainty on the outcome, the communities shall be actively involved in the planning and execution phases of the implementation, to foster collaboration and understanding.
- Measure of Success: A clear definition of metrics for success shall be established, particularly reflecting on the randomness of the Nature and the level of certainty during the design phase.

In sum, for successful implementation of a Working with Nature project in shoreline management, a holistic approach that integrates engineering, environment, and social considerations will need to be given, if not more than a traditional engineering solution.

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Relevant UN SDGs (*https://sdgs.un.org/goals*)
7, 13, 14, 15.

Transhipment Capacity Modelling

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Summary
To determine the feasibility of achieving transhipment throughput targets for magnetite concentrate at Albany Port, Western Australia, BMT developed a discrete event model to simulate logistics from mine concentration plant, storage tanks feeding a 90km slurry pipeline to the port, port dewatering and stockpile, and transhipper loading and offshore transfer to ocean going vessels (OGV). During several phases of feasibility study a 10-year metocean hindcast was used to simulate throughput and inform a wide range of operational parameters including processing plant capacity, stockpile size, transhipper capacity, transhipper fleet size, transhipment location, and operational costs.

Keywords: Transhipment, Capacity Modelling, Discrete Event Simulation, Albany Western Australia

Study Objective
Grange Resources engaged BMT to study the feasibility of exporting 5mtpa of magnetite concentrate from a proposed mine located 90km northeast of Albany, Western Australia. Magnetite concentrate will be transported as slurry via pipeline to Albany Port where it will be dewatered and stockpiled. Stockpiled concentrate will be loaded by conveyor and ship loader onto a transhipment vessel (TSV) for export of magnetite to load Cape class vessels anchored in King George Sound (KGS) in two stages of loading: part-loading at a shallower, protected anchorage, and full-loading at a more exposed deepwater anchorage. The logistics for materials handling from mine to OGV were built into a discrete event simulation model. Results from scenarios simulating a 10-year operational period (hourly resolution) were used to inform selection of a transhipment vessel, confirmation of design parameters for port and mine infrastructure to meet the target throughput and provide quantitative comparison of operational costs.

Modelled Components
The model scope is shown in Figure 1. Components, rates, capacities, planned and unplanned maintenance regimes, and interdependencies for the landside processing and material handling were defined in a workshop with client and process flow design engineers.

The port and transhipment components included slurry filtration (dewatering), stockpiling and reclamation, TSV berthing, loading (from stockpile and direct from filter plant), TSV transit to the OGV, TSV repositioning, 2-stage OGV loading, and TSV return to port. OGV arrival time was randomised with a defined laycan interval. A metocean hindcast over 10-years for wind speed and direction, wave height, period and direction, and current speed and direction was input to the simulation model. Side-by-side TSV and OGV vessel movements in response to wind, waves and currents at the time of OGV loading were computed using a combination of Response Amplitude Operator (response to waves) at different vessel load states, and stresses from winds and currents affecting the weather-vaning of OGV and relative alignment with incident waves. Periods of transhipment inoperability were determined when relative vessel displacement between TSV and OGV due to vessel roll, pitch and heave exceeded safe operating limits for materials transfer, resulting transhipment delays.

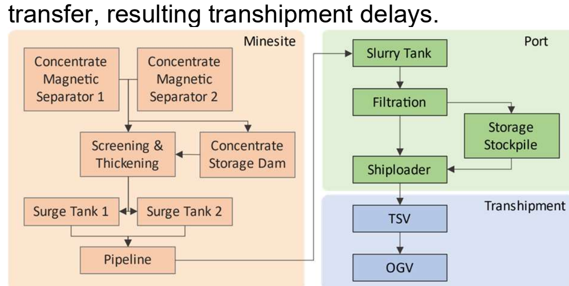

Figure 37 Schematic of the throughput model showing components at the mine site, port and transhipment.

The model was developed using FlexSim (discrete event simulation) and FloWorks (continuous flow module). The model was implemented on a web server permitting multiple users to interact with the model simultaneously.

In addition to standard event logs, outputs from the model were designed to inform specific design interests, including annual throughput tonnage, transhipper cycle time, OGV loading time, stockpile level, delays due to maintenance, waiting for product, and metocean conditions. Detailed analysis of the outputs was used to investigate seasonal and interannual throughput variability, identify bottlenecks in the process stream, perform cost-benefit analysis for increasing component capacity or functionality (e.g., azipod-equipped TSV, single-point loading vs loading by warping.

Scenarios and Analysis
In the Pre-Feasibility Study (PFS) many scenarios were run with the aim of identifying a preferred TSV/OGV combination achieving the throughput target as a basis for further assessment. These scenarios varied the following parameters:

- TSV capacity, single point loading or warping, and fleet size
- TSV propulsion (azipods to control OGV weather vaning during loading)
- OGV size
- Filter plant feed rate
- OGV arrival interval

For the Definitive Feasibility Study (DFS), Grange and landside process flow consultants carried out an independent exercise to explore the sensitivity of simulated throughput performance to a variety of model parameters with the objective of determining optimal configuration, rates and capacities for landside process flow components. This process informed optimal equipment numbers and capacities. This resulted in the identification of a base case scenario that was adopted for DFS. BMT subsequently ran this DFS base case and post-processed the model outputs to assess key performance metrics for the transhipment operation. The post-processing and analysis investigated the following aspects:

- Does overall port throughput achieve project export target of 5Mtpa (dry) (Figure 2)
- Characterise throughput variability
- Characterise the TSV cycle time and variability, TSV loading delays due to concentrate availability
- Characterise OGV loading time, variability, and delays due to metocean conditions (Figure 3) at the part-loading and full-loading anchorage sites, and upstream supply interruptions (Figure 4)
- Quantify TSV operating phases to inform OPEX estimate
- Characterise port stockpile levels
- Identify any impacts to transhipment resulting from constraints on upstream processes.

The stockpile capacity at the port was limited by available land area. The impact of this limitation was assessed by examining effects of stockpile depletion and saturation on downstream transhipment and upstream processing, e.g., requiring the upstream concentrate slurry feed to be suspended when the port stockpile was full.
Simulation outputs were used to develop the OPEX cost estimate, specifically:

- Fuel costs for total TSV operational time
- Energy costs for ship loader operational time
- Number of TSV transits, incurring Port charges
- Number of OGV visits, incurring Port charges
- The number of TSV cycles, OGV visits and delays to OGV loading were used to estimate Port usage charges, Port mooring charges, and penalties for OGV loading delays.

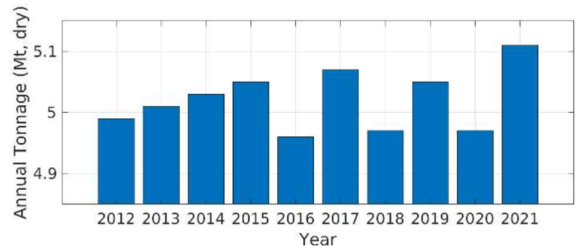

Fig 2 Annual transhipment tonnage

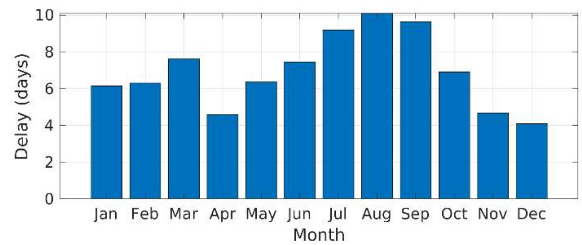

Fig 3 Average transhipment delay per month due to inoperable conditions

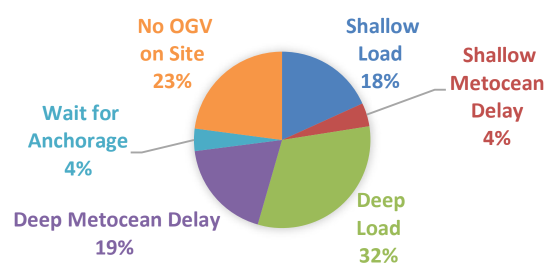

Figure 4 Average percentage of time for OGV activities

Summary

Robust assessment of transhipment throughput was achieved using an integrated model of landside supply, material stockpile and materials handling at the port, and transhipment operations which are subject to both upstream supply and metocean conditions. The development of a representative model requires careful collaboration between diverse engineering disciplines. Optimisation of the logistic chain requires compromises in multiple areas but is ultimately informed by financial objectives and constraints. The integrated model is a powerful tool for analysis of complex interactions in the transhipment logistics chain, informing engineering design, operational strategies, project feasibility and financial performance.

Acknowledgements

BMT gratefully acknowledges the expertise of Grange Resources and process flow engineers for their essential collaboration and support in this project.

This abstract presents a general approach to transhipment feasibility. The method and findings of this study are specific to the context and project definition at the time. As such, any third party use or interpretation of these findings are not endorsed by Grange Resources.

Climate stress testing for waterborne infrastructure

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Summary
Resilience stress testing allows waterborne infrastructure projects to be pushed beyond prescribed limits to investigate the risks and opportunities related to uncertainties in climate change. This paper provides an overview of climate stress testing for port infrastructure, which follows and adapts established processes in the hydropower industry. Resilience stress testing supports the development of climate-ready waterborne infrastructure.

Introduction
Waterborne transport infrastructures adjacent to low coastlines and river floodplains are vulnerable to climate change (sea level, precipitation, waves etc.). The optimisation and specialisation of port infrastructures also increase their vulnerability to climate threats.

The Global Risk Report by the World Economic Forum names the lack of policy to deal with extreme weather and climate change as one of the most significant short- to medium-term global threats [1].

Infrastructure development practices and resilience stress testing
Risk-based engineering design of waterborne infrastructure is a proactive and iterative approach that considers potential risks and uncertainties in the design process to optimise infrastructure design for a pre-selected set of design parameters and design criteria. This traditional engineering approach aims to build a robust and reliable infrastructure that can operate effectively and safely despite the challenges posed by various processes, including climate change.

Who should carry out resilience stress testing, and when?
Port infrastructure investments are typically long-term investments. Understanding the level of resilience of port infrastructure is an essential factor for investors in a climate-uncertain future. Pre-planned climatic adaptation may become less valuable than flexibility, organic and resilient thinking. While traditional engineering design process can manage planned adaptation but has limitations when design criteria and parameters become broader. In that context, PIANC TG193 [2] summarise and highlight future needs, the definition of key terms, a series of case studies, and identify best practices and resilience-related decision-support tools.

Resilience testing requires analytical skills and modelling skills to qualify and attempt to quantify a range of future scenarios. Stakeholders may identify and communicate accurately potential climate stressors, also called "source".

A resilience stress test management process is typically considered a fundamental principle that "infrastructure is at the core of the resilience process. This infrastructure-centric approach allows the realm of possibilities to be explored more fully for climate adaptation, constituting as many "scenarios".

How to carrying-out a climate stress test?
Multiple phase assessment. The hydropower sector Climate Resilience Guide [3] proposed five phases to determine the resilience of existing and future hydropower projects as follows:

- Phase 1 - Climate Risk Screening
- Phase 2 - Initial Analysis
- Phase 3 - Climate Stress Test
- Phase 4 - Climate Risk Management
- Phase 5 - Monitoring, Evaluation and Reporting.

The resilience of waterborne infrastructure may be assessed through a similar methodology outlined for future discussion in the following sections.

Phase 1 Climate Risk Screening
The first phase consists of the following activities:

- Identify infrastructure
- Identification of risk and opportunity
- Identification of uncertainties - This task can be guided by the PIANC, which deals with uncertainties (Technical Note No1) and outlines various uncertain parameters and values [4].
- Select climate scenarios
- Select an approach for each stress test - Qualitative and quantitative approach - not all climate resilience tests need to be quantified, but a screening assessment assists in determining the method of analysis. The stress test may be comprehensive, semi-comprehensive and limited, depending on the risk and opportunity presented by infrastructure resilience.

Phase 2 - qualitative analysis and risk management process
The second phase defines what and how the resilience test will be carried out. The following steps occur during this phase:

- Data collection and analysis - collecting data from General Circulation Models (GCM), Regional Climate Models (RCM) and intercomparison models of climate ensembles can provide boundary conditions for climate resilience models. The PIANC Permanent Task Group on Climate Change (PTGCC) 2023 TG3 climate update [5] provides valuable baseline information for this task.

- Outline baseline - list the existing design criteria and Key Performance Indicators (KPI} for the infrastructure business and the usual climate scenarios.
- Define approach for stress testing - decisions on the type of investigation should be made based on the risks and opportunities associated with the specific KPI under evaluation.
- Stakeholder engagement and risk and opportunity

Phase 3 - Climate stress test

An infrastructure-specific climate stress test is then carried out systematically for each process and scenario to capture the sensitivity of socio-economic and environmental changes associated with climate change. A possible overview of the modelling methodology is provided in Figure 1 below.

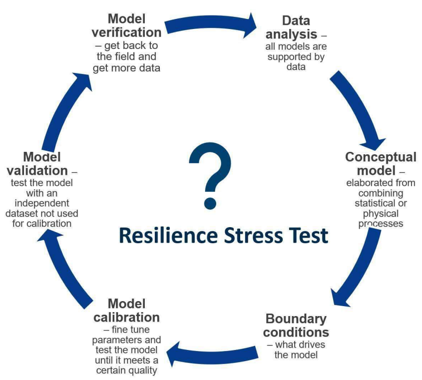

Figure 1: Overview of modelling methodology for climate stress testing

Figure 2 shows a climate stress testing diagram, which outlines the interplay between reliability and economic performance.

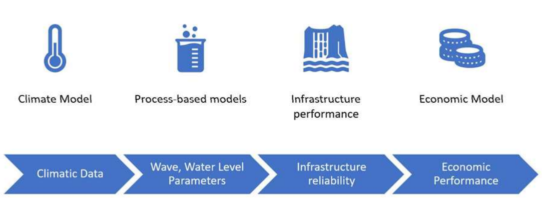

Figure 2: Climate stress testing model diagram for economic performance assessment

Economic appraisal may include benefit-cost analysis from the baseline position defined in Phase 2, revenue generation, profit and loss balance, etc.

Phase 4 - Climate Risk Management Plan

A climate risk management plan is then compiled to present the results of the resilience stress test analysis. The plan may be accompanied by testing various alternative infrastructure options to improve resilience, as follows:

- Identify resilience measures - The plan will seek to identify opportunities to improve the design, and several opportunities have been identified in the PIANC Working Group 178 "Climate change adaptation planning for ports and waterways" [6].
- Optimise design to improve resilience
- Analyse resilience with optimised design
- Update risk and opportunities
- Engage with stakeholders.
- Compile climate risk management plan

Phase 5 - Monitoring, evaluation, reporting

Phase 5 allows for the completion of the assessment with a feedback mechanism to enable future revisions and improvements of the plan.

- Stakeholder engagement to define buy-in
- Climate resilience monitoring plan
- Evaluation and re-assessment of climatic risk

Conclusion

Stress testing complements vulnerability and risk analysis by simulating real-world scenarios, revealing some vulnerabilities and weaknesses that might not surface in regular assessments. By subjecting the infrastructure to such stressors and evaluating their effects on service, infrastructure managers can assess its resilience, identify critical weak points, and devise adaptive strategies to enhance waterborne infrastructure resilience. The ability to provide safe, reliable and accessible waterborne infrastructure is at risk from the global climate crisis. We can no longer delay taking action to adapt to the future effects of climate change and climatic risk management based on resilience stress testing, which can guide port operators and investors in managing an uncertain climatic future.

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Relevant UN SDGs: 9,11,13.

Assessing Capital and Maintenance Dredging Requirements with Navigate Hydrographic in Gisborne Port, New Zealand

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Summary
Eastland, the port authority of Gisborne, New Zealand, are embarking on a large-scale capital and maintenance dredging campaign. Part of this campaign is to accurately assess the volume of both silt and softer sediments that can be removed through maintenance dredging, and the volume of hard rock layers that require capital dredging. Navigate Hydrographic is software designed for easily assessing dredging requirements, and this paper presents how it was able to assist the marine and engineering team prepare and execute this project.

Keywords: Dredging, Software, Hydrographic Survey, Port Management, Eastland

Introduction

The port of Gisborne (Figure 1), located in the eastern coast of New Zealand's North Island, is located near the mouth of the confluence of three rivers. As such, siltation is prevalent within the port waters to maintain depth and dredging is a common undertaking. Eastland, the body who manages and operates the port, organise this dredging activity and contract hydrographic survey operations to provide regular seafloor data updates for planning and analysis.

Figure 38 Gisborne Port (Source: Author Photograph). Gisborne Port lies at the mouth of a significant river system. This means there are constant dynamic seafloor changes in and around the port, which requires regular survey and dredging. The managers of the port, Eastland, conduct regular hydrographic surveys and required software to analyse this.

In recent times, Eastland have invested in new wharf infrastructure, and to maximise the benefit of these new facilities dredging of the two main berth pockets, approach channel and turning basin is required. The marine engineering team have contracted numerous hydrographic and geophysical surveys to assess the volume of both soft sediments and hard bed rock above their desired design depth. However, Eastland were unable to easily interpret this information and relied on drawings from contractors. This meant that easily assessing alternative dredging scenarios became a very time-consuming task. Eastland were looking for a solution that was able to enable their marine and engineering team to conduct their own analysis in house and make decisions quickly.

Navigate Hydrographic

Navigate Hydrographic is an Australian based software company that have been in operation since 2017. The company have created a hydrographic survey data visualisation and analysis software package that is designed for the end user of hydrographic data. In this case, Eastland are an end user of hydrographic survey data, using it to make decisions around dredging and navigational safety.

Eastland and Navigate first met in September 2023 at the Coasts and Ports conference on the Sunshine Coast. Since then, together we have been looking at a software process to achieve the desired project management outcomes.

Hydrographic Survey in Gisborne

Being at the mouth of a river system, Gisborne is subject to significant sedimentary flows, especially in periods of flood. In 2023, Cyclone Gabrielle terrorised the region, with huge rainfall causing damage to the region and a large build-up of sediment and objects in the port's channels.

In dynamic port environments such as this, it is critical to maintain a regular schedule of hydrographic surveys, ideally with a multibeam echosounder. This enables 100% coverage of the seafloor and allows for all significant objects to be detected. Eastland have recently adopted multibeam technology by engaging Discovery Marine Ltd as their hydrographic survey contractor. DML now conduct regular hydrographic surveys in the port to update the port for berth declaration and engineering purposes.

Analysis of Hydrographic Data

One common issue that many end users face after getting a hydrographic survey done is how to visualise and analyse the data. Traditionally a hydrographic chart may be used to present the survey information, however in modern times where a much greater amount of data is being collected using multibeam echosounders, the chart reduces this to a series of numbers on a page. In scenarios like the dredging projects in Eastland, many hours can be wasted between end user and surveyor tailoring the deliverables to suit the end user's purpose.

Navigate Hydrographic addresses this by providing easy to use software for the end user to import and interpret hydrographic data and products, as well as designs that a port authority would typically use.

Assessing Dredging Requirements

Once the survey data has been acquired and provided to Eastland, the marine and engineering team are able to load this information into Navigate along with their desired channel design. This design takes into account larger ships and requires significant dredging.

However, geophysical surveys have indicated that a substantial portion of the dredging required is capital dredging through harder rock layers. A thick layer of silt lies over this rock layer which can be dredged using trailer suction hopper dredging techniques.

Navigate firstly allows Eastland to quickly assess material above design both in a spatial context and volume. The survey data is presented with a simple design analysis tool showing data above design in bright red (Figure 2).

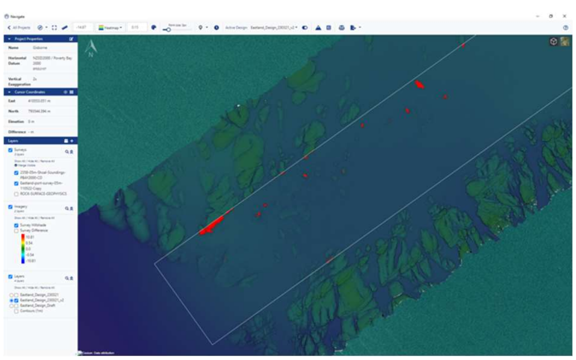

Figure 39 Navigate Design Analysis. Bathymetric data that is above the design depth is shown up in bright red, making it very easy to see what depths are a hazard to navigation and require removal through dredging.

In addition, Navigate allows the team to change the design depths on the fly, so different dredging scenarios can be easily investigated without re-completing all of the calculations. For example, investigating the additional volume to be dredged to achieve an extra 20 centimetres depth can be calculated instantly, and thus the implications to dredging time and cost can be assessed.

Capital Dredging Requirements

When it comes to the capital dredging requirements, Eastland are able to import the geophysical survey data as a different type of survey surface. This means that the exact same calculations can be made against the geophysical surface, capital dredging volumes calculated, and alternative scenarios investigated. The cross-section tool is available to look at the thickness of the soft material above the hard bedrock (see Figure 3).

Figure 3 Navigate Cross Section. Different surfaces can be compared with the design.

Tracking Progress

Once the dredging commences, Navigate can also be used as an effective tool to track the progress of the project and generate visualisations for other members of Eastland. It does this by automatically deconflicting the survey layers and hiding data that has been superseded by any new updated survey. So, calculating updated volumes and design analysis is a painless and simple task.

Discussion and Conclusion

In today's world where time and people are in short supply, having tools that can make decision making efficient are invaluable. With hydrographic survey data in a port context, determining least depth and depths above design are critical for both safety of navigation and for planning major projects like dredging.

Eastland will have full of control over the visualisation and survey data they are paying to be acquired by using Navigate.

A novel solution for measuring infragravity waves using ADCPs

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Summary
Over the past years, Nortek has seen growing demand from clients to measure infragravity waves (IG) due to their significant economic and safety implications. We conducted a series of business case interviews with clients across different industries and research institutions worldwide. These interviews aimed to assess the frequency of IG waves studies, understand their impact, and to explore an operational solution. Based on the interviews, we changed our Acoustic sensor to be able to measure IG waves and implemented a new statistical analysis to the wave measurements.

Keywords: Infragravity waves, Waves, Acoustic Sensors, Ports

Introduction

Infragravity (IG) waves are surface waves with high period (25 to 250 s) and long wavelengths, also known as beat waves, bound waves or subharmonic gravity waves [5]. The energy transfer between high frequency (0.04 Hz to 1 Hz) gravity waves to lower frequency waves (0.004 to 0.04 Hz) has long been described in the literature [1]. There has been an increase in interest in the literature due to shoreline erosion processes [4] and amplification of IG waves inside harbours (seiches), causing considerable safety concerns and economic hazards [1].

IG waves measurement heavily relies on pressure sensors or radar, which brings some measurement issues. Pressure sensors drift over time, need to constantly calibrated, and give non-directional wave measurements. Radar measurements are weather-sensitive and often require multiple instruments for directional measurement. Here we present results from a series of interviews with 16 Nortek clients from all around the world and different industries where we asked questions related to IG waves to implement a new solution for measuring this oceanographic phenomenon.

Results

Interviewees can be categorized into academics (2 interviewees), public sector (2), harbour operators (5), survey companies (2), consultancy (3) and software development/modelling (2). We asked questions related to IG waves during ports planning, monitoring, instrumentation, data analysis, mitigation, market insights, and data presentation.

All of the interviewees reported their first encounter with IG waves was when they were called to investigate anomalies in oceanographic data (tidal data, pressure sensor readings, or incidents like mooring line snapbacks), resulting in economic losses or fatalities.

Mitigation strategies varied according to clients, according to the economic conditions. Solutions such as structural alterations to harbors, to avoid natural harmonic oscillation are the hardest one to implement, but highly effective. Also costly is the option of different mooring line types. However, the predominant approach among interviewees was monitoring coupled with harbor downtime protocols. This underscores the critical need for IG wave research to enable prediction and minimize downtime.

To measure IG waves, all the interviewees use pressure sensors and radar, but also addressing their limitations. Pressure sensors suffer from drift over time and lack real-time capabilities, while radars are susceptible to failures. For data analysis, traditional methods like low-pass filters (two interviewees) and Fourier analysis (all interviewees) were used.

Regarding new technologies the clients are looking for, they universally expressed the need for real-time, processed data for operational purposes. Data utilization varied, encompassing investigatory analysis to understand IG wave causes, real-time model calibration, and long-term data collection for machine learning algorithms. Furthermore, when asked about what features they would like to see included in the future, clients identified a gap in strain analysis on mooring lines, highlighting an area for further investigation.

Discussion

Given the current state of the art for IG waves studies and the feedback received for future needs, we proposed the use of current Acoustic Sensing Technology (AST). This feature is able to mitigate drift and atmospheric interference commonly observed in pressure sensors and radars. The AST was first introduced by Nortek in 2004 [6], allowing for direct high frequency measurement of sea-level elevation as opposed to traditional methods estimating wave parameters from the wave energy spectrum.

The AST does not suffer from the attenuation effects associated with increasing depth, enabling the device to estimate swell and wind-wave directionality. Lower period waves attenuation can be observed as shallow as 5 m below the surface [3]. Additionally, the AST estimates waves from the time series, as opposed to statistical calculation from the wave spectrum. That enables the user to view profiles of nonlinear and transient waves and to estimate time series wave statistics [6].

We employed the Maximum Likelihood Method (MLM) to measure near-surface orbital velocities. Due to the very low signal of IG waves when compared to waves in the sea/swell band, we implemented a pass-band filter to isolate this specific part of the spectrum.

We also propose a package based on wavelet analysis to avoid the need for stationarity analysis. This was corroborated by two of the interviewees, as stated in Costas et al [2]. The theory behind this package can not be shared due to trademarking.

Conclusion

This study sheds light on the challenges associated with identifying and mitigating IG waves in oceanographic settings. We were able to identify the gaps in knowledge in the field and come up with a solution that can be implemented in operational settings in ports, reducing risk and hazards.

Acknowledgements

The authors would like to thank all the interviewees who contributed to this work.

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Relevant UN SDGs (*https://sdgs.un.org/goals*)

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Innovative Low-cost AI Digital Technology for Port Noise Management

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Summary
NSW Ports undertook a trial of SiteHive real-time environmental noise management technology as part of the ongoing pro-active management of noise at Port Botany. The innovative SiteHive Hexanode devices have been revolutionary in how construction noise impacts are managed over recent years, delivering demonstrated cost savings and reduced community impacts. By employing low-cost digital sensors in a new type of monitoring device, which also captures rich contextual data, this Australian designed and built innovative technology could have significant benefits to managing port operations and environmental impacts on communities.

Keywords: Environmental monitoring, Artificial Intelligence, AI, noise monitoring, community engagement, digital technology, data analytics

Introduction

As the largest container port in New South Wales and Australia's largest common user bulk liquids facility, Port Botany operates 24/7 to import goods to support the people and businesses of New South Wales and to export goods to international customers.

NSW Ports recognises that along with delivering value for our shareholders, we need to make a positive contribution to the communities in which we operate, protect the environment and act in an ethical and transparent manner. NSW Ports works proactively with the community, Council, regulators and port operators to minimise noise impacts on surrounding residential areas, with a strong emphasis on continual improvement.

NSW Ports has had an existing comprehensive noise monitoring system in place across the port since 2017, however traditional noise monitoring systems are both expensive to maintain, relying on specialist technical consultants, and whilst they can provide consistent measurements they provide limited contextual information for determining the source of any noise issues across the whole port, due to lack of portability.

A new wave of technology

The SiteHive Hexanode devices utilise a new generation of low-cost digital sensors, in this case MEMS (micro-electromechanical systems) microphones, driven by recent innovations in consumer electronics (e.g. smartphones, audio-visual conferencing systems etc) to reduce the size and cost of digital microphones, whilst increasing the accuracy.

SiteHive has worked extensively to date with both the National Measurements Institute (NMI), and the University of Technology Sydney (UTS), to test and validate the accuracy of the MEMS microphones in line with relevant standards (IEC 61672).

By utilising low-cost digital sensors, the SiteHive Hexanode also captures additional contextual information about the source of noise, for instance multiple MEMS microphones capture the direction of arrival of sound, multiple wide-angle cameras capture images of what is causing instantaneous sounds, and audio recordings can be listened to and are AI classified to determine what is in them.

For the trial at Port Botany, NSW Ports deployed two SiteHive Hexanodes for a seven month period, at three locations shown in Figure 1.

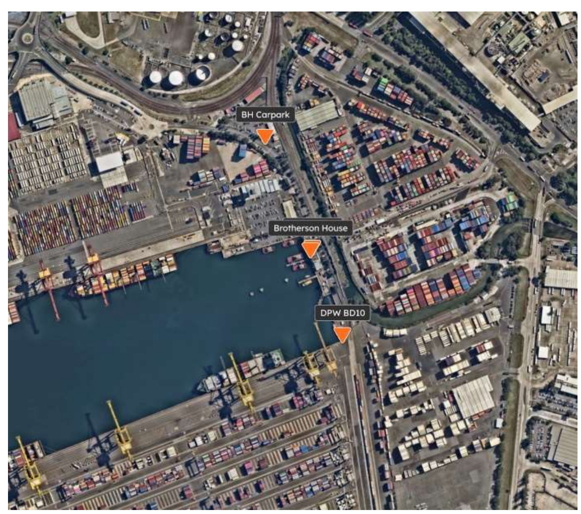

Figure 1: Trial Monitoring Locations of SiteHive monitors at Port Botany.

Primary Innovations

The SiteHive Hexanode provides a range of innovations in pro-active noise monitoring, a range of which were tested in the port's context.

Portability

The SiteHive Hexanode is solar powered and much smaller and more compact than traditional noise logging systems, measuring just 30cm in height and weighing 1.5kg. The portability of the device was tested by moving the device during the trial, and mounting in a variety of situations. A photo of the device on Brotherson House Roof at Port Botany is shown in Figure 2.

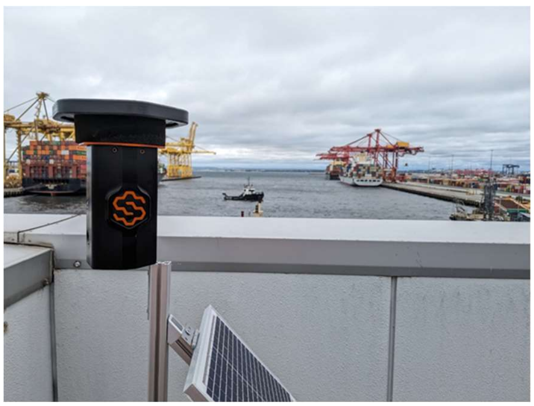

Figure2: Location of the SiteHive on Brotherson House roof at Port Botany demonstrating portability

Directional noise monitoring

The SiteHive hexanode uses an array of MEMS microphones within the device to determine the source of sound with each measurement. It provides both an overall dominant direction of sound per integration period (set to 5 minutes for the trial), a distribution of dominant sources binned into 5 degree segments 8 times per second, so 2400 records per 5 minute integration period.

The directional noise monitoring was tested by positioning the device at various locations and determining if the measurements correctly isolated discrete sound sources. The directional measurements correlated well with port activities observed. Figure 3 is an example showing the dominant direction of sound from the ship loading activities in the berth, with some contribution from the rail line behind.

Images and audio contextual data

Images and audio are captured by the SiteHive Hexanode based on an instantaneous LAmax (or LCmax) exceeding a configurable trigger. By correlating the instantaneous level with the dominant direction of sound at the time, one of the directional cameras captures an image and a 6 second audio file is recorded (3 seconds before from a buffer and 3 seconds after). Images and audio recordings captured were assessed to determine if the source of noise could be usefully determined.

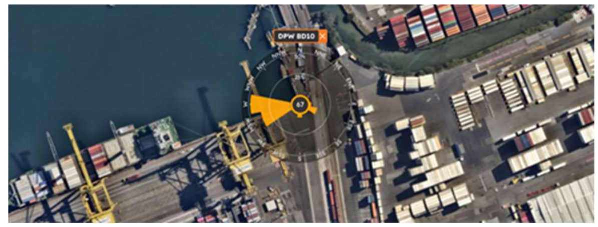

Figure 3: A noise rose showing directional output of noise source contributions

Images and audio contextual data

Images and audio are captured by the SiteHive Hexanode based on an instantaneous LAmax exceeding a configurable trigger. By correlating the instantaneous level with the dominant direction of sound at the time, one of the directional cameras captures an image and a 6 second audio file is recorded (3 seconds before from a buffer and 3 seconds after). Images and audio recordings captured were assessed to determine if the source of noise could be usefully determined.

AI audio classification

As part of SiteHive Enviro Pro software, audio files captured by the SiteHive Hexanodes on site are automatically classified based on the sound profile of the audio captured. This is done using a custom AI audio spectrogram transformer developed by SiteHive, but trained only to date on construction site sounds. During the trial an attempt was made to train the audio classifier to recognise port sounds.

Conclusion

Overall the SiteHive trial proved successful, with the technology showing immediate benefits to operational management of noise at Port Botany.

Benefits were particularly clear in a number of areas, which included:

- cost effective compared with older technology
- AI ability to identify noise sources
- opportunity for community engagement via public website
- portability for campaign monitoring
- low frequency ship noise monitoring
- potential for alignment with NEPTUNES

High-Density Coastal Armour Units for Managing Increased Risk With Climate Change

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Summary
Ports are progressively becoming more vulnerable with climate changes in storm behavior and sea level rise resulting in increased wave energy impacting existing seawall and breakwater structures. Upgrades and repairs would normally require larger and heavier conventional Concrete Armour Units (CAUs) to maintain stable armouring. The higher density of low carbon Geopolymer Concrete (GPC) provides a major benefit in the application of CAUs, by significantly increasing the mass and stability against wave action for units of the same geometric size. In 2018 a field trial was conducted at Port Kembla with high density (2600 kg/m^3) GPC Hanbars being cast and installed with an ongoing monitoring program. Recent inspections and analysis show the trial Hanbars are performing well.

Keywords: Breakwaters, Concrete Armour Unit, Geopolymer concrete, Climate change, Sustainability

Introduction
There is a growing awareness for the challenge with climate change of sustainable retrofitting of port protection seawalls and breakwaters for increased wave attack with changes in storm action and sea level rise. With the increase in nearshore wave heights associated with climate change, an upgrade strategy for armoured coastal structures will be to increase armour stability (by increasing Concrete Armour Unit CAU mass and raising crest heights) to preserve structure integrity.

Concrete armour unit (CAU) stability
The Hudson (1959) [5] equation for breakwater armour stability is widely used:

$$M = \frac{\rho_c H^3}{K_d \Delta^3 \cot\alpha} \qquad (1)$$

where
M is the mass of the rock armour or CAU
H is the incident wave height
α is the structure slope
ρ_c is the Hanbar concrete density
ρ_w is the water density
$\Delta = \frac{\rho_a}{\rho_w} - 1$ is the relative submerged density
K_D is the Hudson damage coefficient

The armour mass is seen to be most strongly influenced in the cubic relationships to wave height and relative submerged density. Even small increases in wave height of 10% or 15% give rise to expected increased armour mass of 33% or 52% respectively. For seawater increasing the CAU density from 2350 kg/m^3 (conventional Ordinary Portland Cement OPC concrete) to a higher density 2600 kg/m^3 increases Δ^3 from 2.2 to 3.6 indicating equivalent CAU stability can be provided for a high density unit being only 61% of the mass of the conventional concrete unit.

Howe and Cox (2014) [3] demonstrated that merely increasing CAU size (with no change in density) of the overlaying additional retrofit layer(s) can result in reduced interlocking with the existing smaller CAU layers underneath, reducing the overall stability of the structure. This can be an issue even for the same CAU type but of different geometric size. The stability and opportunity for application of high density CAU Hanbars was investigated in wave flume testing at Water Research Laboratory WRL by Howe and Cox (2017) [4].

Based on a wide range of physical model testing reported for Hanbar CAUs in Flocard et al (2024) [2], conservative Hudson damage coefficients of 7 to 12 were shown to apply for damage levels of 5% to 10% respectively. These values are consistent with previous recommendations from Blacka *et al.* (2005) [1] for random 2 layer Hanbar placement.

High density Geopolymer Concrete GPC CAUs
Ordinary Portland cement (OPC) used in traditional concrete produces significant greenhouse gas emissions. The process of converting lime to OPC is energy intensive due to the high temperatures required. Additional carbon dioxide is released during the conversion to concrete, further increasing the environmental impact. For port breakwaters and seawalls requiring hundreds to thousands of CAUs, the carbon footprint of the concrete alone is significant.

An alternative to OPC concrete is geopolymer concrete (GPC). Geopolymer concrete (GPC) is an alternative concrete which uses fly ash and steel slag (low-value high volume industrial waste products) in producing a low carbon high density concrete. The Centre for Infrastructure Engineering and Safety (CIES) at UNSW [5] completed many years of laboratory scale research to develop a GPC for application in the marine environment. GPC was shown to provide up to 80% less embodied carbon than OPC concrete depending on the mix [9]. GPC can have superior qualities to OPC concrete, including higher compressive and tensile strength. GPC provides major opportunities in the transition to sustainable low carbon construction and has the additional benefit of higher density for application to CAUs in port seawalls and breakwaters.

Port Kembla Field Trial of GPC Hanbars

To extend the laboratory based research by CIES to full scale, in 2018 (April to July) a field trial was conducted at Port Kembla, NSW into the potential for high density GPC CAU Hanbars to be used in repair of the damaged northern breakwater.

The trial included full scale production of the high density GPC in a conventional concrete batching plant, the transport of the GPC to site in conventional concrete mixing trucks, casting and placement of thirteen 18 tonne high density (2600 kg/m^3) Hanbar CAUs and an ongoing monitoring program of the integrity of the concrete in the aggressive marine environment. Modra et al (2023) [8] reported in detail on the trial and recent monitoring

Figure 40 Placement using under-sized excavator

Discussion and Conclusion

Monitoring for the assessment of longer-term sustainability was undertaken in May 2021 [7] and February 2023. 5 years' on from the installation, the trial GPC Hanbars are performing well:- concrete strength being maintained at about 40 MPa; some non- structural brown staining consistent with the rusting of steel slag contaminants; no major cracking or breakup of the units apart from the damage during installation; no spalling in the GPC.

During the period of the trial (ongoing since 2018) the GPC Hanbars have been exposed to 5 storms of intensity greater than that of the June 2016 storm that had previously damaged the Northern Breakwater. The 3 largest storms had Average Recurrence Intervals of around 5,10 and 18 years.

This trial has demonstrated that low-carbon high-density GPC CAUs have progressed from a laboratory scale concept to the opportunity for full scaled application. CAUs provide a suitable proving ground for GPC, since the mass concrete is relatively tolerant of concrete defects, and CAU structures are relatively easy to repair compared to other marine concrete structures such as wharves.

It is recommended that the next step in "proof of concept" be the construction of a small seawall section in a relatively sheltered environment with relatively small 2 to 5 tonne low carbon high density GPC Hanbar CAUs. Ongoing laboratory wave flume stability testing of different CAUs to the simpler Hanbar is also needed. This should include application of high-density GPC CAUs to new construction and upgrading of existing structures for increased wave exposure with climate change.

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Relevant UN SDGs (*https://sdgs.un.org/goals*)

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Optimisation in Support of GHG Emissions Reductions

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Summary
The efficiency of shipping is related in part to the sailing drafts and windows that are available at each port that a vessel visits. Whilst some ports are unconstrained, many ports apply antiquated methods to determine when a vessel can transit, and the maximum draft achievable for that vessel. This paper will present a case study for the latest digital solutions that integrate AI, IoT and advanced numerical modelling to maximise the efficiency of port operations, allowing ports to safely facilitate larger, deeper vessels, with a focus on the improvements in the Carbon Intensity Index that have been achieved.

Keywords: Digitisation, Port Optimisation, Sustainability

Introduction

Ports and shipping channels are critical components of many nations' transport infrastructure and make a significant contribution to the economy. With volatile and disrupted global trade comes further pressure on ports to be adaptive and resilient. With greenhouse gas emissions (GHG) from maritime transport estimated to exceed one billion tonnes per annum [1], sustainability is an ever present, and increasingly important, consideration for ports. This is occurring against a backdrop of a changing climate that is presenting more frequent and severe weather events.

The United Nations Conference on Trade and Development 2023 Review of Maritime Transport states that "beyond cleaner fuels, the industry needs to move faster towards digital solutions…to improve efficiency as well as sustainability."

Digitalisation has driven access to more data, in real-time, and with greater precision. With the right tools, this data can lead to deeper insights into port and shipping operations, and be leveraged to identify opportunities to enhance safety and improve efficiency. Whilst alternative fuels will be critical to achieving net zero targets, there are digital technologies immediately available that have a proven track record of facilitating reduction in shipping related emissions through enhancing the efficiency of each voyage.

Background

In 2015, 193 countries adopted the United Nation's 2030 Agenda for Sustainable Development and its 17 Sustainable Development Goals (SDGs).

The IMO recognises that most of the elements of the 2030 Agenda will only be realised with a sustainable transport sector supporting world trade and facilitating global economy, and is actively working towards the SDGs. Ports, as critical nodes in the global supply chain, must respond to worldwide, regional and local challenges such as climate change and digitalisation.

With the support of strategic partners including the American Association of Port Authorities (AAPA), the European Sea Ports Organisation (ESPO), and the World Association for Waterborne Transport Infrastructure (PIANC), in 2017 the International Association of Ports and Harbors established the World Ports Sustainability Program. One of the five WPSP themes is 'Resilient Infrastructure' and encapsulates SDGs #9 Industry, Innovation and Infrastructure, #13 Climate Action, and #14 Life Below Water.

In relation to SDG #9, Industry, Innovation and Infrastructure, the IMO states [2] that technological advances in the port sector are key to building resilient infrastructure and central to the effective functioning of the whole transportation sector. A more efficient shipping, working in partnership with the port sector, will be a major driver towards global stability and sustainable development for the good of all people. Furthermore, investment, growth and improvement in the shipping and ports sectors are clear indications of a country or region that is enjoying success in the present and planning for future success.

On #13 Climate Action, the IMO's position [2] is that responding to climate change is one of the greatest challenges of our era, and requires appropriate, ambitious and realistic solutions to minimise shipping's contribution to air pollution and its impact on climate change.

Although one of the most sustainable modes of transport, shipping is estimated to emit one billion tonnes of greenhouse gas (GHG) emissions annually, representing ~3% of the total global emissions [3].

The Paris Agreement requires emissions to be reduced by 50% by 2050, and the IMO's 2018 Initial Strategy for Reduction of GHG Emissions from Ships [4] set an objective to achieve a 40% reduction of CO_2 emissions per transport work by 2030 (compared to 2008 values as an average across international shipping). However, recent data suggests shipping related GHG emissions continue to climb, with the International Energy Agency suggesting a 5% increase in 2022 [5].

In support of the 40% reduction of CO_2 emissions target, amendments to the International Convention for the Prevention of Pollution from Ships (MARPOL) Annex VI were adopted by the IMO's Environmental Protection Committee (MPEC). These include the requirements for Energy

Efficiency Existing Ships Index (EEXI) and Carbon Intensity Indicator (CII) certification from January 2023, with initial ratings given in 2024.

Discussion

The CII reflects the operational energy efficiency of ships, expressed as the grams of CO_2 emitted per tonne-nautical mile of operation.

There are a few key terms in understanding the CII, as detailed below.

The Attained CII is the actual CII of the vessel for the year in question.

$$Attained\ CII = \frac{CO2\ emission\ in\ grams}{DWT \times Dist.Travelled\ in\ N.M.} \qquad (1)$$

The Reference CII is the CII value from 2019.

The Required CII is the new CII that a vessel must meet for the relevant year, considering the reduction factor required for that year.

$$Req.CII = Ref\ CII \times \frac{100 - Z}{100} \qquad (2)$$

Where Z is the reduction factor for the year as per Table 1.

Table 4 CII Reduction Factors

Year	Reduction Factor Z
2023	5%
2024	7%
2025	9%
2026	11%

The CII Rating is a measure of how a vessel's Attained CII compares with the Required CII.

$$CII\ Rating = \frac{Attained\ CII}{Required\ CII} \qquad (3)$$

Based on the CII Rating, a vessel is assigned a Grade from A to E as per **Error! Reference source not found.**. A ship rated D for three consecutive years, or E for one year, has to submit a corrective action plan to show how the required Grade of C or above will be achieved. Administrations, port authorities and other stakeholders as appropriate, are encouraged to provide incentives to ships rated as A or B.

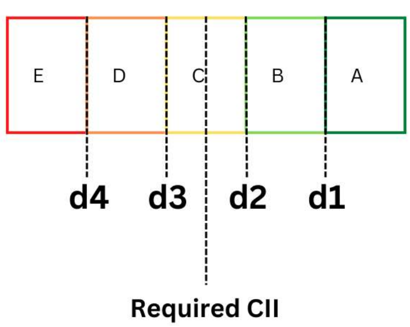

Figure 41 CII Rating Grades

Maintaining the existing Grade will become increasingly difficult with each year as the Reduction Factor (Z) becomes more stringent, demanding vessels find new ways to improve their Attained CII. The Attained CII can be improved (i.e. reduced) through a reduction in CO_2 emissions for the same work, or increasing the distance travelled for the same level of emissions. Ignoring alternative fuels, the reduction in CO_2 emissions is achieved through burning less fuel.

A key criticism of the adopted CII methodology is that it ignores the actual cargo carried during the year, but instead focuses on the potential carrying capacity of the vessel [6]. The IMO had in fact considered a Demand-based CII which used the actual tonne-miles value of a ship, but opted to proceed with the Supply-based CII which uses the DWT value and therefore ignores the actual utilisation of a vessel. It is therefore possible to reduce the CII by sailing extraneous ballast voyages to increase fuel efficient distances.

A study published in 2023 by the World Bank [7] found that around 60% of a ship's time in port is attributed to cargo operations, with 30% accounting for arrival time and 10% idling time. This means there is a significant amount of wasted time, leading to excess fuel burn and emissions. Port turnaround times are the responsibility of both the vessel and the port so both need to work in tandem to achieve the desired results. A ship that spends less time in port will burn less fuel, reduce its emissions, and achieve more optimal arrivals. Improving the efficiency with a coordinated approach to shipping is estimated to reduce emissions of the current fleet by around 20% [8].

One existing, well proven technology that is facilitating CII enhancements is the Dynamic Under Keel Clearance System (DUKC®). The efficiency shipping is related in part to the sailing drafts and windows that are available at each port that a vessel visits. Whilst some ports are unconstrained, many ports apply antiquated methods to determine when a vessel can transit, and the maximum draft achievable for that vessel. DUKC® is a cloud-based digital solution for draft and tide optimization employed to simplify transit planning and scheduling whilst managing navigational risk. Delivered as SaaS, DUKC® is underpinned by detailed modelling of port operations, numerical analysis of ship motions, hydro-dynamic models, channel survey data, and the AI assisted assimilation of real-time and forecast environmental conditions. Connecting advanced calculation engines with the port's available IoT devices and digital data sources, DUKC® allows the sailing draft and window of every vessel to be safely maximised. This increases channel accessibility, berth utilization, and port efficiency, whilst reducing dead-freight and vessel wait times.

Case Study

OMC has partnered with a shipper that regularly calls Port Botany with imports. OMC provides long range planning advice using DUKC® to enable the shipping company to optimize their inbound sailing drafts with certainty that sailing windows will be available during the LayCan.

Taking the example of an LR2 tanker, serving a single route from the Middle East to Botany, the Reference CII is 4.297, whilst the 2024 Required CII is 3.996. This would require moving the same volume of cargo whilst reducing the CO2 emissions by 7%, potentially achieved through operational options such as slow steaming or weather routing, or physical changes to the vessel. Alternatively, using DUKC® the vessel is able to confidently load more cargo to achieve an Attained CII of 3.808 for a CII Rating of 0.95.

Conclusion

The ports and shipping industry faces a range of operational challenges including congestion and delays, larger vessels, and more severe weather events. In parallel, there is the requirement to find ways to reduce CO_2 emissions. Whilst alternative fuels remain a critical element of the long-term solution, there are technologies immediately available that are providing Harbour Masters, Pilots, Terminal Operators, and Shippers with the tools to maximise efficiency whilst ensuring navigational safety.

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Relevant UN SDGs (*https://sdgs.un.org/goals*)

9, 13, 14, 17

Accelerated Low Water Corrosion: a Problem for Reinforced Concrete?

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Summary
Orange and black tubercules characteristic of Accelerated Low Water Corrosion (ALWC) were identified throughout marine reinforced concrete tunnels. ALWC is a major problem affecting steel marine structures worldwide but limited literature exists regarding its presence on reinforced concrete structures. Characterisation of tubercules and the underlying structure confirmed extensive metal loss, tubercule morphology and bacterial activity consistent with ALWC.

Keywords: Accelerated low water corrosion, microbially influenced corrosion, reinforced concrete durability

Introduction

ALWC is a widely documented form of Microbially Influenced Corrosion (MIC) that affects maritime steel structures around the world resulting in localised accelerated section loss [1]. It is most commonly encountered at low water level but can extend to the seabed. ALWC on steel structures has been extensively researched, but its presence on reinforced concrete structures has not been widely documented.

This abstract characterises orange and black corrosion tubercules identified along reinforced concrete seawater tunnels located near ports where ALWC has been reported on steel piles. The objective of the work was to confirm the presence of bacterial activity associated with ALWC in the tunnels and investigate the mechanism behind the formation of tubercules on concrete to assist in developing a mitigation strategy.

Method

The assessment involved:

- mapping the distribution of tubercules along the tunnels;
- concrete cover to reinforcement depth mapping at two tunnel wall locations using Ground Penetrating Radar (GPR) to evaluate whether tubercules are associated with low cover;
- microbiological testing of both seawater and tubercule material suspended in seawater sampled using aseptic techniques using the Biological Activity Reaction Test (BART) biodetection method for iron-related bacteria (IRB), sulphate-reducing bacteria (SRB) and slime forming bacteria;
- examination by Scanning Electron Microscopy (SEM) and elemental analysis by Energy-Dispersive Spectroscopy (EDS) of concrete, tubercules and reinforcement corrosion product from concrete cores sampled directly beneath a tubercule and from an area free of tubercules.

Results

Predominantly orange and black tubercules were distributed in localised clusters along the concrete tunnels. Tubercules were generally arranged in horizontal bands concentrated at the top and bottom of the tunnel walls as shown in Figure 42. These correspond to areas where the steel reinforcement concentration is highest.

Figure 42 Tubercules concentrated in horizontal bands along the lower and upper parts of a tunnel wall. These represent areas with lapped reinforcing bars and have the highest steel density in the wall.

GPR mapping revealed a large variation in concrete cover to outermost reinforcement ranging between 28 mm to >100 mm in the areas scanned. Figure 43 shows the results of concrete cover measurements overlayed on a photograph of a scan area. It is clear from the staining that tubercules preferentially developed in areas of lower cover.

BART testing of seawater sampled both within and outside of the tunnels gave aggressively positive results for IRB and strong but delayed responses for SRB. The water samples were also tested for slime forming bacteria but returned inconclusive results.

Testing of tubercule material suspended in seawater produced similarly aggressively positive results for IRB, strong and more rapid results for SRB and moderate to aggressively positive results for slime forming bacteria. The difference in test results for slime forming bacteria can be clearly seen between the water test samples after 10 days incubation and tubercule containing samples after 4 days incubation in Figure 44. The tubercule containing samples initially appeared similarly pale to the water only samples.

Figure 43 Tunnel wall shown (left) following pressure cleaning and (right) overlayed with concrete cover to reinforcement depth map (stated in mm) measured using GPR. There is a strong correlation between areas stained by tubercules and areas with lower concrete cover (identified as red/orange/yellow regions).

Figure 44 Typical appearance of BART test tubes for slime forming bacteria shown for (left) seawater containing samples and (right) tubercule containing samples. The change in appearance of the tubercule containing samples was registered after 4 days incubation.

Examination of the concrete core extracted directly beneath a tubercule revealed substantial section loss of the reinforcing steel. The chloride concentration in the concrete surrounding the reinforcement was 5 to 10 times higher than elsewhere based on EDS analysis. The iron concentration surrounding the corroded reinforcing bar decreased rapidly within several millimetres to levels found remote from the bar. Similarly elevated iron levels were present in corrosion product at the base of tubercules. Sulphur concentrations did not show any consistent trends with distance from the tunnel wall surface, reinforcement or presence of tubercule, however SRB activity is possible without producing a change in sulphur level determined by EDS.

Discussion and Conclusion

The physical appearance of tubercules and distribution in horizontal bands is similar to bands of ALWC concentrated near Lowest Astronomical Tide level on marine steel structures. Unlike the bands that form on steel structures, the ALWC along the concrete tunnels appears to develop preferentially in areas with more reinforcement and lower cover to reinforcing bars.

The most obvious difference between BART results for seawater and tubercule containing samples was the presence of slime forming bacteria in the latter. It is likely that the slime forming bacteria are important to retain corrosion products on the concrete to enable tubercules to form.

The delayed BART response for SRB in seawater suggests that some other bacteria are required to grow before SRB can thrive. The more rapid response for SRB in tubercule containing samples suggests that SRB growth may be supported by the bacterial community found within the tubercule (e.g. slime forming bacteria).

We initially expected that chloride initiated corrosion was occurring preferentially in areas of low cover within the tunnels leading to anaerobic corrosion of reinforcement and gradual diffusion of Fe ions through the concrete matrix to the tunnel surface. The Fe ions at the surface were suspected to support bacterial colony growth. However, in the concrete core sample examined, SEM-EDS revealed chloride levels near the bar that were elevated relative to those in the bulk concrete. This suggests that chloride may have entered at a defect, such as crack or joint, and tracked along the steel bar-concrete interface to initiate corrosion. It is unclear how the corrosion products accumulated at the surface of the concrete without producing elevated levels of iron in the concrete between the reinforcement and the surface, but they may have been able to track through a crack or other defect that was not within the core that was sampled.

Corrosion mitigation within the tunnels will be targeted to areas where tubercules are present. Cathodic protection is effective in addressing ALWC on submerged steel structures [1] and its use is being considered in the reinforced concrete tunnels.

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Relevant UN SDG: 9

Working with Nature for Biosecure Port Infrastructure

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Summary
We investigated whether the design of marine infrastructure could facilitate native species and reduce biosecurity risk by (1) increasing surface complexity, (2) including natural materials, (3) transplanting native species and (4) increasing daytime lighting. Habitat enhancement panels were deployed on seawalls in Sydney Harbour in three experiments and surveyed over periods of 12-36 months to investigate these design factors. We found that increasing complexity at lower tidal elevations may have negative ecological consequences by facilitating more invasive species in moist, shaded microhabitats. Including natural materials and transplanting native seaweeds had little effect on invasive species. Daytime lighting was most effective at encouraging growth by native seaweeds that then excluded invertebrate species. These findings help to identify factors that can assist in designing biosecure port infrastructure.

Keywords: Nature-based Approaches, invasive species, biosecurity, blue infrastructure, biodiversity

Introduction
Artificial structures such as seawalls, typically support less biodiversity than the natural habitats they replace and can harbour invasive species [1]. Marine life that can survive on these structures are responding to several design factors including the material used in construction and availability of micro/macro habitats as well as local environmental conditions such as light and wave energy. Our understanding of how these factors might influence the types of marine life found on artificial structures is increasingly being used to restore native biodiversity in a practice commonly referred to as "ecological engineering" [2].

Eco-engineering projects like the Living Seawalls project (www.livingseawalls.com.au) enhance biodiversity by adding complexity and surface area [3]. It is, however, unclear whether eco-engineering could be used to design biosecure marine infrastructure.

Figure 1 Living seawalls add mimics of microhabitats like rockpools that are missing from built infrastructure.

Materials and Methods
We investigated whether the design of marine infrastructure could facilitate native species and reduce biosecurity risk with three studies in Sydney Harbour.

Study 1: We manipulated surface complexity by installing complex and flat habitat enhancing panels. We assessed (1) whether colonisation of invasive species was enhanced on the complex panels when compared to the flat panel, and (2) whether colonisation patterns differed among tidal elevations.

Study 2: We manipulated materials by including recycled oyster shells and sandstone in habitat enhancing panels, and we transplanted native seaweed onto the panels. We assessed (1) whether colonisation of invasive species was reduced on the natural materials when compared to concrete, and (2) whether the presence of seaweed transplants inhibited invasive species.

Study 3: We experimentally manipulated daytime lighting in a gradient from total shade to light levels reflecting midday sunlight. We deployed panels to investigate what would grow under this gradient of lighting. We assessed (1) whether colonisation of native seaweeds increased with increasing light intensity, and (2) whether growth of native seaweeds was associated with reduced growth of other species including invaders.

Results
Study 1: At high and mid intertidal elevations, the contribution of invasive species to total abundance and richness was generally very small on both complex and flat panels (Figure 2). At the low intertidal elevation by contrast, invasive species contributed approximately 75% sessile cover, 50% richness and were in some instances 50% more abundant and diverse in growth on the complex rather than flat panels. Within the panels, invasive species were particularly abundant in moist, shaded microhabitats.

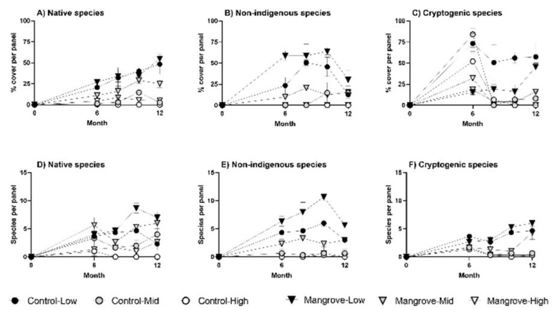

Figure 2 Mean (+SE) percent covers of species colonising complex and control panels over time across three intertidal elevations. Cover and richness increased over time for all classifications, but varied between complex and flat panels, and between tidal levels. Complex panels may facilitate more non-indigenous species in the low intertidal than other tidal levels.

Study 2: At intertidal elevations, the cover of non-indigenous species was greater on sandstone than oyster or concrete materials (Figure 3). At the low and deep subtidal elevations, concrete panels generally had greater cover of non-indigenous species than natural materials, but this was not significant.

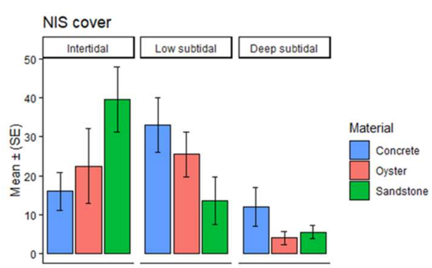

Figure 3 Mean (+SE) percent covers of non-indigenous species colonising natural (sandstone, oyster shell) and concrete panels across three intertidal elevations (intertidal, low and deep subtidal). Cover varied between natural and concrete panels at all tidal levels. Concrete panels may facilitate more non-indigenous species in the low and deep subtidal than other tidal levels [4].

At low subtidal elevations, covers of native and non-indigenous species were similar on panels with and without seaweed transplants (Figure 4). Native species richness increased on panels with seaweed transplants while non-indigenous species richness remained similar to panels without transplants.

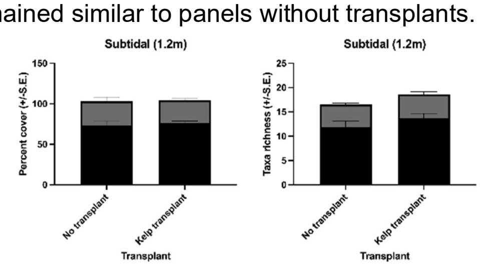

Figure 4 Mean (+SE) percent cover and richness of native (black) and non-indigenous (grey) species colonising panels following seaweed transplants in the low subtidal. Cover was similar between treatments, but native species richness increased with seaweed transplants. Seaweed transplants may increase native biodiversity without facilitating non-indigenous species.

Study 3: Seaweed were more abundant under all light treatments and virtually absent under the shaded treatment (Figure 5). Conversely, invertebrates were more abundant in the low light treatments. Predation reduced the cover of both groups.

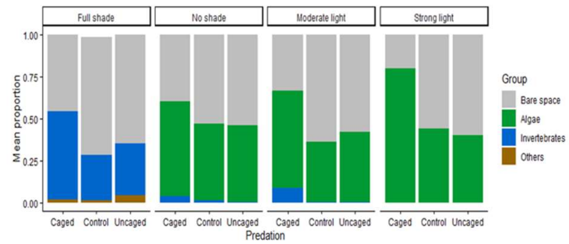

Figure 5 Mean proportion of taxa on panels exposed to a gradient of light. Communities shifted from invertebrate dominance in full shade to increasing native seaweed dominance with increasing light. Enhanced seaweed covers may exclude other taxa including non-indigenous species present [4].

Discussion and Conclusion

Artificial structures such as seawalls, typically support less biodiversity than the natural habitats they replace and can harbour non-indigenous species. Knowledge of the factors that support invasive species colonisation will assist in designing future eco-engineering interventions that reduce biosecurity risk.

Acknowledgements

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Relevant UN SDGs (*https://sdgs.un.org/goals*)
9, 11, 14, 17.

Morphological Modelling for Boating Safety Improvements at Dungeness

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Summary

The highly dynamic nature of the waterways surrounding Dungeness, a key boating access point for tourism and industry for Hinchinbrook Shire Local Government Area in North Queensland, required investigation to formalise a plan for safe navigation access and subsequent boating safety improvements. Council initiated a detailed morphological modelling to study to assess options for navigation access improvements. The modelling study also allows for assessing improvements to coastal resilience and subsequent stabilisation of coastal ecosystems in the region as a secondary objective to boating safety. The modelling study investigates sediment transport patterns and evaluates the impact of proposed dredging with local dredge spoil placement and the alignment of an adjacent coastal structure. By integrating advanced numerical modelling techniques, the model results are suitable for evaluating solutions to balance boating safety and preserving the delicate coastal ecosystem adjacent to the Great Barrier Reef Marine Park.

Introduction

Dungeness, located in the Hinchinbrook Region in North Queensland, provides the region's main boating access into Enterprise Channel. Enterprise Channel is the region's gateway to popular tourist destinations of Hinchinbrook Island and the Great Barrier Reef.

On a day-to-day basis, Enterprise Channel is subject to a high tidal range, subsequent high-velocity tidal flows, and a mild wave climate. The waterway is also exposed to extreme events, especially related to cyclonic activity with extreme flows and waves propagating into Hinchinbrook Channel. The site is shown in Figure 1 below.

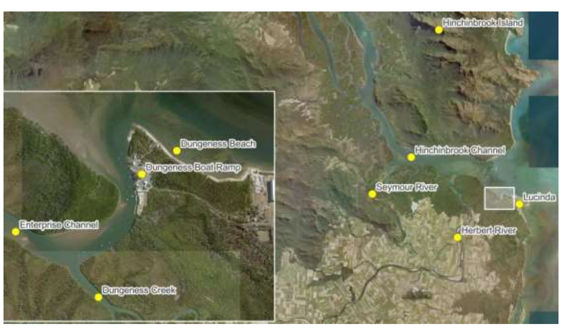

Figure 45 Site location

At present, and in recent years, Enterprise Channel Entrance has been infilling with sediment, resulting in a channel that is no longer navigable at mid to low tide and navigation markers that are rendered useless given the dynamic nature of the present channel.

The lack of a reliable channel has reduced use of the Dungeness boat ramp and increased boating safety hazards for those using the Enterprise Channel for navigation. At the same time, Dungeness Beach and Spit, adjacent to Enterprise Channel, has been rapidly eroding, exposing the navigation channel to additional wave action and resulting in a loss of environmental values with erosion of significant tranches of mangrove forest.

This study aims to utilise a detailed morphological model to review and test options for improving boating safety while also achieving the secondary goal of improving coastal resilience.

Methodology

A robust data collection campaign was initiated to develop boating safety improvement options in a morphologic model to allow for model development and calibration. The data collection campaign focused on calibration of the hydrodynamics of the region, given the dominance of tidal forcings (and relative sheltering from offshore waves).

The data collection scheme included:

- Fixed Acoustic Doppler Current Profiler in Enterprise Channel.
- Multiple Acoustic Doppler Current Profiler transects in key waterways.
- Multi-beam hydrographic survey in the Enterprise Channel and multi-beam transects are in the Hinchinbrook Channel.
- Installation of water level loggers at key sites.
- Sediment sampling and testing regime in Enterprise Channel, Hinchinbrook Channel and adjacent waterways.

These datasets, along with existing datasets including existing water level monitoring stations at Lucinda and Port Hinchinbrook and historic wave monitoring at Lucinda and Townsville, resulted in a robust dataset for establishing, calibrating and validating metocean modelling in terms of hydrodynamics and waves.

The numerical modelling has been undertaken using the MIKE software suite developed by the Danish Hydraulics Institute (DHI). The MIKE suite includes the hydrodynamic (HD), spectral wave

(SW) and sand transport (ST) modules which were coupled together to ensure that the dominant physical processes are represented in the modelling in a physically realistic manner.

Prior to moving forward into the morphological modelling, a focus was initially placed on calibrating and validating the hydrodynamics. Specific calibration and validation standards were set as per [1] aiming for an overall Index of Agreement (IoA) within an allowable tolerance for tide height, velocity and timing. A strong IoA was achieved in line with [1].

An example of the tidal level, velocity and wave height calibration is shown in Figure 1.

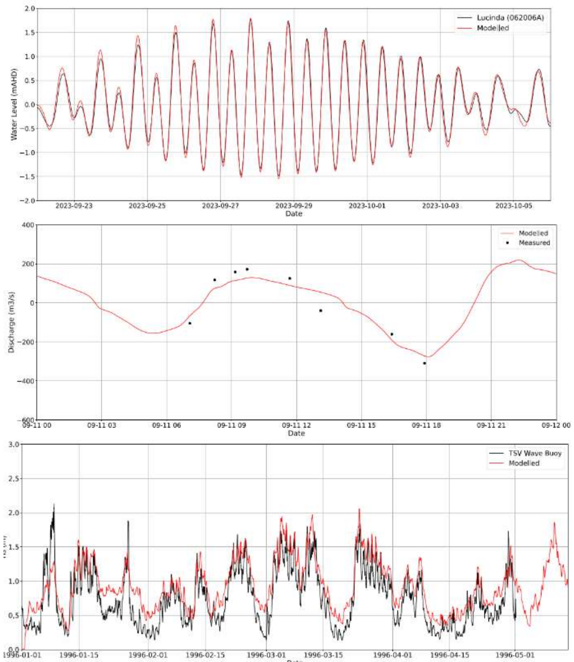

Figure 46 **Top** – Lucinda Offshore water level calibration, **Middle** – ADCP transect water volume validation in Enterprise Channel, **Bottom** – Townsville Waverider Buoy Wave Height Validation.

With a focus on hydrodynamics in the initial modelling stage, a strong confidence in the metocean modelling could be brought forward into the morphological modelling.

Danish Hydraulic Institute (DHI's) MIKE21 Sand Transport module was utilised to simulate sand transport over synthetic El Nino and La Nina periods to test the extremes of each climate pattern.

The morphological model was more difficult to calibrate and validate given the scarcity of relevant data outside prior to the 2023 multi-beam survey; however, attempts were made utilising:

- Satellite imagery
- Localised historic survey of Enterprise Channel
- Known ongoing processes, such as Spit and beach erosion

The model was able to re-create these qualitative morphological processes in the baseline scenario and, therefore, deemed suitable for use in assessing boating safety improvement options.

The baseline model estimates the infill of the Enterprise Channel entrance to be approximately 12,000m^3/yr at present.

Results and discussion

Once the baseline modelling was established and suitably validated, different options were tested in the model, including:

Scenario 1 - Excavation of a dredged channel

While capable of providing initial improvements to navigation, the infill rates in the channel were higher than the baseline (approx. 14,000m^3/yr), and the deeper channel allows for additional propagation of waves and tidal currents up Enterprise Channel, encouraging additional bank erosion.

Scenario 2 - Dredged channel with coastal structure and material placement

Adding a coastal structure stabilises the channel and reduces maintenance dredging requirements (approximately 40% reduction in infill rates), stabilising the foreshore to the west and east of the channel. This reduces the erosion rates of the existing high-value mangrove forests. This is due to the coastal structure re-directing tidal flows offshore into Hinchinbrook Channel, setting up a re-circulation zone near the foreshore rather than the existing strong currents that run longshore.

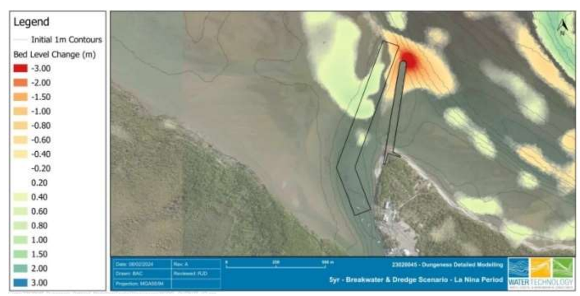

Figure 47 Bed level difference plot results for Scenario 2

Council seeks to improve boating safety with all tide access to the Dungeness boat ramp. A dredged channel alone may not be suitable as this would require high-frequency maintenance dredging. A low-crested coastal structure that re-directs tidal currents and provides wave action protection would reduce channel infill rates and stabilise foreshore that are eroding to the site's east and west.

Future works

Recommendations include regular surveys in Enterprise Channel so the morphological model can be refined and validated further and establishing a monitoring program to operate safe boating facilities.

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Relevant UN SDG 11

First-pass whale-strike risk screening for port development

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Summary
Increases in the intensity, speed and size of ships transiting through whale migration routes is likely to increase the risk of whale-vessel interactions. In the worst-cases this can result in serious injury or death of whales and similar marine megafauna. Methods of assessing whale strike risk are available, but rely on underlying data, which can be difficult to collect and even more difficult to have confidence in. This work explores existing methodologies that can be applied to whale-strike risk. Further, it discusses a simplified first-pass technique that has been used to provide a conservative risk assessment for port development planning in South Australia.

Keywords: EIS, whale-strike, marine ecology, port planning.

Introduction
Port development activities in Australia represent major infrastructure projects, and are likely to trigger environmental approvals under the *Environment Protection and Biodiversity Conservation Act 1999* (Cth.) (EPBC Act). This requires assessment for any project that may have a significant impact on a set of listed 'matters of national environmental significance' – two of which are migratory species and threatened species.

Increasingly, the scope of environmental assessments needs to look at indirect environmental effects. In the case of port development, this may include the impacts associated with new, or intensified shipping lanes once the development is completed.

Conceptually, intensification of shipping lanes that cross whale migration routes is likely to increase the risk of 'whale strike', where vessels physically hit a whale. While specific outcomes of while strikes is poorly documented, bow strikes have been known to result in whale deaths, and whales (both dead and alive) have been observed with scarring from propellor cuts. Such impacts The challenge for proponents of port development is to assess the risk, to understand whether mitigations are required or are possible.

Whale Strike Prevalence
Fortunately, whale strikes are thought to be relatively rare. An analysis of records of whale strikes in Australia found 137 likely cases between 1877 and 2015 [3]. It is expected however that records may understate the total, with larger ships able to strike whales without noticing. Similarly, there may be underreporting even where a strike is known to have occurred.

Existing Risk Methodologies
Several methodologies for assessing whale strike risk have been trialled internationally. They can be based on existing spatial datasets or mathematical models of vessel and whale behaviour.

One study [5] modelled risk for the Santa Barbara Channel in California using a series of coincident probabilities as follows:

$$M = \lambda_b t_b P(S|D_b) P(M\,|v_b)(1 - P(A\,|v_b)) \quad (1)$$

Where $\lambda_b t_b$ represents the rate of whale encounters within the vessels transit time for a given area. $P(S|D_b)$ is the probability of a whale being within the 'strike depth' given a vessels draft, $P(M\,|v_b)$ is the probability that a strike results in mortality given a vessel's speed and $P(A|v_b)$ is the probability that the whale or vessel can avoid a collision given the vessel's speed.

A different technique has been applied around Australia to assess the overall risk from existing shipping [4]. Ultimately, this method relied on overlaying maps of vessel density from AIS data, with sources of spatial information of animal tracks.

Methodological Limitations
The existing models are reasonable approaches to assessing risk. However, all suffer from a fundamental reliance on underlying data. Currently, spatial data for whale movements and numbers relies on tagging and aerial surveys, which can be expensive. Research into remote sensing of whale numbers is promising [2], however it still suffers from the following biases [3]:

- Whales can be easily missed by these techniques;
- Changes in expected timing or migration patterns can limit the data collection;
- Calving cycles can often be multi-year, requiring a minimum of that period to quantify the average seasonal rate;
- Some whale populations are in recover, with populations growing year-on-year. Extended observational datasets are required to capture these effects.

Further to this, data on the behaviour patterns between whales and vessels is poor. The likelihood of whale surfacing is highly species dependent. Further, the ability to avoid vessels may depend on learnt behaviours and is almost impossible to quantify with confidence.

Even vessel data may be difficult to assess reliably. Large and commercial vessels (covered by SOLAS convention) require AIS, however this excludes many smaller and recreational vessels that still may contribute to risk.

Case-study – South Australian Port

A recent port development proposed at Kangaroo Island, South Australia included significant interest in the potential impact on Southern Right Whale (*Eubalaena australis*). Southern Right Whales migrate north during the winter on average every three years. They seek sheltered coves for calving and show a strong fidelity to their calving grounds.

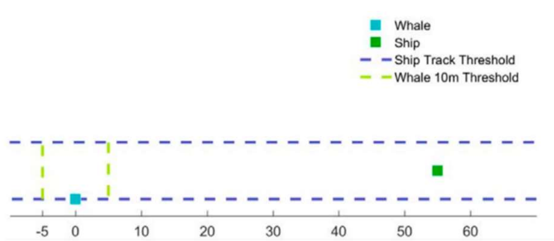
The proposed port was likely to result in a fortnightly ship transit across the Great Australian Bight (GAB), immediately across the whale migration route.

A simple model was prepared to assess the first-pass risk of whale-vessel interaction. This model only seeks to assess the probability of a whale and bow of a ship getting within 10m of one another. The following assumptions were made:

- 260 whales migrate north over two months, and return six months later [1];
- A single ship transits the GAB every 14 days;
- Whales move at the water surface at all times;
- Whales migrate at an average speed of 3kt;
- Shipping moves at an average speed of 15kt;
- Both whales and ship are modelled as points that move in a straight line with no avoidance behaviour.

These assumptions are highly conservative, and discount many mitigating factors for whale strike risk. However, it is useful to demonstrate whether additional data collection is warranted or if the risk can be discounted.

The model was applied theoretically, with an assessment of the average time taken for a whale to cross the ship's track, and the probability of the shipping being in the vicinity over that time period (see figure below).



The results found that the annual whale strike probability was 0.0034, or 1 every ~300 years.
An analysis of sensitivity found a linear dependence on the number of whales and number of vessel transits. Counterintuitively, the speed of the vessel showed a hyperbolic decrease in encounter probability. However, from a risk perspective it is likely that a more advanced model would demonstrate that a fast-moving vessel would be of a higher risk, whereas a stationary vessel would carry no risk – ships tend to hit whales, and not the other way around.

Discussion and Conclusion

There are many logical ways to assess the risk of whale strike associated with proposed port developments, and existing shipping lanes. However, many of these rely on complex data, with large uncertainty and potential biases.

Analysis of simplistic models allows for useful first-pass assessments of relative and incremental risk for new developments.

As further data become available on marine fauna numbers, patterns and behaviours, it is likely that the need to assess their impacts associated with shipping intensification will increase. Practitioners should consider utilising simple tools for first-pass assessments, where useful outcomes are still available even with a dearth of data.

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UN SDGs

14, 9, 11, 12

Sustainable Long-Term Protection of Reinforced Concrete Port structures

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Summary

The development of cost-effective methods to mitigate reinforcement corrosion in existing chloride-contaminated structures is a key focus for many Port Authorities, who look to extend the life of these assets and provide sustainable ongoing Port Operations. Such methods and technologies are vital to asset owners for the management of ageing coastal infrastructure. One such method is the use of distributed galvanic anode systems to provide cathodic protection to reinforced concrete.

This paper presents case studies on the use of galvanic encasements to repair and protect reinforced concrete structures. Long term monitoring of field projects in Australia and overseas over more than 20 years verifies that this is a sustainable and effective long-term concrete repair and cathodic protection solution that can extend the service life of deteriorated concrete structures by 20 to 40+ years.

Keywords: Sustainability, Asset Management, Corrosion Protection, Cathodic Protection

Introduction

Reinforced concrete Port structures can be designed to achieve long service lives, even in aggressive chloride environments they are built in. Left unchecked however, chloride induced corrosion can lead to deterioration of the Port sub structures and many corroded Port assets have had to have sections replaced at great expense with significant environmental and economic impact as well as disruption to Port operations.

Background

In the mid 1970's in North America, impressed current cathodic protection (ICCP) were used as part of the corrosion protection strategy torehabilitate corrosion-damaged bridges containing de-icing salts ICCP has been used here in Australia since the mid 1980's. It has been well documented that for ICCP to function properly and arrest corrosion, the systems must be monitored on an ongoing basis.

Many transportation agencies, port authorities, and facility owners, either because of a lack of understanding of cathodic protection technology or inability to provide dedicated staff to conduct the required ongoing monitoring and maintenance, are hesitant to use ICCP on their structures. The need for ongoing monitoring and maintenance of the current supply is a major drawback for impressed current systems. It should be noted that well designed, installed and maintained ICCP systems can and have performed well over time.

Galvanic anode system that can supply sufficient current to provide effective cathodic protection, does not require specialized knowledge for installation can significantly minimize the need for future monitoring and maintenance and provide a cost-effective option to extend the life of Port assets.

Example installations

One of the first installations of a Distributed Galvanic anodes for protection of reinforced concrete was North Otter Creek Bridge in Onatrio, Canada. This was installed and monitored since 2003 and 20 years later more than sufficient current is supplied by each of the anodes to meet the 100mV criteria generally accepted to achieve full cathodic protection (1).

Figure 1 – long term monitoring showing the system continues to meet AMPP SP21520-2023 & AS2832-5 criteria.

Since 2003 there have been numerous projects

Highway 9 North Otter Creek Bridge DAS

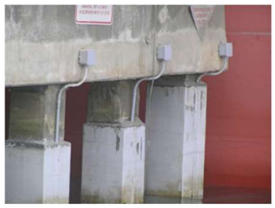
Time (days)	Temp (oC)	Current Density (mA/m2)	Depolarization (mV)
13	7	6.5	273
33	10	6.1	238
61	11	3.5	57
222	20	3.8	271
258	23	2.6	220
267	21	2.5	260
336	23	1.7	211
426	8	1.4	230
486	-20	0.55	142
571	3	1.4	293
676	20	1.8	313
766	8	1.3	284
859	-7	0.8	167
942	10	1.4	330
1165	7	1.24	281

Time (days)	Temp (oC)	Current Density (mA/m2)	Depolarization (mV)
1299	-3	1	201
1573	0	7.6	322
1649	3	1.1	314
1755	20	1.6	421
2000	-5	0.65	273
3174	22	1.8	278
3646	23	1.13	128*
4300	25	1.08	432
5140	23	0.6	202
5383	20	0.57	181
5770	23	0.66	212
6150	23	0.23	185
6554	22	0.59	174
6825	24	0.53	141
7239	28	0.58	161
Average	13.0667	1.877	226.3

The last monitoring was on August16，2023

where galvanic anodes have been installed and performing well in aggressive marine environments.

The North Cargo Piers at the Port of Canaveral in Florida consist of four wharves that handle bulk cargo such as cement, slag, salt, automobiles, and lumber. This project received the ICRI 2007 Project Award. After years of exposure to the corrosive saltwater environment, a major rehabilitation was planned to extend the service life of the busy piers.



Figures 2 & 3 - (show pile conditions before and after galvanic jacket installation at North Cargo Piers

The pile protection consisted of galvanic pile jackets to protect 668 piles. The galvanic jackets consisted of zinc mesh anodes, 22 kg bulk zinc anodes, and a 30mm thick stay-in-place fiber-reinforced polymer (FRP) form. The length of the pile jacket repairs ranged from 1.8 to 9.1 m.

The bottom sections of the cast-in-place pile caps also showed signs of distress. A protection system was devised whereby the bottom (20 cm) of the pile caps were removed and activated distributed galvanic anode strips were placed in two continuous rows on each side of the pile caps. Approximately 6000 lineal ft (1830 m) of pile caps were protected.

The North Cargo Piers continue to be protected 17 years after installation.

Figures 4 - shows the completed installation of pile jackets and repaired pile caps.

In Australia, there are numerous examples of galvanic encasements that will be illustrated in the full paper. These include some of the early galvanic pile jackets at HMAS Platypus wharf in Sydney and more recently published data from Transport for NSW on some of their bridge structures such as Roseville Bridge which has had galvanic encasements installed and shown to be providing full protection a couple of years after installation (2).

Transport for NSW also used supplementary reinforcing to provide additional structural capacity to the pier caps which is an additional benefit of galvanic encasement systems in that both techniques can be carried out in the same process.

Galvanic Cathodic Protection use in Hazardous Port Zones

Several port facilities are classified as hazardous zones with a lot of different hazardous materials being handled daily. One of the benefits of a galvanic CP system is that due to it working on a principal of dissimilar metal corrosion where the zinc within the anode is more active than the reinforcing steel, it does not need external power to energise the system which helps during the installation process as power does not need to be sourced or turned off and on minimising disruption to Port operations as well as ongoing with no requirements for external power.

More recently two stage anode systems that incorporate an initial ICCP phase which then switches to galvanic cathodic prevention have also been used to protect Port structures where Port Operations are classed as hazardous. In addition, the galvanic encasements will not over protect the structure at any given point meaning the galvanic systems are a safe system to consider for Port owners in hazardous classified zones.

Discussion and Conclusion

Galvanic Encasements and overbuilds have been installed on Port and Marine structures for over 20 years and have proven to be a viable option to consider for Port owners where significant corrosion of critical elements has occurred. Galvanic cathodic protection systems can provide a sustainable, safe, low maintenance and cost-effective option for asset owners to extend the service life of corroding reinforced concrete structures compared to replacement. This can also be combined with additional strengthening of elements in the same process making this an efficient overall solution.

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Relevant UN SDGs (https://sdgs.un.org/goals) 9, 11, 14

Potential Acid Sulfate Soils Management for 1.5 million m^3 of Dredged Material

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Summary
The Port of Townsville Channel Upgrade Project encountered the largest quantity of Potential Acid Sulfate Soil (PASS) requiring treatment, in Queensland's history. Almost half of the 3.3 million m^3 of insitu channel dredge material required PASS management. A new cost-effective method of treatment was developed and applied to an average of 4,500m^3 dredge material per day. Due to a lag between material placement and results from testing, a detailed method of tracking was also developed. Dredging works were recently completed and initial conformance in excess of 98% was achieved.

Keywords: Port of Townsville, acid sulfate soils, dredging, reclamation

Introduction

The Port of Townsville dredged 3.3 million cubic metres of seabed to widen an existing shipping channel. Due to the port's proximity to the Great Barrier Reef Marine Park, dredge spoil was placed in a purpose built, 60Ha reclamation area. Prior to commencement of dredging, it was determined that 1.5 million m^3 was subject to PASS management. Traditional methods of treatment would have resulted in costs of over $30M. A novel approach was taken that reduced the estimated cost by 75%.

Potential Acid Sulfate Soils Identification

The dredge area was 14km long and between 30m and 120m wide. Geophysical assessments of insitu-material included bore holes taken at 100m intervals and a seismic survey of the entire dredge footprint. A section of seismic survey is shown in Figure 1. The colours represent layering based on material stiffness. PASS was only found in the upper, unconsolidated layers shown in blue in Figure 1.

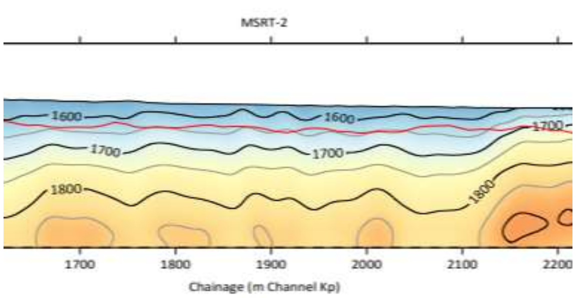

Figure 1. Seismic Survey (Source: SMEC Geophysical Study 2019)

An estimation of total PASS volume was made using a correlation between bore log data and the seismic survey. The study identified approximately 900,000m^3 of PASS requiring management under Queensland legislation.

Figure 2 below shows the approximate location of the PASS boundary. The diagram also shows the extent of the first dredge cut. The depth of the cut is beyond the PASS layer. This resulted in an extra 600,000m^3 of dredge material being mixed with PASS. The extra material required treatment and the total volume of PASS became 1.5 million m^3.

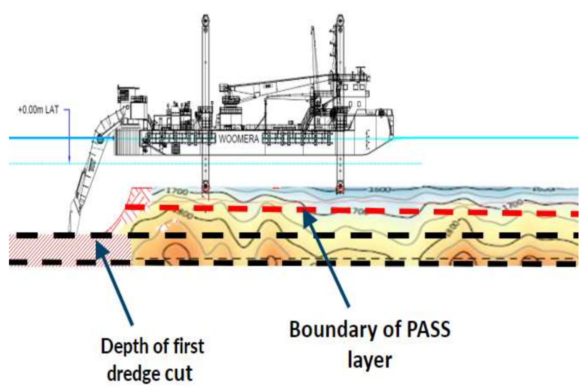

Figure 2. Dredge Cut Depth (Source Port of Townsville)

Treatment of 1.5Mm^3 of PASS

Traditional management of PASS would involve mechanically blending a neutralising agent (e.g. agricultural lime) into the excavated material before final placement. Treatment needs to occur before acid formation takes place. Due to the large volume of material, costs were estimated to exceed $30M. Fluidising the material as a treatment option was to be avoided, as a usable reclamation area at completion of dredging was required.

The treatment method proposed eliminated extra handling of dredge material, and did not require fluidisation, leading to significant potential cost savings. The proposal involved a simplified approach to adding lime. For high-risk areas, lime was added to each dump truck, after being loaded from the barge and before tipping into the reclamation. For low-risk areas it was added to each Lot at the end of each day. The lime dose-rate was based on the geotechnical assessment and would be varied to suit estimated requirements. Mixing of lime with the dredge material would occur randomly during tipping and dozer pushing, until the material reached it's final location.

It was understood the proposed method would not provide consistent mixing of neutralising agent with dredge material. Also, it was expected the self-neutralising capacity of the dredge material would vary. This meant high levels of uncertainty and outcomes were likely to vary from day to day. The key for regulator acceptance of the proposed management plan was extensive testing and comprehensive tracking of placement. Knowledge of placement locations would allow for re-treatment, if required.

Testing, tracking and re-treatment

Dredge volumes of around 4,500m^3 per day were placed into the reclamation. Each day placed material was divided into Lots and test samples were taken across each of the Lots. Sample locations were recorded using GPS and mapped using GIS. Weekly drone flights provided arial photographs of the site. Figure 3 shows the GIS plan of the reclamation area and each dot represents a test sample locations. Green is a conforming test result, orange is non-conforming and grey is pending. Each sample location contains a link in GIS to the data for that sample. Recorded data includes; dredge chainage, dredge depth, a sketch of the Lot placement area, Lot volume, lime dose rate, the date and the test result.

Figure 3. PASS test locations across 60 Ha site (Source: Port of Townsville)

Where a non-conformance identified re-treatment, this would involve additional lime either by excavation and mixing, injection or, where less critical, additional bulk loads tipped on the surface. These areas would be re-tested at the end of works.

A summary of test results during the works is represented in Figure 4. It shows just over 1% of test results were deemed non-conforming (shown in orange). In most cases these were surrounded by conforming material and no further treatment was applied. Audits and inspections supported that no acid generation was evident in any treated material. Final independently supervised 3D verification is expected to take place in the coming months.

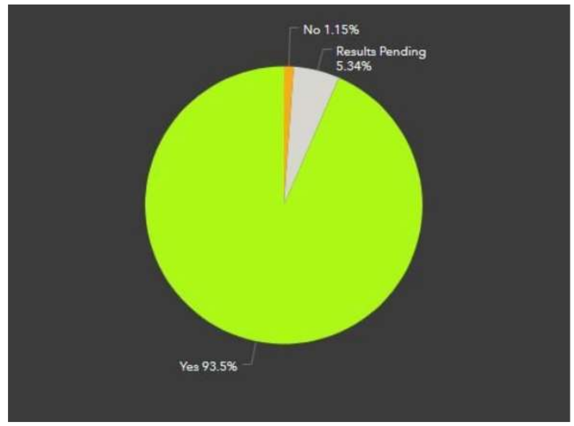

Figure 4. PASS test results during reclamation works (Source: Port of Townsville)

Discussion and Conclusion

Test results were based on a balancing equation using potential acid forming elements and potential acid neutralising elements, within each sample. Acid forming elements were primarily chromium reducing sulfides. Neutralising elements were naturally occurring calcium plus lime added during treatment. Only fine particles were included for calculating potential acid neutralisation, larger particles were sieved out during testing.

The test results obtained during the reclamation works were based on theory, and a conservative method was employed. Final verification testing is required, and this will include new bore samples throughout the reclamation area. The outcomes from testing during the reclamation process indicate that this innovative strategy for managing PASS material was highly successful. This novel methodology, including the detailed records using the GIS database has also resulted in a reduction in final verification works upon closure, due to regulator confidence.

It is important to highlight that a large portion of dredged material had moderate levels of self-neutralising capacity. Also, supervision by a professional who is specialised in Acid Sulfate Soils was essential throughout the works.

Relevant UN SDGs (*https://sdgs.un.org/goals*)
9, 14.

The future of digital Twin Site Investigation & Latent Conditions

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David Kinlan, Inframara Pty. Ltd.

Keywords:
Digital twin, ground modelling. ground investigation, latent conditions

Summary

The past two decades has seen a rapid uptake in the visualisation of *processed* ground (foundational) studies in the marine infrastructure sector. While clear benefits of digitalisation and holistic ground models is understood, there is no sector wide increase in productivity or efficiency in procurement seen for infrastructure projects. A lingering reluctance for many owners to collect and/or provide tenderers with *raw*, verified and digital ground data including geophysical, geotechnical and environmental data, is thought to be a key driver behind lagging industry sector metrics, as well as latent conditions claims. Digitising and unifying ground data acquisition and delivery is a key milestone on the path to improving construction outcomes.

Introduction

The need for adequate foundational studies and ground investigation data is a critical aspect of marine infrastructure projects as misrepresentation of ground conditions remains one of the leading causes of latent condition claims. Industry practitioners are increasingly looking at improved site investigation techniques which produce reliable digital data that accurately reflects site conditions.

Ground Model Development

Some of the most common issues faced by tenderers are inadequate, incomplete or unusable geophysical, geotechnical and environmental datasets. Over the last two decades the potential was realised for improving data acquisition & ground model outcomes by various digital data acquisition techniques. The improvement of ground modelling can lead to significant reduction of project claim values as are captured on the table (Figure 1) below.

Despite such clear evidence as to the benefits of digital ground models and verifiable ground data, the industry continues to operate in silos. While digital data may be collected it is often not shared to those who would most benefit from it. There is an industry need to establish a set of protocols for data acquisition and distribution for the ground model.

TYPE OF INFORMATION PROVIDED TO CONTRACTORS	AVERAGE CLAIM VALUE / CONTRACT VALUE
Minimal investigation no samples or test results	15-25%
Sparse information (1980's standard) borelogs with limited interpretative content	10-12%
Comprehensive investigation/design information & test results, no geotechnical model	2 - 2.5%
Comprehensive investigation/design information, detailed geotechnical model	<0.1%

Figure 48 Roads & Traffic Authority NSW (2014)

The UK Governments Construction Playbook[1] calls for a model clause saying that all subsurface data (including borehole construction information and any downhole geotechnical and laboratory test data) captured, collected or recorded should be provided as a raw data text file, using the Association of Geotechnical and Geo-environmental Specialists ("AGS") file format. Any Data should be marked as open and not as confidential.

Far too often tenderers are advised that digital data will not be provided. This represents a great lost opportunity to increase productivity. Current ground modelling process, acquisition, analysis and reporting is haphazard and a drag on productivity, profits and outcomes. Further, current reporting fails to communicate results to the non-expert.

Digital Twins

The goal of creating the digital twin is to "create a virtual representation of real-world entities and processes, synchronised at specified frequency and fidelity" (digital twin consortium[2]). For the purposes of the initiation phase of any construction project connected to the ground, the digital twin must include the existing setting and verified qualitative analysis of the geology.

The fidelity of the geology must be sufficient to understand material variation across the site. Ultimately, the project owner and their consulting engineer, as well as contracting parties would be able to simulate, analyse and iterate many infrastructure options. This allows for better environmental and economic certainty for designs and associated construction strategies, prior to contract award.

While the digital twin of the ground is not yet realised, the technology and mathematical building blocks are all mature or maturing. These include, but are not limited to Discrete Global Grid Systems, digital geophysical methods, knowledge graphs, and data provenance structures (Figure 2).

Key to the intermediary common ground model and the forthcoming digital twin is the digitising acquisition and data provenance, and verification of all ground data on a common data platform. If we allow the same old ways to underpin the transition to the Digital Twin, the industry will continue to see the same old results, regardless of any digital wrapper.

Latent Conditions

The court cases of Obrascon (2014) and Van Oord (2015) have clearly demonstrated that the tendering contractor cannot simply accept someone else's interpretation of the available data and say that is all that was foreseeable. Further, it is now accepted that ground investigations are only 100% accurate in the precise locations in which they are carried out, and that it is the role of an experienced contractor to identify and fill any gaps.

The experienced contractor therefore is increasingly relying on its interpretation of data points between testing locations. This being the case a high degree of subjectivity may arise. Existing contractual frameworks which allow the contractor to fill in the gaps fall short of providing clients with adequate protection against latent conditions claims.

Proper transparency on the use of ground models and joint verification would go a long way to addressing the incidents of latent conditions claims.

Conclusion

This paper shares the authors thoughts on the present and future status of digital ground data acquisition, ground modelling and latent condition claims, and focuses specifically on key take-aways for procuring good ground data. Experience is shared on ground modelling, digital twins and latent conditions.

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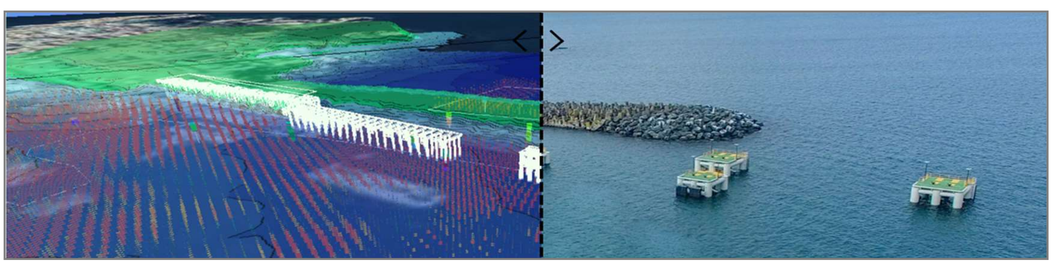

Figure 49 A reality mesh built for the Eden Port Development highlights the pathway to the digital twin of the ground for construction projects.

Enhancing Port Infrastructure: Gellibrand Spring Mooring Dolphins Upgrade

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Summary
This paper delves into the multifaceted process of rehabilitating and upgrading existing spring mooring dolphins at Gellibrand Pier. Various options were explored with a focus on minimising disruption to daily operations, ensuring durability, controlling costs, meeting design loads and compliance standards, and optimising site layout. The culmination of this endeavour resulted in the successful implementation of a final solution in 2022. This paper offers insights into the challenges faced, strategies employed, and outcomes achieved, providing valuable lessons for similar projects in the maritime industry.
Keywords: Gellibrand Pier, Port of Melbourne, Mooring Dolphins.

Background
Gellibrand Pier, situated in Williamstown, serves as a specialised bulk liquid berth currently leased to ExxonMobil Australia. Functioning as a crucial supply route, **Gellibrand Pier** facilitates the transport of crude oil for ExxonMobil's Altona Refinery and Gellibrand tank farm.
Originally known as Railway Pier, **Gellibrand Pier** dates back to the late 1850s. In the mid-1960s, the pier underwent significant remodelling and extension, transforming into its current configuration as an oil tanker berth.
Gellibrand Pier operates as an island berth. It comprises a main roadway and pipe rack leading to a pier head equipped with loading arms. Berthing dolphins flank the pier head, strategically spaced to accommodate vessels of varying sizes. Additionally, **mooring dolphins**, equipped with quick-release hooks, are offset to the fender line, facilitating the secure attachment of vessel breast, head, and stern lines.
The **Port of Melbourne (PoM)** collaborated with **AWMaritime (AWM)** to enhance the ageing **mooring dolphins**, initially built in the 1960s. The purpose was twofold: first, to accommodate the expected increase in the load of spring mooring lines in case of bigger vessel berthing in future (from the original ultimate design load of 1500 kN to 2590 kN), and second, to address the deteriorating condition of the infrastructure.
AWM conducted an extensive analysis of rehabilitation options for these dolphins. The project's main goal was to **enhance the dolphins' capacity** while ensuring minimal disruptions to the **day-to-day operations** of this vital asset.

Challenges & Solutions
The **mooring dolphins** showed severe deterioration, earning an overall condition rating of Six out of Seven per WSCAM [1]. For instance, the concrete cap in the splash zone suffered from extensive chloride ingress, resulting in widespread spalling across the entire soffit area, exposing steel reinforcement, and developing cracks along the cap's perimeter. Also, Ultrasonic Thickness Testing (UTT) measurements of the Steel Peine Piles indicated a notable steel loss within the existing piles, averaging 1.4mm in thickness loss within the splash zone with a maximum section loss of 10.5mm from the original pile thickness of 16.5 mm. The corrosion within the immersed zone was much less, thanks to the Impressed Current Cathodic Protection (ICCP) system installed in 2012.

Given the condition described, although rehabilitation of the steel piles was feasible, any long-term repair on the concrete cap was impractical. The steel pile could be rehabilitated using grouted-filled boxed elements in the splash zone and conventional patch repair within the immersed zone. Nevertheless, it was later realised that the existing piles could not withstand the desired accidental mooring loads (2590 kN), which may imposed from future vessels according to current standards like BS-6349-1-2 [2] and OCIMF MEG4 [3]. According to these references, a mooring dolphin with two hooks (Quick Release Hook) shall be designed to withstand at least 2.1 times the hook capacity, also known as an accidental load. Based on the new standard, the design of the mooring system must guarantee that the mooring dolphin's structure remains intact and does not experience structural damage or failure before the mooring line or its fittings. Therefore, rehabilitation of the existing dolphins using purely the existing piles was obsolete.

Another project constraint was the limited time to conduct the on-site construction work. As the **Gellibrand Pier** is a critical asset to the client and Melbourne and Victoria in general, any disruption to operations that potentially impacted fuel supply was intolerable. The upgrade of the mooring dolphins needed to be completed without impacting fuel supply and distribution. **Gellibrand**, being a busy berth, gives an average vacancy of four days per month with a maximum planned shutdown period of two weeks. **PoM** discussed the project planning with ExxonMobil and the construction contractor to agree on the required number and timing of the two-week shutdown periods during which the works will be conducted. This required ExxonMobil to develop and implement a schedule for its imports to ensure sufficient reserves in the tank farm and refinery output whilst providing certainty around fuel supply to Melbourne and Victoria during the two-week construction periods.

It was decided to use precast concrete elements for the pile caps to accommodate such a short on-site construction installation window. A conventional pile cap comprises infill steel reinforcement and in-situ concrete pouring into a precast concrete bathtub, which involves lengthy onsite work. Choosing a precast concrete cap reduces onsite construction time from weeks to hours. However, using a precast concrete element poses another challenge about the maximum allowable lift capacity. The lift of the precast element shall be done from a crane, most likely a crawler crane mounted on a barge. **PoM** engaged local construction contractors to keep the overall project cost down. These contractors have limited lift capabilities (Maximum 70 tonnes). Therefore, the construction contractor's capability sets the maximum precast weight (65 tonnes). The design opts for a relatively thin precast concrete cap to conform with the construction limitation. A relatively thin pile cap (740 mm) would keep the soffit of the concrete pile cap above the splash zone and increase the system's durability.

Achieving a relatively thin cap involves establishing a pin connection between the pile cap and the pile. This approach contrasts with the conventional fixed pile-to-pile cap connection method in conventional dolphin cap designs. In a fixed pile-to-pile cap connection, the concrete pile cap must be deep enough to transfer the high bending moment induced by mooring loads (i.e., pile cap thickness over 1.5m in this scenario). However, to address this issue in this project, we opted for a pin connection between the pile cap and the pile. This decision could significantly increase the pile sizes or their numbers, as a pin-top/cantilever structural system shall transfer approximately double the bending action induced by mooring force compared with a fixed-top/portal-like structural system.

Another challenge we faced was the restricted space available on the site for installing new piles. Given the location of the **spring mooring dolphin** relative to the berth pocket, which we couldn't disrupt, and existing steel piles (nine per dolphin), the space left for adding new steel piles that could meaningfully support the structure was extremely limited.

We opted to link the mooring dolphins with an appropriate tie beam system to address these difficulties. We also used vertical piles instead of raker piles to minimise the risk of pile clashes with nearby piles. Vertical piles were also the construction contractor's choice of installation methodology. This solution helps spread the mooring forces across both dolphins, thereby lessening the stress on individual piles and reducing the size and number of piles needed.

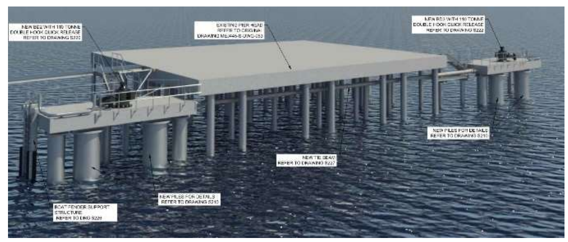

Figure 50 Isometric View of New Spring Mooring Dolphins

Discussion and Conclusion

This paper discusses the challenges faced during the project, including the asset's poor condition, non-compliance with current standards, constrained construction timelines, and limited space for new installations. Overcoming these challenges, a partnership among **AWM**, **PoM**, construction teams, and asset users successfully constructed two **mooring dolphins**. These are in line with up-to-date standards, built to endure for 50 years while maintaining uninterrupted daily operations at the wharf. The adopted design method is estimated to reduce the project's overall cost by half compared to building new mooring dolphins.

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Relevant UN SDGs (*__https://sdgs.un.org/goals__*)
8, 9, 11 and 17.

Asset Sustainability Strategies – Port Bonython jetty remediation

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Summary
This paper demonstrates that the development of optimal strategies for the sustainable remediation of ageing port assets requires an understanding of the criticality of the asset, the expected remaining functional life, and the different remediation options available. WGA was engaged by the South Australian Department of Infrastructure and Transport to develop a strategy for the jetty infrastructure at Port Bonython, which informed their decision to extend the functional service life by a further 50 years. WGA subsequently undertook the design for these works, including replacement of mooring and berthing infrastructure, significant concrete remediation, modified port rules during the construction works and temporary works design.

Keywords: sustainability, asset strategy, concrete remediation, Port Bonython

Introduction
Port Bonython is a deep-water liquid hydrocarbon export terminal located 16km from Whyalla in the Upper Spencer Gulf. It includes a 2.4km approach jetty extending out to a T-head arrangement comprising four mooring dolphins, four breasting dolphins, a continuous fender and a loading platform (refer overview in Figure 1).

The jetty, originally constructed in 1982 and owned and operated by the Department for Infrastructure and Transport (DIT), is a deep-water port with depths of 20m. The facility is utilised by Santos Australia for the export of their hydrocarbon products and by IOR for the import of diesel products.

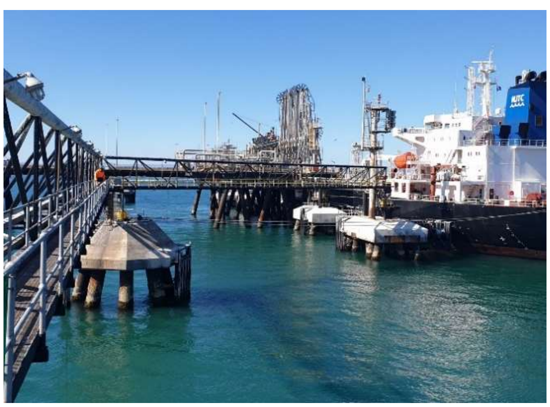

Figure 51 Overview of T-Head arrangement showing mooring dolphin 2 and breasting dolphins 1 & 2

With the asset approaching the end of its original design life, it was established that it was imperative to extend the functional service life due to its criticality for the current operations of Santos and IOR. This also considered the centrality of the asset in future plans for the region including a hydrogen energy industry.

Of the various structural components, the breasting and mooring dolphins presented the greatest cost implications to the overall asset strategy due to the extent of concrete deterioration to the pile caps and the constraints on undertaking remediation works without disrupting the continued operation of the port. It was also important to coordinate remediation works of the pile caps with upgrades of critical mooring and berthing components already scheduled for the dolphins.

Condition Assessment
An accurate appreciation of asset condition is essential for prioritising the remediation works within the asset strategy. This was undertaken via site inspections using the Ports Authority Wharf Condition Assessment Manual (WSCAM) system of rating the condition score of structural elements based on observed defects.

Due to the criticality of the concrete pile caps on the mooring and berthing dolphins, the advanced WSCAM inspection data (incorporating visual inspection and physical delamination testing) was supplemented with the following concrete tests:

- Laboratory analysis of concrete cores to identify the depth of chloride penetration into the concrete substrate (refer output in Figure 2);
- Half-cell potential testing to identify regions in the concrete structure with a high probability of reinforcement corrosion.

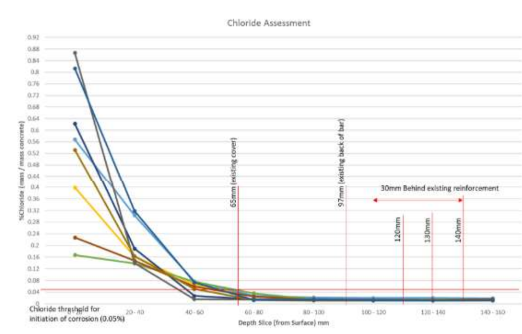

Figure 52 Chloride results from mooring dolphin core samples (Source [1])

These tests confirmed that the deterioration of the pile caps from delamination and spalling was the result of chlorides in the concrete at the level of the reinforcement reaching threshold values. This was significant, as the rate of deterioration accelerates once the chloride concentration at the level of the reinforcement exceeds threshold levels.

It was concluded that a repair campaign only confined to localised patch repairs of the areas currently showing delamination would not be a sustainable long-term solution, as the adjacent concrete yet to begin delamination but with high chloride concentrations present could be expected to commence delamination within the functional service life of the repairs.

Asset Strategy

Different asset remediation strategies were considered according to the following criteria:

- Structural component criticality;
- Expected remaining functional life as predicted by WSCAM condition rating score;
- Typical extension of functional life expected from each remediation option;
- Expected further mobilisations for maintenance required to achieve extended functional life.

Remediation strategies were developed for a functional life extension of: 20 years; 50 years; and, a hybrid strategy that assumed that a further extension of functional life was implemented after the 20-year option. To assist with the comparison of these options, rudimentary estimates were developed for each strategy of the predicted CapEx and OpEx over the extended functional service life of the asset, expressed in net present costs (refer Figure 3).

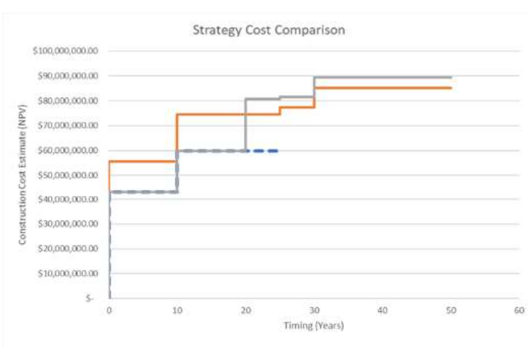

Figure 53 Cost estimates for each strategy, expressed in net present costs assuming 4% discount rate. (Source [1])

It was determined that the 50-year extension of functional service life was the most sustainable strategy. The access constraints of undertaking remediation works without disrupting the continued operation of the port are such that the most sustainable strategy was equivalent to the one that minimised the total number of mobilisations to site over the extended functional service life.

Remediation Design

The design of the concrete remediation of the dolphin pile caps to achieve a 50-year extension of functional life involved the hydroblasted removal of the outer 180mm of the concrete face on all exposed surfaces of the pile cap (i.e. “de-skinning”), effectively removing the outer concrete layer with a high chloride concentration. After replacing corroded reinforcement in the exposed outer layer, the outer concrete “skin” was re-instated with a new concrete mix, designed for high durability outcomes to achieve the new 50-year design life.

The remediation details also incorporated the design modifications required to upgrade the fender systems on the breasting dolphins and the quick release hooks on the mooring and breasting dolphins.

Of particular note, was the design of a post-fixed chemical anchor solution for the new quick release hooks on the mooring dolphins, developed in coordination with Hilti. This required hydroblasting the entire top face of the mooring dolphins to expose the top layers of reinforcement such that the new anchors could be drilled without damaging the structural integrity of the pile cap.

Construction Support

A key component of WGA’s construction support involved preparing temporary port rules for the mooring of vessels to allow for a mooring or breasting dolphin being offline due to remediation works.

Significant stakeholder consultation with the contractor, the asset users (Santos and IOR), DIT (asset owner) and Flinders Ports (pilot services) was necessary to develop a framework that allowed the contractor to develop a methodology to undertake the remediation of the dolphins while maintaining the asset as operational.

Conclusion

The Port Bonython jetty remediation demonstrates how a sustainable strategy to extend the functional life of a structure can be developed with close collaboration between engineering consultant and asset owner. Given the opportunity, this collaboration can extend beyond the development of the remediation strategy to the design and implementation of the works, with satisfactory results onsite.

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Relevant UN SDGs
Relevant UN SDG: 9

The effect of mooring line type on mooring safety of Ultra Large Container Ships

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Summary
Safe mooring of large container ships has become increasingly more challenging. Large side wind areas, high mooring decks and bollards located at the quay edge make it more and more challenging to ensure safe mooring of large (>350 m, Post New-Panamax) container ships in wind. This paper shows how the limiting wind speeds for safe mooring depend on the mooring lines. The considered mooring line materials are nylon, polyester and a High Modulus Polyethylene combi-line (11m nylon tail). The results are based on numerical modelling of the response of a future 450m moored container ships in gusting wind.

Keywords: safe mooring, Ultra Large Container Ships, Dynamic Mooring Analysis, mooring line material

Introduction
Safe mooring of large container ships becomes increasingly more challenging. Bollards are located at the quay edge, and combined with high mooring deck levels, short, steep lines can often not be avoided. The behaviour of moored ships in wind and how to ensure safe mooring has been an important topic in port engineering and port operations in the last years [1][2][6][8][9][10].

This paper shows how the limiting wind speeds for safe mooring for a future 450m (≥26,000 TEU) Ultra Large Container Ship (ULCS) depend on the used mooring line material and breaking strength. The considered mooring line materials are nylon, polyester and a High Modulus Polyethylene (HMPE) combi-line (11m nylon tail). The limiting wind speed is defined as the wind up to which the Working Load Limit (WLL, equal to 50% of Minimum Breaking Load (MBL)) of the mooring line has not yet been exceeded [5].

The limiting wind speeds are determined based on numerical modelling (i.e. a Dynamic Mooring Analysis (DMA)) of the response of the moored container ships in time-varying (i.e. gusting) wind. The software used to carry out the DMA has been developed by the Maritime Research Institute the Netherlands (www.marin.nl). The effect of the port environment on the wind field has not been considered (for information on this subject, see Windlass | MARIN). The wind coefficients are based on wind tunnel tests carried out by Marikom, on the instructions of Hamburg Port Authority [3][4], which assumes a uniform wind field. The results presented in this paper are the maximum line forces in a 3-hour simulation, using an hourly mean wind speed as input.

Details ship and mooring arrangement
The considered container ship is a future container vessel of 450m length overall (≥26,000 TEU). The deck plan is scaled from a Post New Panamax container vessel of 24,000 TEU [7]. Table 5 depicts the ship's main dimensions. The container vessel 26,000 TEU is moored with 16 lines. The mooring line type options are presented in Table 6. The assumed pretension in all lines is 5% of the MBL. Figure 54 shows the mooring arrangement (heading: 154 degrees North).

Table 5 Main particulars ship used in analysis

Parameter	Future vessel Post New Panamax
Cargo capacity TEU	≥26,000
Length over all L_{oa}	450m
Length between perpendiculars L_{pp}	427.5m
Beam B	63.3m
Depth D	30.0m
Draught T	15.5m
Displacement Δ	~345,000t
Transverse windage area A_s	19,295m^2
Longitudinal wind area A_f	2,883m^2

Table 6 Particulars analysed mooring lines

Parameter	Type 1	Type 2	Type 3	Type 4
No. of line	16	16	16	16
Material	HMPE	HMPE	PE	Nylon
MBL (t)	230	160	130	130
WLL (t)	115	80	65	65
Tail			No tail	No tail
Material	Nylon	Nylon		
Length (m)	11	11		
MBL (t)	310.5	220		

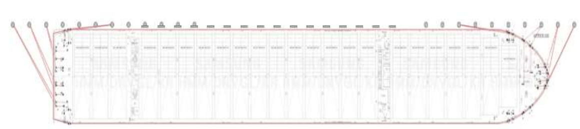

Figure 54 Mooring arrangement layout

Maximum mooring line forces and motions

Even though the MBL is higher for the combi-lines, the maximum line force is smaller compared to the polyester and nylon lines. Figure 55 shows the maximum force in each line in beam off-quay wind of 13m/s (hourly mean wind speed).

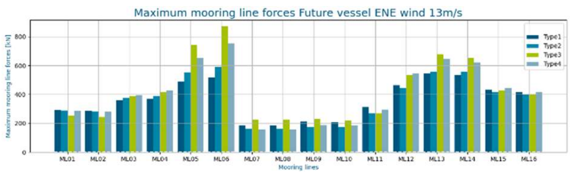

Figure 55 Bar plots maximum line forces in beam off-quay wind

The dynamic response is larger for the polyester and nylon mooring lines. Large motion amplitudes occur, resulting in high tension peaks. The difference in maximum mooring line forces between polyester and nylon lines is small. The sway motions, however, show more difference, 0.5, 0.7, 1.3 and 2.7m for respectively line type 1 to 4.

Limiting wind speeds

The limiting wind speeds are higher for the stiffer combi-lines than the softer polyester and nylon lines. Figure 56 depicts the limiting wind speeds for all four line types. The reason is twofold:

1. The WLL is higher (respectively: 115, 80, 65 and 65t).
2. The mooring is much stiffer, resulting in much less dynamic response.

It should be noted, though, that the limiting wind speeds for combi-line with the highest MBL (line type 1) are governed by the bollard capacity (SWL: 200t). Figure 57 shows the limiting wind speeds for separate criteria for combi-line 1. This shows that there is a limit to how much the MBL of a combi-line can be increased in order to improve the mooring.

Conclusions

The mooring of ULCS in wind can be improved by adapting combi-lines (HMPE combined with a nylon or polyester tail) instead of polyester or nylon lines. The dynamic response decreases for increasing line stiffness. The bollard capacity, however, should be considered as well.

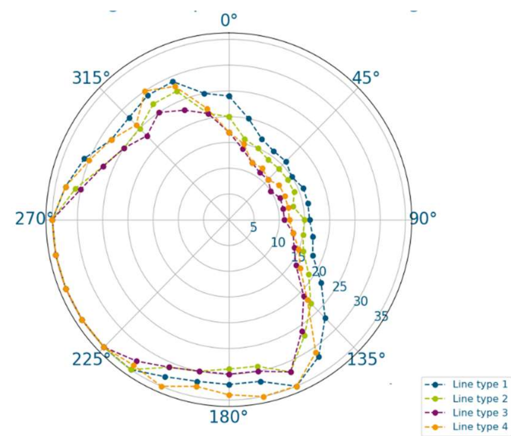

Figure 56 Polar plot limiting wind speeds

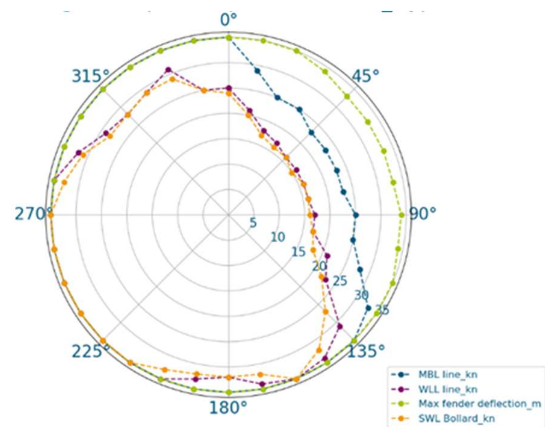

Figure 57 Polar plot limiting wind speeds combi-lines (line type 1)

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Scaling Up: Lessons Learned from Physical Modelling and Opotiki Harbour Development with Hanbar Units

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Summary
Since the 1970s, numerous breakwaters in NSW, and more recently in New Zealand, have undergone construction or upgrades using Hanbar concrete armour units (CAU). These are distinct to Australasia, with limited information in standard coastal engineering literature. This study provides placement density guidelines as well as recommended damage coefficient (Hudson K_d) for design. An overview of the Opotiki Harbour Development ("OHD") in New Zealand is then provided. The OHD comprises twin 400 m long breakwaters armoured with Hanbars to fix a dynamic river mouth. Multi-stage physical modelling approach was adopted by conducting 2D modelling of key sections of the trunk, quasi-3D modelling of the head, and full 3D modelling of complete structures.

Keywords: Concrete Armour Unit, Breakwater, Hanbar, Physical Model, Opotiki.

Introduction
The Hanbar CAU can be best described as a three thick legged unreinforced concrete unit and was initially designed and used by the Australian state agency NSW Public Works Department in the mid-1970s [1]. 12 t Hanbars were first reported to be used in NSW for repairs in 1975 on the Wollongong, Bellambi and Ulladulla breakwaters. Hanbars were subsequently used on the Port Kembla coal loader seawall in the early 1980s and on the extension of the Eden breakwater. During the 2000s and 2010s, Hanbars units of size ranging from 8 t to 28 t were used across NSW and QLD for repairs and upgrades on more than half a dozen breakwaters.

The first use of Hanbars outside of Australia took place in 2020, with the upgrade of the Pitt Island wharf and revetment [2]. More recently, the construction of the two 400 m long training walls for the Opotiki Harbour development in New Zealand, required the use of over 12,000 Hanbar units of size ranging from 2 t to 15 t (see Section 4).

Hanbar Details
Being a locally designed and used armour unit, there is relatively limited information in the international literature in regard to the design, manufacture and installation of Hanbars. Blacka *et al.* (2005) [3] provides a summary of geometry specifications of Hanbars CAUs.

The largest economic benefit in production of the Hanbar arises from the simple fabrication process and formwork required for casting the unit. It consists of an open-ended single draw mould that is filled from the top. The Hanbar mould has no base and a 1:10 taper on all sides, allowing the unit to be demoulded by simply lifting the mould vertically off the unit using standard equipment such as a crane or excavator.

Design recommendations
The widely adopted placement method of the Hanbar units is as a random double layer, with 60/40 ratio for bottom/top layers. A new review of placement density used in previous physical modelling studies [4] allowed to establish the following placement relation:

$$N = k_p M^{2/3} \quad (1)$$

where
M = mass of the considered Hanbar unit
N = number of units per m^2 of breakwater slope used during double layer placement
k_p = packing density coefficient recommended to be set between 1.27 and 1.41

Using the results of over 150 tests across different conditions, conducted for normal incident wave conditions, the 2024 analysis [4] confirmed that a conservative Hudson [5] damage coefficient K_d value of about 7 was found to apply for a damage level of 5% (usually adopted as initiation of damage), which is consistent with previous recommendations [3] for random placement.

Opotiki Harbour Development
Introduction
The Opotiki Harbour Development Project involves stabilising the entrance of the Waioeka River to allow reliable and safe access for maritime activity. This project is the first major river training works to be designed in New Zealand in over 100 years and includes twin 400 m long training wall breakwaters, dredging of a navigable channel into the harbour, and closing the natural river mouth.

Physical modelling overview
A staged approach to physical modelling was adopted, which enabled a more accurate assessment of key coastal processes as well as design optimisation and validation:

3. Quasi-3D modelling of the breakwater head
4. Full 3D modelling of complete structures

Physical model scaling was based on geometric similarity with an undistorted length scale of 1:40.5 being used for all the modelling stages.

Physical modelling results

2D physical model tests were conducted to determine actual K_d under various wave conditions, including normal and 45-degree incident waves. Test results recorded displaced and rocking units to assess structural stability. For normal incident waves, a K_d value of 7 was found to be adequate for 5% damage level, increasing to 10 for 45-degree incident waves. Increasing the size of Hanbar units on the 2D model reduced average overtopping rates by enhancing wave dissipation and increasing crest height. Overtopping rates decreased by a factor of 4 between head-on and 45-degree oblique wave models under the same wave climate.

Figure 58 Q3D model of breakwater head

The full 3D model tested cumulative armour damage under different design conditions. Hanbar layouts were tested in the 3D model to assess and validate the performance of the design layout. The heads of both walls were armoured using 15 t Hanbars while the trunks included a combination of 2/5/6.5/10 t units. Heads and transitions between differently sized armoured areas were stable, with less than 1% damage. Testing also assessed the stability of the armoured crest, with a specific interlocking pattern to enhance visual appeal.

Project construction and update

Physical modelling was finished early 2020, and construction site establishment commenced six months later in October 2020. A stockpile site near the eastern entrance was created to receive 400,000 tonnes of core, underlayer, and armour rock. A casting yard nearby produced over 12,000 units in under 2 years. Contractor feedback highlighted the economical fabrication of required formwork, with moulds removed in less than 4 hours after casting.

Figure 59 OHD harbour channel on its opening day [Source: ODC government]

The construction of the landward ends of the training walls started in April 2021 and dredging in July 2022. Opening of the new channel took place a year later and soon followed by the closing of the existing river mouth to promote flow down the new harbour entrance channel. Completion of construction and placement of Hanbar units is currently expected for mid 2024. The contractor has reported that placement of the Hanbar units was significantly easier and faster than other units they previously worked with. Placement densities for the different unit sizes derived from the physical modelling have been found to be achievable on site.

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Relevant UN SDGs (*https://sdgs.un.org/goals*)

8, 9, 13, 14.

Geotextile design considerations for ‘closed’ rock bund reclamation structures

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Summary
Geotextile material is typically used within rock bund reclamation structures to minimise the release of fine material into the surrounding marine environment. Geotextile material is typically chosen because the material allows ‘two-way’ flow through rock bund structures prior to filling with dredge material. To address regulatory approval conditions, geotextiles must remain intact during installation, construction and also whilst in service when placed within reclamation structures. The project has identified a gap within industry guidance for the design of geotextile material within ‘closed’ or ‘fully confined’ rock bund reclamation structures, which differ from bunds constructed with low permeability cores. This abstract provides a summary of the design approach adopted for the Port of Townsville Channel Upgrade Project, created to provide a catalyst for filling the identified gap in current design guidance.

Keywords: Port of Townsville, rock bund design, geotextile design and stability

Relevant United Nations Sustainable Development Goal number 9 addressed; *to build resilient infrastructure, promote inclusive and sustainable industrialisation and foster innovation* (https://sdgs.un.org/goals)

Background
The Port of Townsville Limited (the Port) is seeking to increase the capacity of its existing shipping channel through dredging activities by increasing its width. Legislation requires all capital dredge material to be beneficially reused for land reclamation, as opposed to being deposited at sea. A rock bund was recently constructed to create a 62ha reclamation area, which will encapsulate the dredge material (see **Figure 1**). The rock bund measures approximately 550m along the eastern and western bunds and 1100m across the connecting northern bund.

Figure 60 Channel Upgrade Project (Source: Port of Townsville)

Introduction
This abstract provides a summary of the following:
- Geotextile material adopted within the rock bund design;
- Hydraulic stability design approach and in situ model validation;
- Recommendations for designers of ‘closed’ rock bund structures that require geotextile material.

Geotextile Selection
The primary function of the adopted geotextile was to minimise the release of dredged material from within the reclamation area into tidal waters, in accordance with State Government development approval conditions. In addition, the geotextile material needed to be:
- Adequately robust to minimise the risk of damage during construction.
- Sufficiently permeable to enable water to flow through the geotextile to achieve equilibration of water levels inside and outside of the rock bund.

A ‘non-conventional’ heavy duty non-woven geotextile, Geofabrics Australia 1209RP (material used for geotextile sand containers), was adopted for the rock wall bund based on:
- Discussions and recommendations from Geofabrics Australia
- Following this, on-site dry trials undertaken by the construction contractor, undertaken prior to installation, to assess in situ strength and elongation material properties.

Site based dry trials were undertaken to demonstrate that the geotextile was not damaged during **i)** placement of rock in accordance with the drawings and specification, and **ii)** vehicles passing at a horizontal distance of greater than 1m from the geotextile. The important points to highlight when selecting geotextile material for design purposes are:
- Most rock bund projects are likely to require a bespoke geotextile design requiring the interaction and support of the client, designer, contractor and supplier;
- Geotextile design has the potential to be a process of iteration, based on in situ dry trial performance;

- There is very limited design guidance on the 'survivability' (durability) of geotextile material, typically relying on either designer and/or supplier experience;
- Hydraulic permeability of geotextile material requires consideration and investigation within the context of the specific site, as summarised below.

Hydraulic Stability Due to Tidal Flow

Permeability of geotextile is typically not a controlling factor on flow for conventional rock bunds with low permeability cores. Flow through geotextiles is generally assessed based on the unit area flow per head (AS 3706.9). This approach however does not account for time variable changes in the conductance or transmissivity of the geotextile material due to changing heads (tide levels). To assess this issue for the relatively low permeability 1209RP geotextile, an 'unconventional' hydraulic numerical model, using the Analytical Aquifer Simulator (AnAqSim™) software was developed. This was designed to simulate the hydraulic grade lines and flow of water through the bund and geotextile over a range of tide levels that were anticipated to be experienced throughout the construction process (i.e., from 0.0m LAT to +4.1m LAT). The purpose was to assess the potential for different water levels inside and outside the bund and its impact on geotextile stability over the tidal cycles. This informed the design of the rock buttress at the rear of the rock wall bund. **Figure 2** shows the rock buttress required, within the typical section of the intermediate bund structure (prior to construction of the rock bund crest).

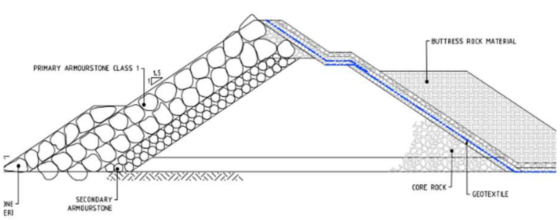

Figure 61 Intermediate bund structure (Source: SMEC drawing 30032296-GE-SME-01-219 rev C)

The AnAqSim model [1] was run to assess several different construction scenarios from a fully geotextile lined (Scenario 1) rear slope, to lining the rear slope with different extents of clay lining (Scenarios 2 to 4) and fully clay lined rear slope.

The modelling identified that a tidal lag (difference between the open coast tide level and the water level inside the reclamation compartment) would form when only the geotextile was placed as per Scenario 1. The magnitude of the tidal lag increased as dredged clay was progressively placed on the rear of the rock bund (i.e., from Scenario 2 to fully clay lined) as summarised below in **Table 1**.

Table 7 Predicted head across seaward side of bund

Scenario	Linear Extent of Clay Lining (Chainage , m)	+4.1m LAT Tide	+3.6m LAT Tide	+3.0m LAT Tide
1	0	1.5	1.2	0.8
2	550	1.5	1.2	0.8
3	1075	1.8	1.4	0.9
4	1625	2.0	1.5	0.95
Fully clay lined*	2177	2.1	1.6	1.0

**values estimated, not modelled*

Model Validation

Water level measurements inside the reclamation pond were undertaken by the Port, with water level measurements outside the reclamation area at Berth 1 available through Queensland Government monitoring. The graph in Figure 3 shows a 1.55m tidal lag during a spring tide event where no clay lining was installed, showing a strong correlation with the modelled results. This provided confidence in the rock buttress design. The assessment highlighted the 1209RP geotextile as the limiting factor to tidal flow.

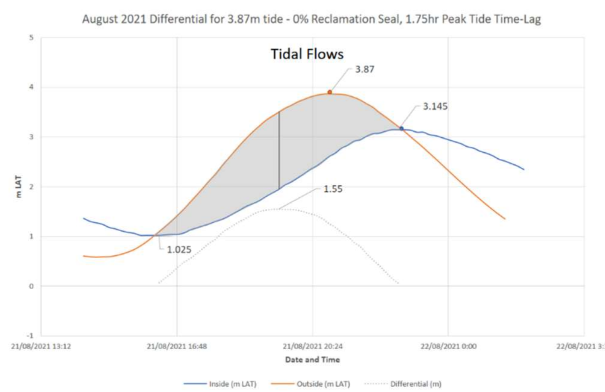

Figure 62 Measured water levels (Source: Port of Townsville)

Recommendations

The project has identified a gap within current guidance for the design of geotextile material within 'closed' or 'fully confined' rock bund reclamation structures. Recommendations for the design of geotextile material within rock bund reclamation structures are:

- Geotextile material is 'called up' on drawings and specifications in the first instance as provisional, subject to on-site dry trials to assess in situ performance;
- The permeability of the geotextile should be assessed by a suitably qualified hydrogeologist over the expected tidal cycles for the various construction stages, to estimate maximum tidal lag. This information can be used to calculate the quantity of rock required to maintain hydraulic stability of the adopted geotextile.

References [1] Fitts Geosolutions [AnAqsim] www.fittsgeosolutions.com/anaqsim/

Defining Coastal Hazard Design Criteria in Tropical Environments

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Summary
With the increasing threat from climate change, methodologies for defining coastal hazards are required particularly in tropical regions that are affected by tropical cyclones. We present a comprehensive methodology for defining the storm surge, design criteria and coastal erosion hazards in tropical environments using a numerical modelling and Monte Carlo approach.

Keywords: Cyclones, Coastal Hazard, Wave Modelling, Coastal Inundation

Introduction

Coastal environments globally face increasing vulnerability due to the impacts of climate change, necessitating a reassessment of coastal hazard management strategies. While this is challenging in temperate regions, tropical environments face additional complexities due to the occurrence of tropical cyclones (TCs).

Coastal hazard associated with storm tide occurs due to the coincident effects of extreme meteorological and oceanographic conditions. For the oceanographic component, this includes tidal and non-tidal sea level variability, but it is often heavily influenced by wave conditions. Wave effects from non-cyclone conditions are often addressed by simulating wave conditions since 1979 coincident with the start of reliable satellite records for defining reliable wind fields. Wave conditions associated with specific Annual Return Intervals (ARIs) are estimated by fitting probability distributions to this record.

This is more challenging for TC conditions as TCs occur more sporadically than non-cyclone wave events. Furthermore, the relatively small size and high intensity of TCs means they are not well resolved in global-scale wind and wave models[7]. TCs that pass close to an area of interest and generate large waves are often coincident with strong onshore winds and lower atmospheric pressure. This is less pronounced for mid and far-field cyclone events which may produce large waves without any associated significant local meteorological changes. Furthermore, the most extreme changes in meteorological conditions may not coincide with the arrival time of the most energetic wave conditions. A reliable record of cyclone tracks is available back to 1979 and while this is a useful record, in most TC affected locations this does not produce a long enough record for the estimations of reliable TC associated storm tides.

We describe a numerical modelling and Monte Carlo (MC) approach to account for both cyclone and non-cyclone hazards which has been successfully applied at multiple locations in tropical locations.

Method

Long-term sea level variability can be understood using wavelet analysis, a method which decomposes signals into time-varying frequency components. This method separates tides and tidal components from weather system effects, inter- and intra-annual effects and interdecadal effects (see Figure 63 for an example). This decomposed signal was used in subsequent MC modelling.

Non-cyclone wave conditions were simulated using the SWAN wave model with spatially and temporally varying spectral wind and wave boundaries [4] and a nested model grid approach. Where possible, the wave model was calibrated against measured wave conditions at the study sites. This produced a 45-year record of wave conditions. As noted above, this type of wave modelling does not adequately resolve TC conditions due to limitations in spatial resolution of wind fields used to force the wave models.

Cyclone wave modelling was undertaken using the SWAN wave model with nested grids. To understand cyclone effects over a long time period, the modelling used a 10,000-year MC generated synthetic set of cyclone tracks [2]. Cyclone tracks were converted into spatially varying wind and pressure fields [6] which formed boundary conditions for subsequent numerical modelling. Simulating 10,000 years of cyclone activity is computationally demanding and requires careful consideration of model grid definition, grid resolution (0.15 x 0.15 degrees) and model timestep (15-minute). Different large scale model grids were used depending on the passage of the cyclone (east or west) of the study site.

Monte Carlo models are a statistical method used to simulate stochastic processes by repeatedly sampling random inputs from several probability distributions. In the context of simulating long-term sea level data, an MC model works by first defining probability distributions for factors that influence sea level. The model then generates and combines many samples from these distributions to create a series of possible events. In this case, probability distributions were generated for long-term sea level variability and metrological and wave conditions. Wave conditions were converted to wave setup and runup using empirical relationships (e.g. [5] and [8]). The modelling considered joint probabilities and changes in cyclone frequency due to varying ENSO conditions [1]. The result of this modelling was a 10,000-year record of sea level, storm tide and associated wave conditions for cyclone and non-cyclone conditions.

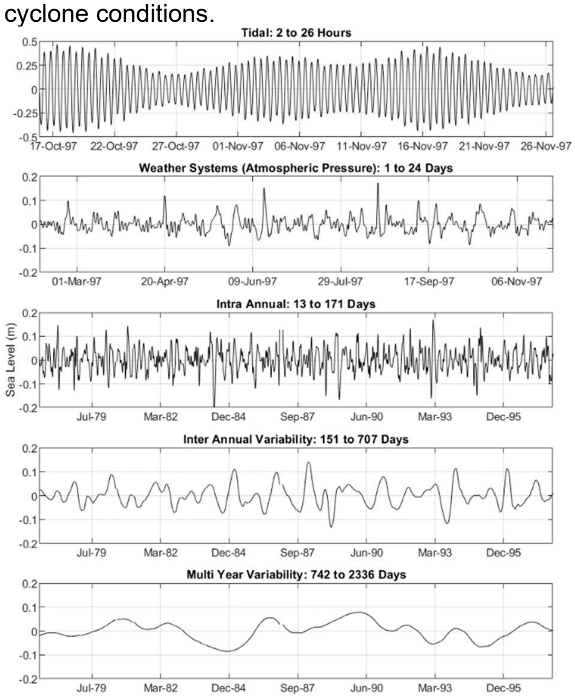

Figure 63 The long-term Rarotonga tide gauge record decomposed into different frequency components. This shows the sea level variability at a range of timescales and can be used as a set of inputs for storm tide Monte Carlo modelling.

The results of the MC modelling were used as boundary conditions for 2D XBeach GPU modelling for a range of ARIs. XBeach GPU [3] is functionally equivalent to the standard XBeach, however GPU processing allows for significantly faster run times. The model was run at 3 m resolution covering large stretches of coastline up to approximately 10 km. The model provided detailed maps of coastal inundation which was calibrated against historical cyclone events (e.g. Figure 64). The modelling was rerun for multiple climate change scenarios to understand how coastal hazards are expected to change for different future projections.

Application

This methodology has been successfully applied at multiple locations in the tropical Indian and Pacific Oceans. These include:

- **Rarotonga**: defining coastal hazard including coastal flooding along the entire north coast of the island to provide inputs for a subsequent risk model.
- **Tonga**: defining coastal hazard including harbour wave penetration and design criteria for two ports.
- **Mauritius**: designing solutions for coastal erosion and inundation for several hotels around the island.

Figure 64 Coastal flooding on the north coast of Rarotonga due to the passage of Cyclone Sally (1986). The inundation levels are compared against observations providing confidence in the model performance.

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Relevant UN SDGs: 13, 9, 15, 8

Creating a Data Corpus for Marine Oil Spills: A Case Study

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Summary
In data-driven approaches, decision-making is assisted by data schemes and the available technology. Recently, semantic technologies can increase the value of data, meaningful processing, and the use of simple but knowledgeable information by providing language processing in the decision-making solution. In the maritime domain, the main difficulty of data processing is the publicly available data in a formal structure or data corpus. This paper addresses a case of oil spill data in marine regions as it is becoming evident and mandatory for international regulations. Each piece of information infers, retrieves, and delivers new knowledge in a changeable and unrestricted environment.

Keywords: Data corpus, Marine oil spills, Case study, PACPLAN

Introduction
The occurrence of oil spills in marine environments poses significant ecological, economic, and social challenges worldwide. Effectively managing these events requires comprehensive and up-to-date data on spill incidents, their impacts, and associated response efforts. However, data in a formal structure or data corpus often lack the necessary scope and depth to support and inform decision-making and policy development. A particular case of oil spill data in marine regions makes evident and mandatory this new perspective for international regulations. Each piece of information is used to infer, retrieve, and deliver new knowledge in a changeable and unrestricted environment. This paper proposes a case study approach for the cooperative regional initiative in the PACPLAN area. The creation of a new data corpus specifically tailored to address this critical gap in knowledge may improve decision-making and governance perspectives on oil spill detection in the marine region and contribute to the current and increasing future responsibilities toward society [1].

Methods
In data-driven approaches, decision-making is based on knowledgeable information. To gain insights into valuable content, artificial intelligence systems (AI) offer different services with applications of semantic technologies. According to [2,3], these are 1) schema-driven semantics, 2) data-driven semantics, and 3) metadata-driven semantics. Each semantic service works with a data corpus or a collection of datasets with a common purpose. The application of semantic technologies will increase the value of data and improve data processing in the maritime domain. Creating a new data corpus in this context begins by combining data from heterogeneous sources, such as in-situ data, AIS data, and open data. At this stage of our study, we cannot appreciate the size of the data corpus. However, in this paper, we point to technical data that can be introduced for improving decision-making and governance perspectives on oil spill detection in a particular case study. Another direction relates to the need for standardised vocabularies. Problems associated with a lack of standardisation derive from difficulties in data comparison and data configuration and integration among several managerial systems. Moreover, "the integration of several heterogeneous data sources is a benefit for maritime decision-makers and maritime security [1, p. 742]".

As stated in [1] static data stored in databases, FTP servers, or external systems makes its update and reusability difficult. Although some variables may retain the concept of time as a timestamp, they still fix the variable to a certain instant of time. The data collection process presented below seeks a dynamic perspective for the interpretation and usability of the oil spill information in the case study. Regarding the value of data and data conceptualisation for decision-making, the collection process includes the rationale behind each of the selected variables since they respond to immediate data requirements. Marine oil spill awareness also requires a multidisciplinary approach to the identification of multiple sources of information in a changeable and unrestricted managerial environment.

Results
The case study: The Pacific Data Hub (PDH) is one initiative for the Pacific Islands on the north seas of Australia with an important number of datasets that bring services and create comprehensive resources designed to centralise data and information pertinent to the Pacific region. It encompasses vital areas such as population statistics, fisheries science, climate change, disaster risk management, public health, food security, and human rights. Spearheaded by the Pacific Community (SPC) and backed by the New Zealand Ministry of Foreign Affairs and Trade. The PDH is a single, authoritative access point for Pacific data, fostering investment in a sustainable regional data infrastructure. The PDH addresses data challenges in policy and

development to ensure timely and reliable data. This data-driven approach supports informed policymaking and decision-making, ultimately improving development outcomes across the Pacific. The PDH is also a key player in the evolving Pacific Data Ecosystem, which aims to enhance data management and utilisation through collaboration among Pacific Island Countries and Territories, the SPC, and the Secretariat of the Pacific Regional Environment Programme (SPREP).

Data corpus development:
The Pacific Islands Regional Marine Spill Contingency Plan (PACPLAN) of October 2000 is a collection of documents that outline the endorsed responsibilities for cooperative regional responses to major marine spills in this region. The PACPLAN documents include analyses for marine waters within the 200 nautical mile limits of the 22 Pacific Island Countries and Territories members of the South Pacific Regional Environment Programme (SPREP). The PACPLAN aims to minimise damage from marine spills and hasten recovery, with objectives including regional cooperation and implementation of international conventions. It covers all pollutants, focusing on oil spills, which apply to spills requiring regional cooperation (Tier Three). Tier One and Two spills are within the capability of individual ports or national resources.

Data collection 1: The GEN-6 form is a structured document that reports pollution incidents specifically related to purse seine fishing activities over a decade, from 2004 to 2014. This form is an integral part of the SPREP Marine Spatial Planning Programme. It is a critical tool for understanding and mitigating the environmental impacts in the Pacific region. The Responsible Authority must complete and send a Pollution Report (POLREP) to SPREP/PACREP for all spills. [4]
Data collection 2: The SPC/FFA Regional Purse Seine Observer Daily Log (FORM PS – 2) is a detailed record used by observers on purse-seine fishing vessels in the Pacific region. It is part of the data collection efforts coordinated by the Pacific Community (SPC) and the Forum Fisheries Agency (FFA). The SPC/FFA Regional Purse Seine Observer Set Details form, also known as Form PS - 3, is a crucial document used by observers aboard purse seine fishing vessels. This form is part of the data collection efforts to monitor and manage fishery resources effectively, ensuring sustainable fishing practices in the Pacific region. [5,6]
Data collection 3: A Situation Report (SITREP) is a structured document used in various fields, particularly in military, emergency response, and project management, to provide a concise overview of the current situation. The primary purpose of a SITREP is to inform stakeholders and decision-makers, ensuring that everyone involved has the most up-to-date information to make informed decisions. It’s a critical tool for effective communication during ongoing events or incidents. Situation Reports (SITREPS) provide incident updates and should be sent regularly via facsimile. [7]
Data collection 4: the Pollution Report (POLREP) is a standardised form used to report marine pollution incidents. It is a critical tool for maritime safety authorities to receive appropriate information, enabling an effective response to pollution events. If the spill impacts their areas, all POLREPs should be shared with affected or interested parties, including neighbouring governments. [7]

Conclusion
To contribute to a new data corpus for improving decision-making on oil spill detection, we have drawn attention to the PACPLAN documents bringing meaningful content to the development of the data corpus making it accessible and freely available for specialised public [8]. This research will continue with standards that put in place the metadata-driven semantics into the data corpus.

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Relevant UN SDGs: 11, 14, 15, 17

Extending the life of marine infrastructure

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Summary
Marine Infrastructure has high capital costs and long design life and often the infrastructure has to work beyond its original design requirements. When such structures reach an end-of-life scenario there are often major business decisions required to ascertain the future value of the infrastructure.
This abstract looks at an example of how, through lean design and quality engagement, we can extract additional life from aging infrastructure in a manner that supports the clients' operational requirements and lowers our carbon impact through careful consideration to materials and construction methodology.

Keywords: *Otago, Marine Infrastructure, Asset Management, Sustainability, Early Contractor Involvement*

Introduction

The Ravensbourne wharf is located on the northern shore of the Otago Harbour and is accessed by a relatively narrow navigational channel. The wharf is connected to land by a timber approach jetty that carries a conveyor from the berth to the fertilizer plant on the foreshore.

Fig 1 – Image of Ravensbourne Wharf and approach Jetty with vessel approaching newly strengthened structure

The operators are major suppliers to the Otago Regions Agricultural Sector. This import facility supplies significant volumes of fertilizer product to the Region and offers the ability to bring product into the factory straight from the cargo vessel meaning no double handling or road haulage which offers both economic advantages and lower emissions. The industry and the factory do however face complex long term investment decisions and only have a relatively short-term secure business plan. This means that any spend on infrastructure needs to be carefully considered in relation to alternative supply options.

Aging Infrastructure

The wharf and approach jetty were constructed of timber back in the 1930's. The lateral loads from the vessels were intended to be taken through a series of raker piles. With larger ships and an aging structure strengthening was carried out in the mid 1990's to develop a different load path for the lateral loads imposed by berthing and mooring. The strengthening scheme included a continuous berthing beam supported on intermittent steel piles with Supercone fenders transferring lateral loads back into a load transfer beam spanning the length of the wharf.

Due to age, deterioration, and continual loading cycles the raker piles had all but failed and the vertical piles were taking all of the energy through deflection. The structure was failing and could no longer sustain the lateral loads.

Short term requirements

The client's business case was a simple comparison of whether the wharf could be reinstated within a lower value than the alternative double handling and road haulage associated with using a different import facility. It was also clear that the emissions impact of this operation was not acceptable to the local community. Therefore, the environmental implications, the operational costs and carbon footprint were key drivers.

The wharf still had residual capacity for small operational deck and conveyor loads and therefore it was decided that there was value in investigating design options for taking the lateral vessel loads out of the existing structure.

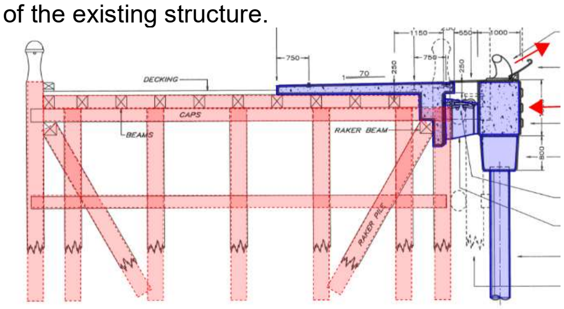

Fig 2 - Typical cross section through wharf showing original timber section in red and the 1990's upgrade in blue.

Construction logistics challenges

To complicate matters the wharf is located in close proximity to the narrow navigational channel and therefore careful consideration was to be given to the Marine Risk during construction and future operational use.

The site could also only be accessed from the marine side and therefore all work would need to be undertaken from marine plant with no deck loadings imposed on the existing wharf. In addition, marine plant would have very restricted depth issues when accessing the rear of the wharf due to the seabed ramping up to 0mCD at the back of the wharf.

All materials would have to be brought, a considerable steaming distance, from Port Chalmers adding complexity and cost for any works, particularly with the use of concrete.
With these restrictions in mind and from discussions with the ECI Contractor it was clear that the available plant and the site constraints would be of significant influence on the design solution.
From a design perspective the tight knit grid of piles under the wharf, especially at the jetty connection, left little room for new structural components.

Key Issues – what would a successful project look like?

- An extension of life of 5 years or more.
- Limited reliance on the existing wharf.
- Limited impact on the navigation.
- Cost effective – within defined budget limit.
- Short programme duration.
- Limited site works and a reliance on offsite fabrication.
- Restricted lifts to meet the limitations of the contractor's plant.

The Approach

- Transfer imposed horizontal loads from the timber structure through the use of a new fender beam and prop solution.
- Utilise soil and structural spring stiffness to absorb energy.
- Pre casting of concrete units and replication of design.
- Use of void formers to limit the amount of in-situ concrete required.
- Limit reinforcement stitching through welding connection where appropriate.
- Allow the Contractor flexibility in construction tolerances – particularly the rear piles.
- Limit the lifts to suit plant and equipment.
- Utilise the existing fender beam and piles as far as possible.

The Solutions

With an outline design developed and good understanding of the geotechnical and structural capacities. Several workshops were held with the ECI Contractor to fine tune the design and make changes which improved their construction efficiency and hence reduced the costs.
Initial designs looked at providing raker piles in a location behind the existing fender beam however this was complex and required considerable interaction with the existing structure. Discussions with the ECI Contractor and the harbourmaster led to the allowance of the berthing line creeping out a further 2.1m towards the navigational channel. This then allowed for a new berthing beam to be created and for the inclusion of the existing beam in the structural frame.
A major win was the use of precast shells and void formers for the fender beam. The cost of getting concrete to the site along with pumping the concrete into the shells was high due to the site location and logistics. As the beam was 145m in length the void former alone saved approximately 45m3 of concrete, the equivalent of 4 barge deliveries which took a day each. The precast shells offered a high level of quality assurance, reduced the requirement for significant overwater temporary works and as the units could be transported and stored on the work barge this led to significant savings in transportation costs, time and plant requirements.
The pinned prop member running under the wharf was measured and fabricated post pile driving. This allowed greater tolerance on the driving of the rear pile and further reduced the requirement for time on site and potential rework.

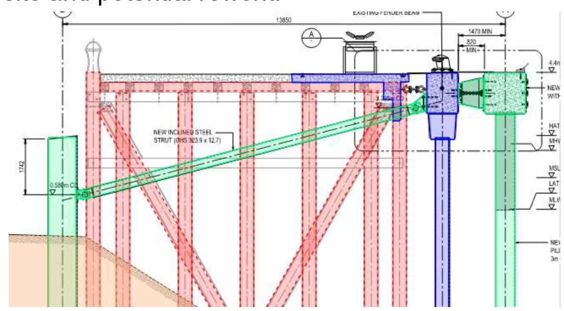

Fig 3 - Typical Cross section through revised wharf showing the new structure in green and noting the revision to the fender load path.

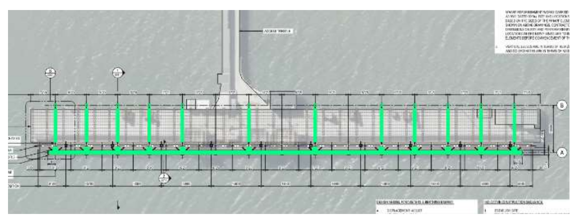

Fig 4 - Plan illustrating the new fender beam and prop locations.

The Resulting outcomes

The design and costing proved that a refurbishment with a limited design life and with some sensible restrictions on operating conditions could offer the operator a cost effective and viable solution to their material transportation issues. The scheme allowed the clients production facility to remain financially viable and continue to provide product to the region's agricultural businesses. With reduced road haulage and double handling operational emissions were reduced which was a win for the local community.
The construction element was successfully caried out and delivered within programme and under the estimated budget.
The first vessel came alongside the wharf within a month of completion and the road haulage operation ceased.

- **Acknowledgements. and References.**

Port Otago
HEB Construction

Security of Rail Mounted Machines in Storm Events

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Summary
The security and integrity of rail-mounted machines relies on the understanding and management of the risks associated with storm wind loading, resistance capability of drives, brakes and/or rail clamps and tie-downs, maintenance practices, controls systems, and operating practices and procedures. Historical design and operating practices may not achieve the management of risk at a tolerable level expected by Owners and Operators. This paper reviews the potential for impacts on asset security and personnel safety where deficiencies in resistance to wind forces associated with storm conditions may occur.

Keywords: Asset, Machine, Storm, Security, Integrity

Introduction
The objective of this paper is to review the parameters that affect the risk of damage and loss to rail-mounted machines (stackers, reclaimers, shiploaders, ship-unloaders etc.) under storm events. These machines are used at mines and ports in Australia and around the world. Historical design and operating practices may not achieve the management of risk at a tolerable level expected by Owners and Operators.

Asset Security and Integrity
The management of risk associated with asset security and integrity of rail mounted machines (Stackers, reclaimers, shiploaders, ship-unloaders etc.) at mines and ports is integral to the safety and financial performance of the operating organisation. Unlike static structures, the integrity of rail-mounted machines is reliant upon the varying restraint capabilities (some that may only be present at a single location along the travel length) provided for varying wind forces.

A failure to secure these machines in storm wind events has led to uncontrolled motions and collisions resulting in partial or total loss of machines in Australia and overseas. Storm events (as opposed to large synoptic events such as cyclones or hurricanes) can occur in short timeframes that may be incompatible with the design and operating assumptions made for machine restraint.

Wind Forces
Large synoptic systems such as cyclones/hurricanes tend to be slow moving and are now able to be predicted for certain locations with some accuracy and warnings that amount to hours/days. There is generally sufficient warning time to relocate the machine to a dedicated non-operational tie-down location to provide the restraint systems to withstand a cyclonic wind loading event.

However, local storm type systems can arise and arrive in much shorter timeframes (i.e. minutes to hours). The ability to accurately predict the wind speed magnitude is also limited, generally due to the highly localised and variable effects of downbursts (either micro-bursts or macro-bursts). The (Australian) Bureau of Meteorology provides the following warnings for wind impacts associated with storms:

Severe thunderstorm – damaging or destructive winds (generally wind gusts exceeding 90km/hr).

Damaging winds – defined as sustained winds of gale force (63km/hr) or wind gusts of more than 90km/hr.

These warnings are generally issued only *after* the detection on weather radar facilities.

A study of a recent wind loading event at an east coast port city identified that during a passing storm, the time between the first wind gust beyond 20m/s (72km/hr) of the approaching storm and the last wind gust of 20m/s (72km/hr) of the same departing storm was 7 minutes. The same storm provided less than 5 minutes between a wind speed of 10m/s (36km/hr) and 30m/s (108km/hr) and less than 10 minutes between 10m/s (36km/hr) and a peak wind speed exceeding 40m/s (144km/hr).

Design Parameters for Wind Loads
Conventional design criteria applied to these types of machines tend to address operational limitations, relocation, and tie-down design wind speeds.

Operating wind speed – This is ordinarily prescribed at a windspeed in the order of 20m/s (72km/hr). All operations and associated motion capabilities should be permissible up to this windspeed.

Relocation wind speed – This is ordinarily prescribed at a windspeed in the order of 20m/s (72km/hr) [1]. Operational capabilities may be limited (i.e. relocation motions only etc.) between the operating windspeed and the relocation windspeed.
It is conventional for design to assume that the machine is in tie-down for windspeeds beyond the

relocation windspeed. The key risk exposure explored in this paper is that associated with wind speeds of greater than the relocation wind speed while the machine is not restrained by its tie-down facilities, due to a rapidly approaching storm. These wind speeds may be at or near to the Region A type limit state wind speeds (45m/s(162km/hr) for V_{500}).

Tie-Down wind speed – This is conventionally prescribed as the V_{500} (500-year return period [2]) regional gust windspeed. This can vary significantly from 45m/s to 80m/s.

Mechanical Resistance to Wind Loads

The security of rail-mounted machines against wind loads is reliant upon:

Motion drive powers and brakes – A machine needs to have sufficient drive power for motion against the applied wind loading, plus all other resistances. It also needs to have sufficient drive braking power against the applied wind loading, plus all other actions, including the arresting of inertia.

Rail clamps – Rail clamps may be needed to provide sufficient resistance to applied wind loading. Most rail clamp systems are static brake systems and cannot be used while the machine is in motion.

Mobilisation of sufficient wheel to rail friction – Where positive locking is not possible, there needs to be a sufficient magnitude of friction mobilised to prevent sliding of the machine. Resistances that are reliant on friction must also consider the impacts that settings, wear, surface condition (i.e. wet, greased etc.) can have on the assumptions made.

Positive locking mechanisms/tie-downs – Where mechanical braking and/or friction is not sufficient to prevent uncontrolled motion, positive locks/tie-downs are needed.

Operating Practices

Operating costs and loss of production costs can drive operating practices and procedures. There is an obvious tension between not ceasing production due to an approaching storm (where the wind speed prediction is inaccurate) and to ensure the security of the asset by achieving restraint. The timeframe to relocate from one end of a facility to the tie-down may be in the order of 10-20 minutes for a port facility, and up to 30 minutes for a stockyard.

Control Systems

Control systems have an impact on the ability of the mechanical resistances to operate as intended:

Wind speed averaging – Initiation of preventative actions can be delayed due to averaging of wind speeds/loads over an excessive period.

Interlocks preventing braking/clamping – Some interlocks may prevent the engagement of brakes/clamps due to the programmed sequence of events, or due to activation not being permitted until a motion is completely stopped.

Time to activate brakes/clamps – The timeframe to activate a brake or a clamp may be too excessive to arrest an uncontrolled motion, or a motion leading to being uncontrolled.

Design Standards and Future Developments

Design standards such as AS 4324.1 prescribe operating wind speeds in the order of 20 m/s (72 km/hr). Some purchasers (and some standards) then prescribe a ‘relocating’ wind speed of between 25m/s (90km/hr) and 30m/s (108km/hr) and a tie-down windspeed at the region design level.

These standards are commonly missing maintenance of the security of the machine that is not within its tie-down location but does experience wind loading beyond the relocation windspeed. This can occur during a rapidly approaching short duration storm event. Additional guidance on resistance requirements for wind speeds that may be experienced during operations, but away from their tie-down location, should be provided.

Discussion and Conclusion

Owners of critical infrastructure and machines need to be aware of the multiple factors that can affect the security of their rail mounted machines. The increases in the quantity of machines through the expansion of export markets, coupled with the apparent increase in the frequency and intensity of storm events naturally increases the likelihood of a localised storm impacting a facility.

The prevention of significant losses for machines requires the adequate prescription of the design criteria to be applied, for both new and existing machines to provide suitable resistance to storm wind forces and protect the asset and the safety of those on and around the asset.

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[1] Standards Australia, AS 4324.1:2017 Mobile equipment for continuous handling of bulk materials Part 1: General requirements for the design of steel structures, p 20.

[2] Standards Australia, AS/NZS 1170.2:2021 Structural design actions Part 2: Wind actions, p 25.

Relevant UN SDGs (*https://sdgs.un.org/goals*)

3, 9.

Blue Infrastructure and Revitalization Plan of Multipurpose Ports for Sustainable Marine Tourism Development in Labuan Bajo - Indonesia

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Summary
Labuan Bajo has been designated as a super priority tourism area that requires accelerated supporting infrastructure, including a multifunctional port. The research examines alternative blue infrastructure policies and port revitalization plans to support sustainable tourism. This research uses a participatory-qualitative approach and sustainability analysis. The research results show that policy intervention is an important factor in port relocation and integrated development of blue infrastructure has a strategic role in the blue economy (BE). The marine economic integration policy is the right policy choice in the optimal scenario for the future of sustainable marine tourism management in Labuan Bajo.

Keywords: Blue Infrastructure, Multipurpose Ports, Marine Tourism, Working with Nature

Introduction

The Labuan Bajo Coastal Area stands out as a crucial hub for economic development. Renowned for its iconic Komodo dragon and breathtaking natural landscapes, Labuan Bajo has gained worldwide recognition as a top-tier tourist destination (Suraji et al., 2020). Multi-purpose ports are one of the important elements of logistics support that need to be organized or separated from ports that support tourism. These two port or terminal functions are very important in supporting tourism in Labuan Bajo, East Nusa Tenggara (NTT).

Ports must plan and manage their operations and future expansion (growth) in this way in order to cope with the limited or decreased environmental space and increased interactions between port and cities. By accommodating this in harmony with the surrounding cities and nature, green growth can clearly be seen as an economic driver (PIANC, 2014). The Wae Kelambu Multipurpose Terminal will be intended for logistics traffic and loading and unloading of containers, cargo and liquid bulk so that it will separate tourism activities and loading and unloading of containers at Labuan Bajo Port (Ministry of Transportation. 2020). The designated location for the port is not yet included in the spatial plan which requires policy intervention.

The development of tourism and its accompanying infrastructure should consider the environmental capacity, especially in the context of Komodo National Park, renowned for its diverse wildlife and requiring meticulous upkeep to address both economic and environmental concerns. A harmonious approach is necessary, given the intricate relationship between the ecological and social elements (Biggs et al., 2022). The Socio-Ecological System framework is a new approach used to produce policy alternatives based on multiple criteria.

The research examines alternative blue infrastructure policies and port revitalization plans to support sustainable tourism. This study aims to pinpoint and examine crucial social, ecological, and governance factors and evaluate the suitability of marine and coastal area utilization in the Labuan Bajo and Komodo National Park regions.

Materials and Method

This research used a qualitative approach to map coastal infrastructure and port revitalization plan, key variables, alternative policy and analyze factors influencing the development of marine economics (tourism) in Labuan Bajo.

Data was collected through a participatory approach, specifically focus group discussions using the World Café method. Participants and informants included representatives from the government, universities, National Park managers, tourism authority managers, and local communities. The analysis of key variable employed a Matrix of Cross Impact Multiplications Applied to a Classification (MICMAC) and Alternaltive Policy uses the policy analysis method with the MULTIPOL technique (Multicriteriapolicy) (Fauzi, 2019).

Results and Discussion

Based on research by Suraji (2020), the results lead to strategic issues primarily tied to resource utilization. Plans to relocate public and fishing ports in Labuan Bajo (Ministry of Transportation, 2017; Ministry of Maritime Affairs and Fisheries, 2018) is one of social and economic issues. The decision to move the port or goods terminal must be made, even if economically the port is not feasible. Rahmah, 2020 stated that the results of research during the analysis review period assume for 20 years resulted in an inappropriate benefit cost ratio of 0.23.

A series of coordination meetings, field visits and policy interventions from the Coordinating Ministry for Maritime Affairs and Investment were carried out in order to accelerate the transfer of the port to the designated location, in Wae Kelambu. Based on the Draft Presidential Regulation concerning spatial planning for the national strategic area of the Komodo National Park, the space allocation for the planned multipurpose terminal is a fisheries cultivation zone (Suraji, 2020), so that the precautionary principle and Blue Infrastructure approach are integrated in the development of the multipurpose port/terminal area and its surroundings needs to be implemented.

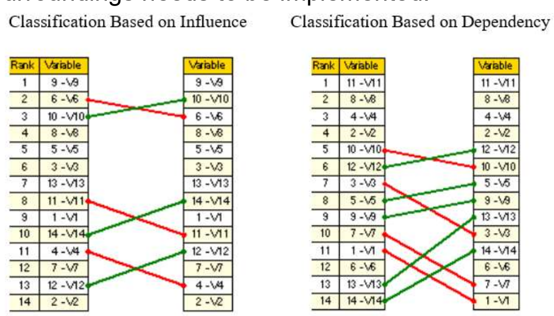

Figure 1. Classification Based on influence/dependent

Figure 1 shows the classification ranking of variables that most influence tourism development in Labuan Bajo, along with the ranking order as follows: Human Resource Capacity Development (V9); Economic Equality between Regions (V6); Down-streaming (V10); Policy and Regulation (V8); and Blue Infrastructure (V5). Meanwhile, Blue Infrastructure (V5) is a prerequisite for the hard systems needed to develop tourism in Labuan Bajo.

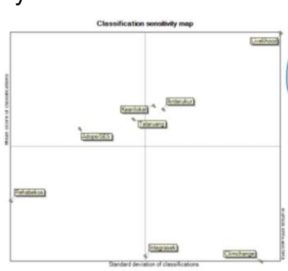

Figure 2: classification sensitivity map

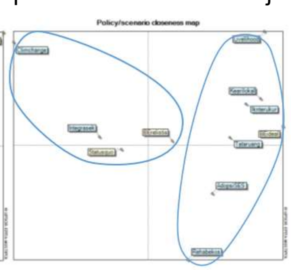

Figure 3: Policy closeness toward scenario

Figure 3 shows that the choice of inter-sector integration policy is the most superior policy in the scenario between the status quo and realistic blue economy E. Based on the sensitivity map classification as shown in Figure 2, the SES Adoption and Spatial Planning policies are determinant policy factors, while the Climate Change Policy and integration between sectors can be supporting in supporting the implementation of the BE Ideal scenario. The BE ideal scenario with 3 (three) policy alternatives, namely Livelihood, Local Government and measurable fisheries, is a policy factor that can be exposed and is a high priority for implementation.

Conclusion

- Policy intervention is an important factor in port relocation and integrated development of blue infrastructure has a strategic role in the blue economy
- Identifying key variables essential for sustainable coastal tourism management, particularly in a newly established coastal tourism destination, is a critical initial step. All variables have a substantial impact, with no minor influences observed.
- A realistic scenario by evaluating the blue economy BE status quo requires integration between sectors, including integration of infrastructure development with the blue infrastructure concept. Integration policies between sectors can ultimately support the development of Labuan Bajo tourism in an ideal blue economy BE scenario.

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Relevant UN SDGs 8, 9, 11, 14.

Multi-Disciplinary Collaboration on Design and Construction of Offshore Marine Centre 2

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Summary
Offshore Marine Centre 2 is a new-build maritime facility in Tuas, Singapore, designed to provide staging and berthing for offshore structures manufacture and maintenance. The designers Arup worked closely with the contractor and client to refine the reference design through innovative technical solutions, which ultimately led to reduced materials, costs, program and embodied carbon impact to the project. Key to the project's success was the excellent culture of collaboration and learning between all parties.

Keywords: Tuas, port design, structural engineering, geotechnical engineering, building services

Introduction

The Offshore Marine Centre 2 (OMC2) in Tuas, Singapore is a Offshore and Marine (O&M) facility that will provide staging and berthing for offshore purposes, including offshore wind farms. Together with the contractor, Penta-Ocean Construction Co. Ltd, and the end client, JTC Corporation (JTC), the designers Arup applied a multi-disciplinary approach to optimise the design and deliver the construction of this facility throughout the COVID-19 period.

Figure 65 Site map showing major components (background photo by Penta-Ocean). Service trenches are in blue.

Arup and Penta-Ocean developed the final scheme from the reference tender design (Figure 65). The prescribed live load on the staging area was 250kN/m^2, to support the heaviest vehicles (Self-Propelled Modular Transports, or SPMTs) and offshore modules. The required draft was -10m Chart Datum.

Design vessels for Berthing

A range of module transportation barges and submersible/semi-submersible vessels were provided in the project brief that could potentially berth at OMC2, in its current specification with a 200m-long wharf, or in a future expanded size at 400m long. We considered the full range of ships expected to service the facility to be designed for, including for vessels that suited the design 'Drill Ship' typology.

Wharf design

The final wharf structural scheme was Contiguous Bored Piles (CBP) with Reinforced Concrete (RC) tie beams and bored piles to act as a tieback structure (Figure 66).

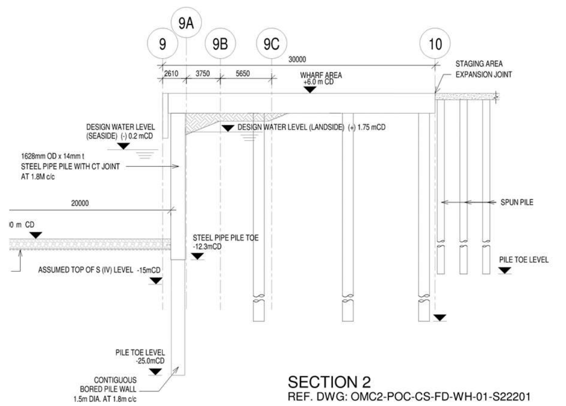

Figure 66 Wharf typical section, showing CBP with tieback structure

To achieve this, we removed the sandbags on the reclaimed revetment, drove the CBP steel casings with C-T interlocking joints into the slope, and then backfilled behind the steel pipe piles to form a construction platform so that we could cast the CBP within the casings. The bored piles were constructed behind, and all were tied together with the CBP capping beam and the tie beams. For an optimised design, the CBP had an asymmetrical steel reinforcement cage, with larger bars near the seaward side, to account for the enveloped high bending moments causing flexure seaward.

The bored pile designs were optimised by taking samples from each pile location during drilling. Pocket penetrometers were used to estimate the SPT-N values, and point load tests were done onsite to confirm the location of the rock layer. This confirmed the actual geotechnical capacity achievable at each pile location.

A precast vertical downhang wall was mounted on the front of the capping beam so that the fenders could be mounted (Figure 67**Error! Reference source not found.**). To allow for seaward deflection of the capping beam due to foundation movement, the downhang wall was connected to a steel H-section which could be bolted onto the top of the capping beam via slotted holes which were provided to assist in the alignment.

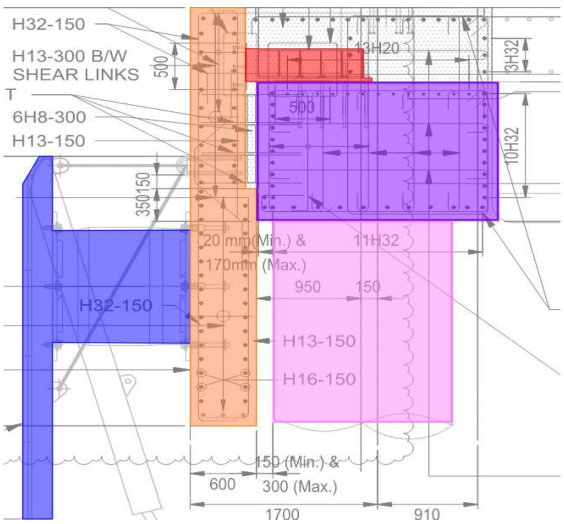

Figure 67 Fender downhang wall (orange) with fender (blue), mounted on H-section (red) that is bolted to the capping beam (purple), which sits on the CBP (pink)

Staging area design optimisation

The tender design for the staging area consisted of an 800mm thick RC flat slab supported on 1m diameter bored piles at 6m centres. Penta-Ocean had a preference to use precast, pretensioned, driven spun piles to improve productivity.

We targeted a reduction in the slab thickness of 100mm to reduce concrete volume by more than 4000m^3 over the ~4.4Ha staging area. The slab concrete used 50% ground granulated blast slag (GGBS) cement replacement, which has a 45% CO_2e reduction compared to 100% Ordinary Portland Cement (OPC).

Reducing the slab thickness reduced the bending and punching shear capacity, and to avoid punching shear reinforcement at each pile head location, an optimised standard design of 600mm diameter spun piles at 2.5m centres was adopted. This design saved cost and time. We set up a web portal for the contractor to input real-time information on the final pile toe levels. Not only did this allow us to monitor piling progress, but the pile toe could also be checked against the design anticipated level, to identify obstructions such as boulders (if the pile toe was too short).

Service trench redesign

Service trenches run underneath the staging area and stacking yard for O&M module fabrication of the entire development to distribute Mechanical and Electrical (M&E) services to each staging plot. In the tender design, the service trench beneath the staging area was completely flat, which did not drain well. There was risk of backwash from the sea entering the service trench (Figure 68). It also conflicted with the staging slab above, leading to areas with insufficient headroom (less than 1400mm).

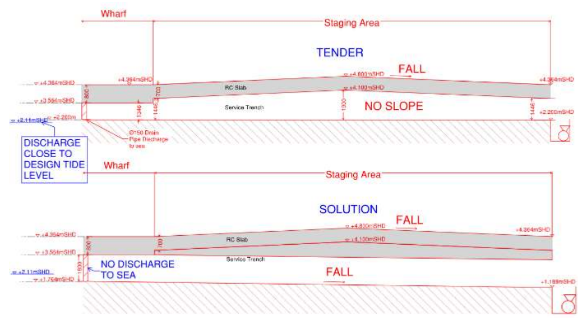

Figure 68 Tender services trench (top) and optimised service trench (bottom), not to scale

We changed the service trench drainage strategy to drain inland and added concrete infill to maintain headroom of 1800mm. This eliminated the backwash issue and provided sufficient headroom for access throughout the length of the trench, without adding to payable Gross Floor Area (GFA) (for headroom areas of more than 1800mm).

Cooperating with contractor

During the COVID-19 pandemic, contractor labour in Singapore was heavily restricted due to government movement controls. JTC lead the implementation of Hubble, their workforce management system, to facilitate productivity monitoring. Digital design was integrated into the workflow of consultant, contractor, and client. A combined BIM model was issued weekly for all disciplines to fly through and deconflict clashes. JTC Optimus was used as a common data platform for speedy and yet rigorous construction approvals.

Conclusion

This project showed multidisciplinary coordination and technical innovation, which was driven by site practicalities. Digital tools were used to improve safety and productivity, while advanced analysis was undertaken to achieve material, carbon, cost, and time savings.

Acknowledgements

The authors acknowledge the help of the ultimate client, JTC, in reviewing the content of this paper.

Relevant UN SDGs (*https://sdgs.un.org/goals*)

8, 9, 13

Resilient Maritime Structures in the Pacific Islands

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Summary
This study outlines a comprehensive approach for designing and upgrading maritime structures in the Pacific Islands. It addresses challenges posed by climate change, seismic threats, and larger vessels. The approach respects local cultural and environmental heritage and employs innovative engineering solutions for resilience and durability. The goal is to create functional, resilient, and sustainable maritime structures that harmonize with their surroundings.

Keywords: Maritime Structures, Pacific Islands, Rehabilitation and Upgrade, Climate Resilience, Seismic Design.

Introduction

The Pacific Islands are at the vanguard of climate resilience, confronting escalating climate change challenges, including rising sea-levels, the need to accommodate increasingly larger vessels, and the rehabilitation and upgrade of aging assets. These islands are susceptible to seismic threats, soil liquefaction, and often face a lack of crucial data, such as geotechnical and hydrodynamic conditions. Strategic foresight and innovative design are essential for the successful improvement of wharf infrastructure. This study outlines strategies to strengthen wharf resilience against seismic disruptions, meet the demands of larger maritime vessels, and overcome the limitations imposed by scarce foundational data. The focus will be on the impacts of climate change, specifically sea-level rise, the adaptation of wharves for larger vessel capacity, and the challenges posed by inadequate data.

Objective

With a history of involvement in the Pacific spanning various sectors, including port developments, Stantec has actively contributed to numerous maritime projects across the Pacific Islands. These projects range from the creation of new infrastructures to the rehabilitation or upgrading of existing facilities. This study aims to address the complex design challenges associated with the development of new wharves or the rehabilitation and upgrade of existing ones within the Pacific Island context. The approach encompasses a review of recent wharf upgrades, an examination of the challenges stemming from changes in original design parameters such as the intensity of seismic events, and an analysis of the potential for soil liquefaction and hydrodynamic forces. The study also investigates the implications of accommodating larger vessels than those for which the original wharves were designed and the strategy for the rehabilitation and upgrades of existing assets.

Main Considerations

Maritime engineering in the Pacific Islands presents a unique set of challenges that require a detailed and comprehensive approach to the design and upgrading of wharves and jetties. The isolation of these locations, along with environmental and logistical constraints, calls for a holistic strategy that considers a broad spectrum of factors. *Site Investigation and Seismic Considerations*: A deep understanding of local conditions is crucial, achievable only through extensive geotechnical and environmental studies. These investigations should explore the region’s seismic history, evaluate the risk of soil liquefaction, and assess its potential impact on marine structures. Given the limitations of empirical data, particular attention should be given to the effects of seismic activity on soil behaviour. The design should consider the effect of additional lateral load on piles due to liquefied soils during a seismic event. The triggering of liquefaction and strain-softening may not be required for depths greater than 15 m below ground level, considering that the empirical relationships developed to date are limited to data to 15m depth of the seabed only. Similar approach has been implemented in the design of a barge ramp in Port Moresby, Papua New Guinea. *Performance-Based Seismic Design (PBD) Approach*: PBD offers several advantages for maritime structures like jetties and wharves over traditional Force-Based Design (FBD). PBD focuses on displacements rather than forces, providing a more accurate prediction of seismic damage and allowing for safety levels tailored to specific performance objectives. This approach can lead to more cost-effective designs by efficiently addressing risk and ensuring economic efficiency. Additionally, PBD offers greater design flexibility and can overcome the limitations of FBD, such as its poor correlation between force and damage, thereby enhancing the overall resilience and reliability of maritime structures during seismic events. This approach has been successfully applied in some recent projects completed by Stantec, such as the design of a new jetty in Vanuatu. *Tsunami Preparedness:* Incorporating tsunami-resistant features is essential to protect against sudden and extreme wave events. This includes the design and implementation of infrastructure that can withstand the force of a tsunami, ensuring the safety and longevity of maritime structures. *Climate Change Adaptation:* Designing for resilience against climate change, including rising sea-levels and increased storm intensity, is crucial. This includes considering the design wave and current. Structures must be resilient to the effects of climate change, as well as seismic events and tsunamis. Incorporating tsunami-resistant features to protect against sudden and extreme wave events is also essential. *Structure Type and Material Selection:* The choice of structural type and materials significantly influences the durability of the structures. Materials must be selected for their resistance to the corrosive tropical salt-spray and other harsh environmental conditions. Incorporating materials that require minimal maintenance not only reduces the long-term costs associated with upkeep but also contributes to the sustainability of the structure. The use of unreinforced precast concrete blocks, similar to the quay wall designed in Nanumaga, Tuvalu Islands, would be a good choice for the construction of quay walls if the geotechnical consideration allows. Wharves with concrete piles, such as the secant pile design in Nauru, are preferred to open wharves with steel piles or sheet pile wharves. All steel piles should be protected by HDPE encasement to extend the design life. Concrete elements should be precast concrete as much as possible because of better quality control. They can also be fabricated and cured in better conditions and then transferred to the project location. The modular design approach, where concrete or steel elements are prefabricated off-site and assembled on location, is particularly advantageous in remote areas, reducing the complexity and environmental impact of construction. *Cultural and Environmental Sensitivity:* The design process must respect the cultural values and environmental heritage of the local communities. Active engagement with these communities to understand their needs and incorporating their feedback into the design ensures that the structures are not only functional but also harmonize with the local context. The design must also consider the ecological impact, employing construction methods that minimize disruption to the marine ecosystem. This approach ensures the long-term viability and sustainability of the structures. *Adaptability and Resilience:* As the size of vessels increases and the needs of the maritime industry evolves, it is essential that wharves are designed with adaptability in mind. This includes the ability to accommodate larger vessels and the flexibility to incorporate future technologies. Cost-Effectiveness: The economic aspect of the design is a crucial consideration. While initial investments in high-quality materials and sustainable practices may be higher, they result in lower maintenance costs and a reduced environmental footprint over the structure's lifespan.

Rehabilitation design and upgrade of existing assets

The rehabilitation and upgrade of maritime structures in the Pacific Islands face challenges due to deteriorating conditions, lack of original seismic design considerations, susceptibility to soil liquefaction, and threats posed by rising sea-levels. These issues are further compounded by resource limitations, logistical difficulties due to remote locations, stringent environmental regulations, and potential socio-economic impacts on local communities. Addressing these challenges requires a comprehensive strategy that includes detailed assessments, innovative engineering, community involvement, and adherence to sustainable practices to enhance the resilience and durability of the maritime infrastructure. Stantec has implemented several innovative approaches in the upgrade design of existing assets, including: *Independent Berthing and Mooring Dolphins*: These mitigate the lateral loads applied to the existing structure, enhancing stability and safety. Additional Tie Rods and Anchoring Piles: Integrated into the existing bulkhead wharf, these elements are designed to withstand increased lateral soil loads during seismic events and facilitate the elevation of the apron level in response to rising sea levels. This method has been successfully employed in the rehabilitation of wharves in Palau and the international wharf in Honiara, Solomon Islands. *Submerged Sheet Pile Structures:* Positioned in front of the existing berth line, this structure enables seabed dredging beyond the original design specifications, accommodating larger vessels. A similar approach was adopted for the wharf design in Kiribati. *Emerging Technologies to Reduce Chloride Ingress*: These technologies are applied to concrete in piles, beams, and deck soffits to prolong the structural integrity. This technique mirrors the one used in the rehabilitation of Suva Wharf in Fiji.

These strategic enhancements aim to improve the longevity and functionality of maritime infrastructure, ensuring they meet contemporary demands and environmental challenges.

Discussion and Conclusion

Discussion: The unique challenges posed by the Pacific Islands' environment necessitate innovative and adaptable solutions for the design and upgrade of maritime structures. The strategies outlined in this study, including performance-based seismic design, the use of high-density polyethylene encasement for steel piles, and the modular design approach, have shown promise in enhancing the resilience and durability of these structures. The successful implementation of these strategies, as evidenced by Stantec's projects, underscores their effectiveness. *Conclusion:* In conclusion, the design and upgrading of maritime structures in the Pacific Islands require a comprehensive, forward-thinking approach that balances engineering excellence, environmental stewardship, and community involvement. By addressing immediate needs and anticipating future challenges, we can create maritime structures that are not only functional and resilient but also harmonious with their surroundings and sustainable for the future. This study serves as a blueprint for achieving these goals, contributing to the broader efforts to enhance climate resilience in the Pacific Islands.

Submerged and emergent revetment concept design of Golden Beach

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Summary
Stantec was engaged to complete concept designs for a 240m long revetment along the Golden Beach. Cyclone Seth also caused the split of Bribie Island and consequently exposed Golden Beach to wave action and changed the current and sediment regime in the lee of Bribie Island. A concept design for a new submerged revetment was required, given the poor condition of the existing revetment. Ciria Rock Manuals and EurOtop 2018 were used for the concept design. The splash zone on the crest was calculated, and a scour protection system was designed.

Keywords: Submerged and emergent breakwater, coastal structure, concept design, Golden Beach

Background

Golden Beach is a coastal suburb of Caloundra in the Sunshine Coast Region, Queensland. It is located within the Caloundra urban centre, directly southwest of the Caloundra CBD. Tropical Cyclone Seth was a tropical cyclone with a track lasting 15 days. The cyclone's significant impacts included severe flooding in southeast Queensland and hazardous surf along the southern Queensland and northern New South Wales coast.

Cyclone Seth also caused the split of Bribie Island. The split, occurring on 2nd January 2022 and through a narrow spit at the northern end of the island, was a result of swells from Cyclone Seth battering the ocean side, and associated high water levels in Pumicestone Passage.

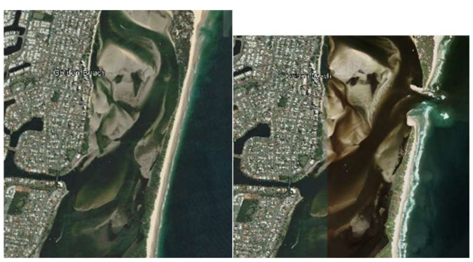

Figure 69 Bribie Island before and after break through

Figure 69(Google Earth) shows Bribie Island prior to (left pic) and post (right pic) the storm event. The split and resulting newly formed tidal channel is considered a natural occurring event [1]. The new channel has changed the wave, current, and sediment regimes in the lee of Bribie Island making the existing coastline and coastal protections more exposed to wave conditions. The new tidal channel is expected to cause damage to the existing coastal protection, increase coastline erosion, increase siltation and inland flooding. Stantec was engaged to conduct a condition assessment and a concept design for a 240m long revetment along the Golden Beach.

Visual Inspection

A visual inspection was conducted by two Stantec engineers. The following failure modes were identified as part of the assessment: Toe flattening, loss of crest elevation, core exposure / voids, slope steepening, slope sliding, armour unit breakage, loss of interlock, drifters / missing armour, function loss and safety risk.
Based on the condition rating provided in WSCAM (Wharf Structures Condition Assessment Manual 2022) the following map was prepared.

Figure 70 Condition assessment rating map

Figure 70 (Stantec's condition assessment report) shows that the existing revetment is in poor condition, and the design of a new revetment would be required.

Concept design

A rubble mound revetment was proposed for the concept design. The metocean data and design parameters were extracted from existing report [2] provided by the client. Table 8 shows the design parameters used for the concept design.

Table 8 Design parameters

Parameter	Description	value
Hs (m)	Significant wave height	1
Tp (s)	Peak wave period	9.8
DWL(m)	Design water level	1.65

The revetment was initially designed to limit the overtopping mean discharge and volume as recommended by EurOtop 2018. However, the crest level needs to be designed to align with the existing natural surface level to minimize the adverse effect on visual amenity.

Natural surface level of the land in some stretches was located almost at the same level or below the design water level. Therefore, a submerged or emergent revetment design was proposed for those sections.
Vidal et al developed a stability formula for rock-armoured statically stable low-crested structures (both emergent and submerged) [3].

$$\frac{H_S}{\Delta D_{n50}} = A + B\frac{R_c}{D_{n50}} + C\left(\frac{R_c}{D_{n5}}\right)^2 \quad (1)$$

where Hs = significant wave height; Rc = crest freeboard; D_{n50} = the median nominal stone diameter and A,B,C = coefficients of the stability curves for initiation of damage.
The range of the rock armour was calculated between 450-750 kg.

Wave runup and mean discharge overtopping and volume were calculated using the formulation in EuroShop [4].

$$\frac{R_{u2\%}}{H_{m0}} = 1.07 \cdot \gamma_f \cdot \gamma_\beta\left(4.0 - \frac{1.5}{\sqrt{\gamma_b \cdot \xi_{m-1,0}}}\right) \quad (2)$$

$$\frac{q}{\sqrt{g \cdot H_{m0}^3}} = 10^{-0.50} \cdot exp\left(\frac{R_c}{\gamma_f \cdot \gamma_\beta \cdot H_{m0} \cdot (0.33+0.022 \cdot \xi_{m-1,0})}\right) \quad (3)$$

where Ru2%= run-up level exceeded by 2% of incident waves, q= mean overtopping discharge per meter structure width, Hm0= significant wave height, $\xi_{m-1,0}$ = surf similarity or Iribarren number, γ_f= surface roughness factor, $\gamma\beta$= oblique wave factor and γb= berm factor.
Based on the overtopping calculation for the low crest revetment the mean overtopping discharge exceeded 100l/s per m and crest of the revetment had to be protected [4].
Therefore, the splash area on the land was calculated using Cox and Machemehl's method [5].

$$L_s = 0.2\Psi\, T\sqrt{g(R_u - R_c)} \quad (4)$$

Where Ψ = importance-of-structure factor; T = wave period(s); R_u = fictitious wave run-up level (m) and R = crest level relative to SWL(m).

From the formulation above the length of the splash area (Ls) estimated about 10m.
In order to design the scour protection behind the revetment, velocity on crest of the revetment was estimated using the formula given in EurOtop 2018 [4].

$$\frac{v_{front}}{\sqrt{gH_{m0}}} = c_u\sqrt{\frac{R_{u\,max}}{H_{m0}}} \quad (5)$$

Where cu = stochastic variable; Ru max = maximum run-up of all waves in a sea state and Hm0 = significant wave height.
The decay of flow velocity along the crest is a function of the distance from the seaward edge [4].

$$v_{2\%}(x_c)/v_{2\%}(x_c = 0) = exp(-1.4x_c/L_{m-1,0}) \quad (6)$$

Where Lm-1,0 = spectral wavelength in deep water
And other parameters shown in the Figure 71.

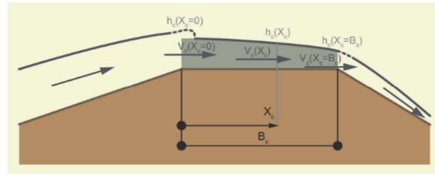

Figure 71 Velocity along the crest of the structure

The Vfront calculated 4.45m/s and reduced to 4.2m/s with a 5m distance from the edge of the crest. Figure 72 illustrates a sample section of the emergent revetment with crest scour protection.

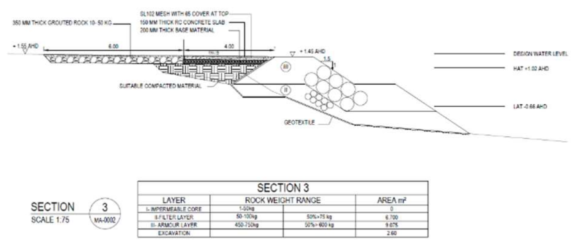

Figure 72 A sample cross-section of the emergent revetment

Discussion and Conclusion

Low-crested structures may be used for protection in areas where wave conditions need to be modified but overtopping is acceptable or where horizontal visibility is a requirement, e.g. for aesthetic purposes [6]. These structures generally allow significant wave overtopping and the erosion behind the structure is a concern. In this abstract paper a case study presented for the low crest revetment and how to deal with the scouring on the crest.

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Enabling Auckland's Transition to a Low-Emission Ferry Fleet

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Summary
As part of their mission to create a transport future for Auckland that is cleaner, quieter and more comfortable for all, Auckland Transport has established the Low Emission Ferry Programme. This ambitious programme will see Auckland have one of the largest low-emission ferry fleets in the Southern Hemisphere by 2030. This case study provides an overview of the programme, across vessel build and infrastructure, and progress to date. It also examines some of the key challenges faced with a particular focus on:

- Navigating uncertainty associated with emerging technology.
- Maintaining timetables and accommodating the vessel mix.
- Delivering landside infrastructure in time for the new vessels.
- Complexities associated with highly developed urban environments.

Keywords: Decarbonisation, CleanEnergy Transition, Electric Ferry, Vessel Charging, Shore Power.

Introduction

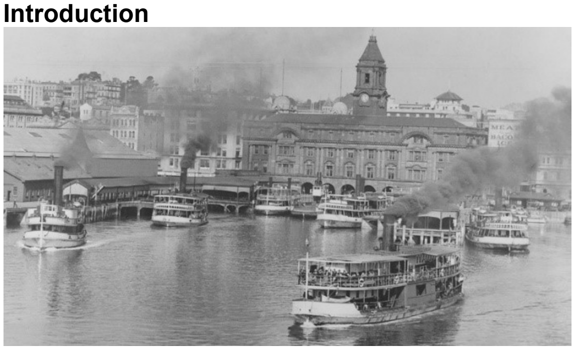

Figure 1 Auckland Ferry Building and wharves 1925 (Source: Auckland Libraries Heritage Collections D-TWF-0002)

Auckland has long relied on ferries as a means of passenger transport across the Waitematā Harbour and today's ferry network plays an important role in Auckland's transport system. It provides critical access to some parts of the region, and modal choice in others, in turn providing a direct and fast access option that delivers transport system capacity and resilience.

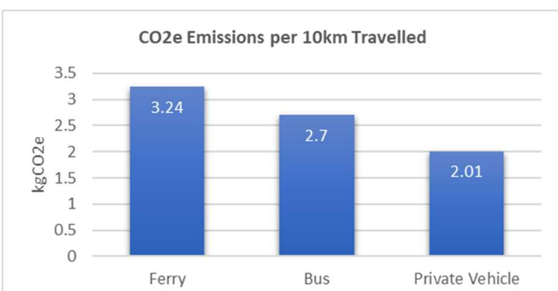

Figure 2 Graph showing the ratio between kilometres travelled and the associated carbon dioxide equivalents (CO2e) emissions for ferry, bus, and private vehicles. (Source: Auckland Transport Ferry Fleet Upgrade and Renewal Single Stage Business Case)

The current ferry fleet is ageing, landside infrastructure requires updating and diesel ferries are carbon-intensive, emitting approximately 20 per cent of Auckland Transport's total greenhouse gas emissions from public transport whilst carrying only six per cent of total passengers.

As part of their mission to create a transport future for Auckland that is cleaner, quieter, and more comfortable for all, Auckland Transport has established the Low Emission Ferry Programme (the Programme) to enable the transition to new low-emission ferries across their network. The Programme will see Auckland become a world leader in this space. By approx. 2030, Auckland is set to have one of the largest low-emission ferry fleets in the Southern Hemisphere.

This case study provides an overview of the programme, across vessel build and landside infrastructure and progress to date. The study also examines some of the key challenges faced by Auckland Transport and its partners in delivering the landside infrastructure required to support the arrival of the new electric and hybrid vessels. In particular, it will focus on:

- Delivering landside infrastructure in time for the new vessels.
- Maintaining timetables and accommodating the vessel mix.
- Navigating uncertainty associated with emerging technology.
- Complexities associated with highly developed urban environments.

Programme Overview

Four electric or electric-hybrid ferries are under construction with the first ferry launching in late 2024, two in 2025, and one in 2026. A pipeline of further ferries continues until the early 2030s. The new low-emission ferries have greater passenger capacity, improved accessibility, and a more consistent customer experience compared to the current fleet.

Figure 3 A visualisation of the new electric ferries which are currently under construction (Source: EV Maritime (www.evmaritime.com))

The Low Emission Ferry Landside Infrastructure Project (the Project) will deliver charging infrastructure and wharf upgrades at up to nine locations on the Auckland ferry network over several stages from 2024 to 2030. These stages are aligned with the staged rollout of battery electric and plug-in hybrid ferries.

Stage 1 of the Project is to provide landside infrastructure at three terminals, being Downtown Ferry Terminal, Hobsonville Point and Half Moon Bay, and is required to be operational by quarter two of 2025 to align with the arrival of the first low-emission ferries that are currently under construction. Further chargers are planned to be installed, in stages, at Downtown Ferry Terminal between 2027 and 2030 with this important location sitting at the heart of Auckland's ferry network.

Key Challenges

In addition to reducing emissions, other key drivers include improving customer experience, passenger accessibility, vessel reliability and efficiency, and providing standardisation where possible. To maintain a rapid turnaround ferry network, it is necessary for the new ferries to obtain a top-up charge at berth while loading and unloading. This requires a fast-charging system which would be difficult to achieve with existing technology. To enable the rapid charging required, Auckland Transport have chosen to select a new high-power charging system, the standardised CharIN Megawatt Charging System (MCS) which is currently under development. With the new standard yet to be fully resolved and few operational examples worldwide, the adoption of this innovative technology presents a number of challenges for the team in terms of electrical design and physical operation.

The tight timescales and emerging nature of the technology has required a collaborative approach to be adopted with consultants, equipment suppliers and contractors working closely with Auckland Transport to develop solutions which can be delivered in time for the arrival of the first vessels. Increased standardisation, modularisation and offsite fabrication have been key outcomes of this collaboration. Electrical specialists have worked with the client team, equipment suppliers and power companies to develop solutions that are able to deliver sufficient power and enable the new fast charging systems. These solutions include staging upstream network upgrades to align with the staged rollout of the new vessels at the Downtown terminal.

Accommodating the range of new vessels required to meet Auckland Transports' needs as well as facilitating the continued use of diesel vessels has also presented a challenge requiring close collaboration between designers and operators. This close collaboration has allowed designs to be developed which meet operational requirements, while maximising the use of existing infrastructure and enhance customer experience where possible.

With several of the terminals being located in highly valued urban or public spaces, finding available space for the critical landside charging infrastructure has also been a significant challenge. The project team have engaged with key stakeholders and mana whenua groups to identify, and come together around, shared values or interests which has enabled us to navigate complex issues relating to operational requirements, land use and community outcomes.

Figure 4 A photo of Queens Wharf and the existing berths at Downtown Ferry Terminal. (Source: Auckland Transport)

Conclusion

The tight timeframes, technological uncertainty and complex urban environments pose significant challenges for the Project and wider Programme. By building a collaborative team that brings knowledge and experience of delivering major infrastructure projects in the local environment and engaging specialist equipment suppliers early, Auckland Transport, are working together with its partners to overcome these challenges and connect the city's people and places with safe, accessible and more sustainable transport choices.

Relevant UN SDGs (*https://sdgs.un.org/goals*)
7,9,11,13.

Advanced LiDAR-UAV Surveying Technology at Patimban Port Development Project

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Summary
This paper reports on initial findings from the improvement process of infrastructure monitoring at Patimban Port using LiDAR-UAV, given the need for a more efficient inspection and management approach for surveying breakwaters and reclamation areas. Test flights and accuracy verification were conducted to assess the feasibility and accuracy of LiDAR surveying. Control points were installed at intervals for comparison with Total Station surveying. The study demonstrated the accuracy of LiDAR surveying, achieving the target accuracy of mean error and RMSE within 10 cm for both horizontal and vertical measurements. It shows that the LiDAR-UAV technology can be a reliable alternative for various monitoring applications in marine construction management.

Keywords: LiDAR-UAV, Surveying, Inspection, Marine Construction Management

1. Introduction

Currently, many construction sites around the world are considering the implementation of Light Detection and Ranging sensors equipped on Unmanned Aerial Vehicle (LiDAR-UAV) for surveying. This advanced LiDAR-UAV technology is expected to replace traditional measurements using Total Station and enable large and distant target areas to be surveyed automatically in a short time. This transition is enhanced by advancement of camera technology in recent years, resulting in the growing precision of LIDAR surveying approaches in the industry. Results from an aerial LiDAR survey around a road area showed that the Root Mean Square Error (RMSE) for levelling measurement on road surface was as small as 5.4 cm and those of non-road ground was 11.3 cm (Mandar K et al. 2020). Similarly, a regular LiDAR-UAV survey on a large reclamation port area revealed a 13 cm vertical error in tracking surface settlement, proving the effectiveness of LiDAR-UAV surveying method for the long-term monitoring in ground improvement operations (Joonghee L et al. 2023).

This study attempts to investigate the implementation of LiDAR surveying in the Patimban Port Construction Project in Indonesia. The port is constructed on a very soft ground with huge reclamation area (Fig. 1). This demands an efficient framework for monitoring the settlement of reclaimed area at a regular time interval to support the maintenance and inspection operations. Additionally, we also aim to apply the LiDAR-UAV surveying technique to survey the settlement of the breakwater located at far offshore, which is difficult to reach out by conventional levelling survey (i.e., by Total Station) (Fig 1). Therefore, in this study, as a preparatory survey step, the accuracy and optimum survey conditions (flight attitude, control points arrangement) of LiDAR-UAV was validated against a conventional survey using Total Station.

2. Study Location

Patimban Port is an artificial island-type port located 1 km offshore of Subang coast in the Republic of Indonesia with an estimated total site area of 300 ha after completion. Phase 1-1 of the project which comprises a car terminal, a container terminal, a seawall, and a breakwater bounding for the port have been completed in 2021. Reclamation work on the Phase 1-2 car terminal and container terminal is ongoing (highlighted by yellow shade area in Fig 1). Settlement monitoring of breakwater is not continued since Jan 2023 due to the damage of settlement benchmarks. However, it is still being visually inspected on site once a month.

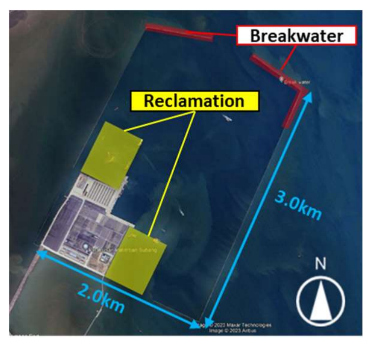

Figure 73 Patimban Port in Indonesia

3. Materials and Method

Table 1 shows the equipment list utilized in survey and Figure 2 shows the work flowchart of LiDAR-UAV implementation.

Table 9 Equipment list

Item	Name
UAV	Matrice 300 RTK
LiDAR Camera	ZENMUSE L1
Mobile Station	D-RTK2
Total Station	KOLIDA / KTS 442R6LC

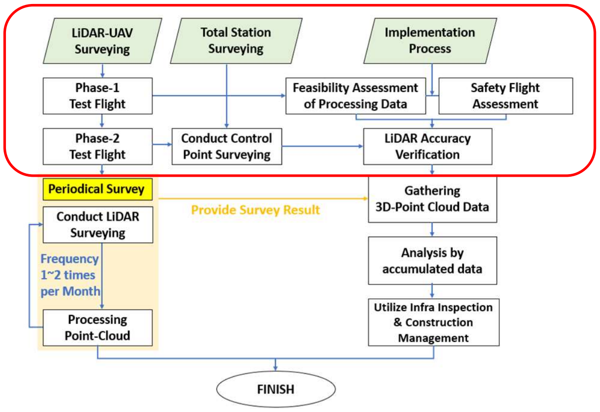

Figure 74 Flowchart of LiDAR drone implementation

3.1. Survey work and data processing

We conducted LiDAR survey and Total Station survey for accuracy verification in the South Seawall area of Patimban Port. Control points (10 pieces of square shaped with 62 cm per side) were strategically placed at 50 m intervals for comparison purpose (Fig 3). The primary objective was to find the optimum flight conditions (altitude and speed) to align with a target accuracy of within 10 cm for both horizontal and vertical measurements with reference to "Public surveying - working rules and regulations of Japan" (MLIT, 2023). Trial flights (results not discussed here) suggest that a flight speed of no more than 2.5 m/s can maintain an overlap ratio of more than 80% as recommended by Japanese Standard. Therefore, in this report, we only investigate the dependence of survey accuracy on flight altitude (Table 2). Processing and evaluation of 3D points cloud data captured by LiDAR was carried out by using DJI TERRA software in which the center of each control point was detected, and the respective elevation data was extracted. Total Station surveying was carried out using PP1 as the reference point and single-store surveying from P1 to P10.

Figure 75 Control points arrangement

Table 10 UAV Flight Conditions

Item	Option 1	Option 2
Flight Altitude (m)	50	80
Flight Speed (m/s)	2.5	2.5
Overlap Ratio (%)	80	80

4. Results

Table 3 shows the survey accuracy of LiDAR against Total Station measurements. The results validate the effectiveness of LiDAR, minimizing the target errors (i.e., mean error and RMSE within 10 cm) for both horizontal and vertical measurements. In particular, the vertical accuracy is high, with both the mean error and RMSE being around 1~3 cm. It is also found that flight altitude might affects the accuracy of the point cloud and that an altitude of 50 m is optimal for construction site scale surveys when higher accuracy is required.

Table 11 LiDAR-UAV vs. Total Station survey accuracy

	Altitude (m)	x	y	z
Mean error	50	4.4	3.4	1.7
	80	4.0	5.9	2.3
RMSE	50	4.9	4.2	1.8
	80	4.5	6.3	2.7
			Unit: cm	

As shown in Figure 4, the elevation (z) errors for all points are within 5 cm absolute value, regardless of the distance between the reference and verification points. This suggests that accuracy is maintained even when surveying at remote locations.
In conclusion, LiDAR-UAV survey proves to be a reliable and time-saving alternative for levelling survey, which can be applicable for settlement monitoring in the marine construction work. Settlement monitoring of breakwater and reclamation works are therefore scheduled to be implemented in the next phase of our study.

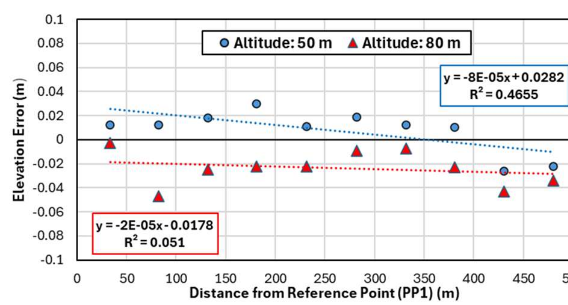

Figure 76 Relation between distance from reference point and error values

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Revolutionizing Maritime Engineering and Navigation through Advanced Data Intelligence and Artificial Intelligence Applications

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Summary

Our research leads the integration of Data Intelligence (DI) and Artificial Intelligence (AI) in the maritime industry, enhancing navigation and operational processes. Our innovations, including the Live Under Keel Clearance (LiveUKC) system and advancements in hydrodynamic predictions, leverage real-time data and advanced algorithms to improve safety and performance. By employing techniques like reinforcement learning, Recursive Least Squares, and data assimilation, we significantly enhance the precision of vessel motion predictions. Our efforts chart a course towards a more intelligent maritime horizon, emphasizing the significant role of Data Intelligence and Artificial Intelligence in enhancing maritime practices.
Keywords: Data Intelligence, Artificial Intelligence, Live UKC, Navigational Safety, Vessel Behaviour

Introduction

The maritime industry, essential for global trade, is on the edge of a big change. The maritime industry is shifting from traditional methods to modern problem-solving with Data Intelligence (DI) and Artificial Intelligence (AI). These technologies are making operations more efficient, safer, and better for the environment.

In this shift, our research and development efforts, supported by a series of collaborative projects and internal advancements within our Data Intelligence AI team, have been leading the way. Leveraging DI and AI alongside real data, machine learning, and analytics, we have tackled numerous navigational and operational challenges. Our innovative solutions not only enhance decision-making but also significantly improve safety and performance in navigation.

As the maritime industry moves to a future where data and technology play a bigger role, the importance of these advanced technologies is clearer than ever. Our Live Under Keel Clearance (LiveUKC) system is an example of how far we've come. It analyzes real-time vessel movement data to accurately determine essential navigational parameters. With AI, this system is part of our push to make maritime operations safer, more efficient, and driven by data.

Our published works lay the foundation for the Live DUKC system, addressing various challenges in ship motion prediction and illustrating the potential of DI and AI in modernizing maritime navigation and port management. This paper aims to showcase our leading contributions, demonstrating significant advancements towards a more efficient, safe, and intelligent maritime future.

Advances in Hydrodynamic Prediction through DI and AI

Our journey towards improved accuracy in predicting vessel movements involves combining advanced data intelligence and AI techniques. Our latest research highlights how these technologies can automate and refine the calculation of crucial hydrodynamic parameters, essential for maritime operations.

- **Reinforcement Learning for Motion Equation Parameters**

Our initial study presented at MASHCON-2020, Ostend, introduced the application of reinforcement learning to the intricate challenge of determining roll damping and restoring parameters, crucial for the precise prediction of vessel roll motions [1]. Utilizing real-world operational data, our methodology fine-tuned the estimation of these parameters, illustrating the adaptability of reinforcement learning to complex, nonlinear system behaviors.

Our work presented at ISOPE-2020 extended the application of reinforcement learning for identifying the coupled heave-pitch motion parameters from sea response data [2]. By utilizing measured sea response data, we could accurately determine the direct and cross-coupling damping and restoring parameters.

These advancements contribute substantially to the enhancement of safety and operational efficiency in maritime navigation by providing an improved understanding and modeling of ship dynamics across different motion axes and under various sea conditions.

- **Recursive Least Squares for Center of Gravity Estimation**

The LiveUKC system exemplifies our efforts in refining maritime operations, leveraging AI and real-time data for Exceptional accuracy in navigational parameters estimation. A key feature of this system is our innovative application of the Recursive Least Squares (RLS) algorithm, which automates the estimation of vessels' longitudinal and vertical centers of gravity from wave-induced motions, as highlighted in our recent work [3]. This approach allows for the decomposition of measured data and the precise calculation of vertical displacement motions (heave). By leveraging local tangential accelerations and the angular velocities captured by IMUs on full-scale vessels, our methodology efficiently estimates the distance between the IMU's location and the vessel's Center of Gravity (CoG). By automating data processing and removing the need for manual input and specific location data, we significantly boost operational safety and efficiency.

- **Regression Techniques for Hydrodynamic Parameters**

Building on our collaborative research efforts [4], we have furthered the utilization of regression techniques to automate the estimation of critical hydrodynamic characteristics, such as the radius of gyration and metacentric height. Leveraging real measurement data, this approach enhances our understanding of vessel stability and response under a variety of sea conditions.

- **Enhancing Vessel Motion and Squat Prediction Accuracy with Data Assimilation**

The integration of data assimilation techniques marks a pivotal advancement in improving the accuracy of vessel motion and squat predictions. This approach leverages the accessibility of live vessel motion data, facilitated by technological advancements such as iHeave, to refine prediction models. Data assimilation uniquely combines real-time measurements with simulation forecasts, optimizing prediction accuracy by continuously updating the model with new observations.

This method follows a sequential process where a model forecast is aligned with new data, adjusting the model's parameters to better reflect current conditions, and generating an updated forecast. The iterative nature of this process benefits from live data, enabling adjustments to models in real time to reflect actual maritime conditions accurately.

Addressing Uncertainties in Ship Motion Predictions

Each study adds to our ongoing effort to make ship motion predictions more reliable. We've used a range of DI and AI methods, including reinforcement learning, and regression, to accurately estimate hydrodynamic parameters, whether they're linear, nonlinear, coupled, or uncoupled. Integrating these with data assimilation in the Live UKC system, showing how our research directly improves practical applications.

Conclusion: Steering Towards an Intelligent Maritime Future

This collection of works signifies a substantial leap forward in integrating data intelligence and artificial intelligence within the maritime industry. Our investigations, ranging from real-world data application to advanced algorithmic solutions, highlight our role as pioneers in the field. The creation of the Live UKC system, a result of our teamwork and in-house progress, showcases our dedication to pioneering new solutions. It's a key part of moving toward more precise, efficient, and safer ways of navigating and managing ports.

As we navigate the complexities of maritime engineering and operations, combining AI with real-time data analysis becomes essential for the future. Our progress up to now sets a strong base, but it's what lies ahead that's truly exciting. Through continued research and development, we plan to introduce innovative data intelligence AI services that will set new standards for maritime safety and efficiency. Our work and discoveries serve as a guide, leading the industry to a future where smart technology and maritime know-how merge to offer precise navigational solutions.

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Utilising Tsunami and Shelf Wave Forcing to Investigate Seiche in NSW Harbours

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Summary

Coastal harbours are often subject to periodic water level and current speed oscillations ('seiche') in the order of 1 minute and longer. These oscillations can impede harbour operations by causing vessels to surge and sway at their berth, strain or break mooring lines, or cause other damage through overtopping or scour. The theoretical estimates for oscillation periods have not always matched the measured values. This paper uses the forcing due to three recent tsunamis (2022-2023) and thirty shelf wave records (1993-2017) to investigate seiche behaviour in NSW harbours due to the traditional forcing by bounded waves, surf beat, and relatively recently investigated tsunami and continental shelf waves. Some of the successes and difficulties encountered in reconciling theoretical results and results from physical, numerical model simulations and measured seiche in the field are discussed in this paper.

***Keywords**: seiche, tsunami, continental shelf wave forcing functions.*

Introduction

Harbours known to seiche typically require investigations utilising both physical and numerical models to minimise or mitigate adverse impacts by any proposed development that may alter the resonant characteristics of the harbour or its response to incident forcing functions. Manly Hydraulics Laboratory (MHL) has for over two decades recorded seiche or infra gravity wave (>30s) activity from time to time at all the NSW harbours, but particularly at Coffs, Crowdy Head and Ulladulla. Recent proposed developments in these harbours have resulted in investigations (using both physical and numerical models) into harbour response to forcing functions that result in seiche at these harbours to minimise impacts on the proposed development. Proposed developments and damage during the June 2016 east coast storm (**Figures 3a and 3b**) have resulted in MHL investigating the problems caused by seiche in the Coffs [1], Ulladulla and Crowdy Head harbours.

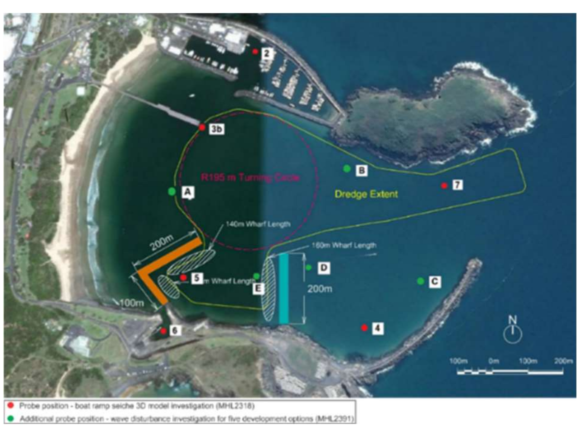

Figure 1 indicates the layout of a 1:58 scale 3D model used to successfully model strategies to reduce disturbance in the Coffs Harbour boat ramp caused by seiche.

Figure 1 Layout of 3D basin for Coffs harbour indicating proposed developments and wave probe positions.

Figures 2a and **2b** indicate disturbances in Coffs Harbour due to tsunami (1-2 days) and continental shelf wave (5-21 days) forcing mechanisms.

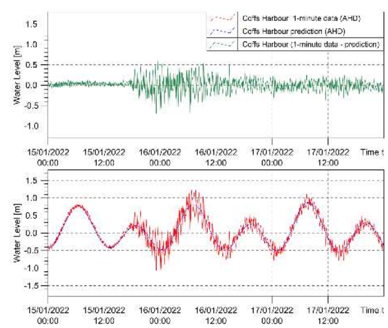

Figure 2a Disturbances in Coffs Harbour due to a 2-day tsunami forcing a 105s–130s seiche

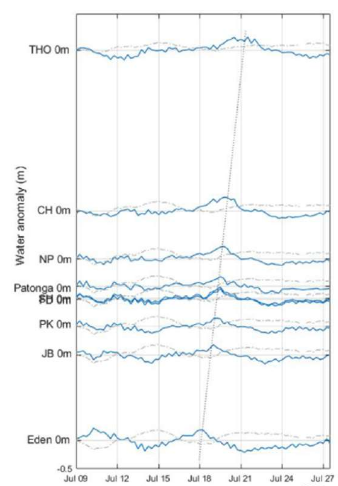

Figure 2b Observed tidal residuals from Eden to the Tweed, including Coffs Harbour (CH), exhibiting the propagation of a continental shelf wave (CSW) (Viola, 2017)

Figures 3a and 3b Damage at Crowdy Head harbour jetties due to seiche activity during the June 2016 storm

Historic field data

Figure 4 and **Table 1** indicate historic data collected at the Crowdy Head and Coffs harbours over the last two decades. Seiche period estimates using Bessel functions to arrive at oscillation periods for a circular harbour, such as Crowdy Head (50s-60s), differ greatly from the historic data collected at the harbour (**Figure 4**), which alternatively indicate 200s-230s.

This data (along with data from Coffs Harbour) was utilised to simulate seiche both physically and numerically in these three harbours to evaluate proposed development strategies. MHL proposes to provide results that will further elaborate the investigation into these critical seiche periods and their related forcing functions.

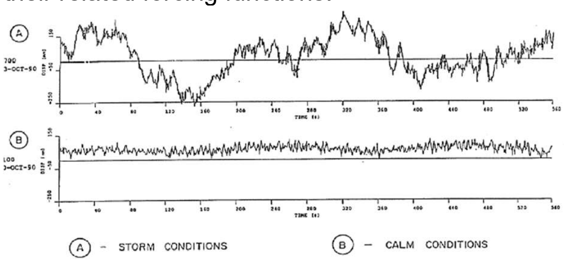

Figure 4 Historic data on 200s–230s seiche collected at Crowdy Head Harbour

Table 1 Historic seiche amplitudes and periods in Coffs Harbour

Date	Time	H_S	H_{max}	T_{P1}	T_{P2}
09/02/1988	22:00	0.53	0.99	712	109
15/05/1990	08:00	0.49	0.82	712	132
26/04/1989	18:00	0.40	0.62	712	109
23/10/1992	18:00	0.49	0.94	712	66

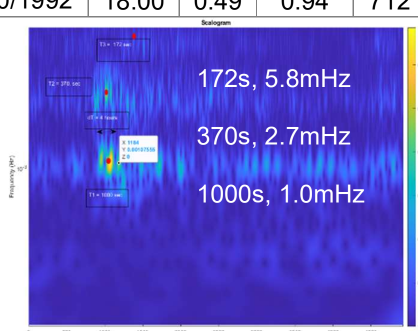

Figure 5 Morse wavelet analysis of tsunami (2023) forcing at Coffs Harbour

Results from utilising the Morse, Morlet and Bump wavelets will be discussed in this paper.

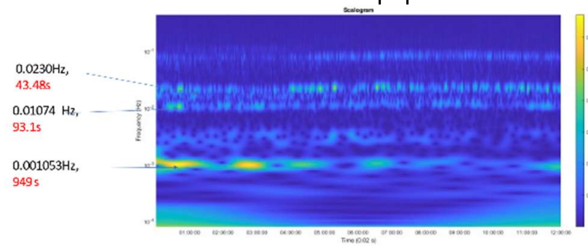

Figure 6 Morse wavelet analysis of shelf wave (22 August 2017) forcing at Coffs Harbour

Summary

This paper will elaborate on the following:

- the simulation of recorded seiche periods both numerically and physically in three recreational harbours in NSW,
- the simulation of seiche periods using short wave spectra in Coffs harbour thereby identifying and relating forcing by bounded long waves and surf beat to recorded specific seiche events,
- the comparison of oscillation periods obtained by Fourier analysis, Physical model forcing by bounded waves and surf beat in Coffs Harbour with periods obtained by wavelet analysis of tsunami forcing (<2 days) and Continental Shelf Forcing (6-18) days,
- the determination of analytical methods of identifying modes and seiche frequencies both in rectangular (Coffs) and circular (Crowdy Head) harbours,
- the ramifications of accurate seiche simulation to the estimation of vessel movement at specified berths in a recreational harbour and the reduction of related mooring forces for the proposed development in these harbours.

References

[1] Jayewardene, IFW Couriel E, Light O, Kulmar M, 2016, *Simulating Long Waves in a Coffs Harbour 3D Physical Model Using Short Wave Spectra*, Journal of Shipping and Ocean Engineering 6 (2016) 15-21

[2] Kofoed-Hansen, H, Kerper, DR and Kirkegaard, J, 2005, *Simulation of Long Wave Agitation in Ports and Harbours Using a Time Domain Boussinesq Model*, Proceedings from Fifth International Symposium on Ocean Wave Measurement and Analysis, WAVES 2005, Madrid, Spain

[3] Viola, C, 2017, *Spatio-temporal Variability of Tidal Residuals along the New South Wales Coast driven by Climate and Synoptic Processes*, PhD Thesis, University of Newcastle, Australia

Tropical Cyclone Modelling to Determine Defensible Design Conditions

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Summary

Tropical cyclones (TCs) affecting the Western Australian coastline have potential to become more severe and to move southwards due to changing climate. The corresponding impacts need to be included to obtain defensible design conditions for coastal designs. This extended abstract presents the assessment of design conditions for the Drummond Cove coastline by simulating selected historical cyclones and potential future cyclones. The study indicated that the potential future cyclones result in increases of cyclonic water levels and significant wave heights at Drummond Cove by approximately 40% and 14%, respectively compared to the selected historical cyclones.

Keywords: changing climate, tropical cyclones, design conditions, extreme value analysis, Drummond Cove

Introduction

The northwest coastline of Western Australia, especially the coastal stretch between Broome and Exmouth experiences frequent TCs during the TC season that usually ranges between November and April. Although the TCs activities in the mid-west coastal region are less frequent, there is potential for TCs to move southwards and to become more severe due to changing climate. Therefore, understanding of impacts of TCs driven by changing climate is critical to obtain defensible design parameters.

One of the industry practices for the assessment of wind, wave, water level and current conditions due to TCs is the Monte Carlo simulation method that simulates many artificial cyclone events. However, this method requires adopting a coarse model resolution due to extensive numerical modelling required and has limitation in predicting the extreme conditions for nearshore areas. Seashore Engineering (2018) developed design storms for the Western Australian coastal sites by modifying one selected nearby cyclone event for each site. This method is only suitable for preliminary designs.

This extended abstract presents the assessment of cyclonic water level and wave conditions at the Drummond Cove coastline, which is located 12 km north of Geraldton in Western Australia, by numerically simulating selected historical and potential future TCs in the area. A fine resolution mesh was applied for the nearshore project area to obtain sufficiently accurate design conditions for the concept design stage.

Methodology

MIKE 21 coupled Hydrodynamic Flow (HD FM) module and Spectral Wave (SW) module were applied to simulate selected historical and potential future cyclones as follows:

- Nine selected historical cyclones that occurred within 500 km radius of the project site (Bureau of Meteorology);
- Seashore Engineering (2018) design cyclone;
- Selected nine historical cyclones with 0.4 m Sea Level Rise (SLR), which represents the expected SLR by 2073 (‘future cyclones’); and
- Sensitivity testing by simulating modified cyclones by increasing the intensity and/or shifting the tracks while including SLR (‘modified future cyclones’).

Figure 77 presents the paths of the selected historical cyclones and the Seashore Engineering (2018) design cyclone.

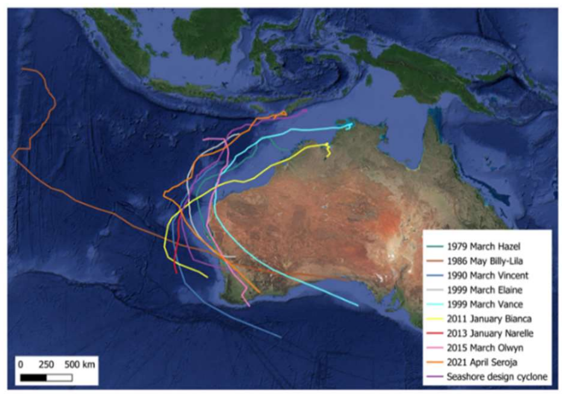

Figure 77 Selected historical TCs and the Seashore Engineering (2018) design cyclone for Geraldton

The model domain, mesh and bathymetry are shown in Figure 78 . The model domain extends from Cowaramup to the south to the Withnell Point (Dirk Hartog Island) to the North and to a seabed level of approximately -5,600 m Lowest Astronomical Tide (m LAT) offshore. The model mesh provides coarse resolution offshore (10 km) to allow for efficient computation time, while near Drummond Cove, the resolution is higher (20 m) to accurately model water levels and wave conditions for the area.

The main driving forces for both HD and SW modules are tropical cyclone pressure and wind conditions. Corresponding maps were generated for the area affected by the cyclone using the MIKE 21 tool and merged with ambient wind conditions from

NOAA NCEP Climate Forecast System Reanalysis (CFSR) for the remaining area.

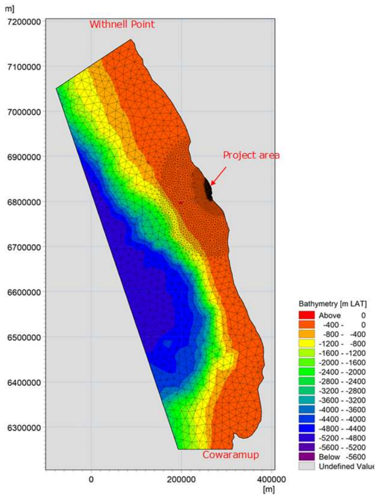

Figure 78 Model domain, mesh and bathymetry

The model was calibrated and validated using measured water level (WL) and wave conditions near Geraldton for TC Bianca (January 2011) and TC Narelle (January 2013). Visual comparisons as well as statistics that included Index of Agreement (IOA), Root Mean Square Error (RMSE) and Bias were used to assess the model performance.

Extreme Value Analysis (EVA) was performed to estimate extreme water levels and significant wave heights (H_s) for different Average Return Intervals (ARIs) by fitting Gumbell and Weibull distributions for different historical and 'future cyclones'.

Results

Visual comparisons as well as model performance statistics showed good agreement between modelled and measured water levels and wave parameters ensuring well calibrated and validated model. An example plot of model calibration in terms of water levels is presented in Figure 79.

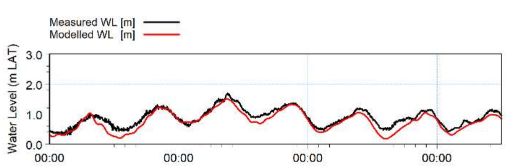

Figure 79 Comparison of measured water level and modelled water level for TC Bianca

Peak water level and peak significant wave heights at the project location from the simulated cyclones were extracted. The results indicated that the peak water levels and peak significant wave heights from 'future cyclones' were increased by approximately 30% and 7%, respectively compared to those from historical cyclones. Corresponding increase from 'historical cyclones' to 'modified future cyclones' were approximately 40% and 14%, respectively. These values represent the average increases at the project location from the simulated cyclones.

Figure 80 presents an example plot of EVA results for peak significant wave heights for historical cyclones and 'future cyclones' that indicates increase of extreme significant wave heights within the range of 6% to 10% for different ARIs from historical cyclones to 'future cyclones. Similar analysis conducted for peak water levels indicated increase in extreme water levels within the range of 13% to 26% for different ARIs.

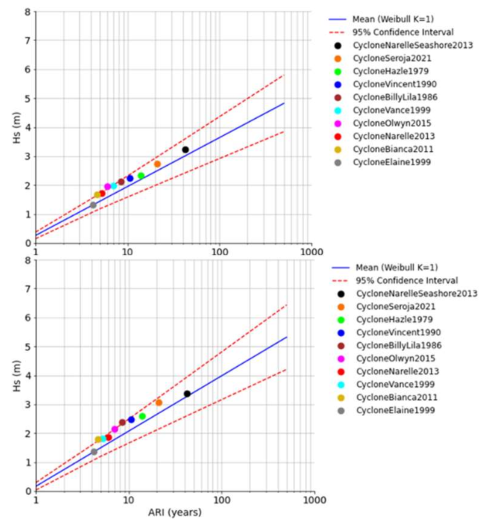

Figure 80 EVA of peak significant wave heights for different historical (top) and 'future cyclones' (bottom)

Conclusions

Cyclonic design conditions for Drummond Cove were assessed by simulating historical as well as future potential cyclones driven by changing climate that provides defensible design parameters for the coastline at the concept design stage. The study indicated that likely modifications to cyclones due to changing climate result in increase of cyclonic water levels and significant wave heights at Drummond Cove by approximately 40% and 14%, respectively. It should be noted that the extreme water levels and wave conditions were derived under cyclonic conditions only (excluding the thunderstorm events), therefore, results for low ARIs (eg., less than 10 year ARI) may not be valid.

References

[1] Seashore Engineering (2018), Design Storms for Western Australian Coastal Planning, Tropical Cyclones. Report No. SE015-01-RevB.

[2] Young and Sobey (1980), A predictive Model of Tropical Cyclone Wind-Waves. 7th Australasian Hydraulics and Fluid Mechanics Conference, (18-22 August 1980, Brisbane), pp 480-483.

Relevant UN SDGs 11, 13

Snapback Characterization for Arresting Structure Design: Physical Testing Insights

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Summary

Mooring line Snapback transfers substantial kinetic energy to impacted structures, yet crucial variables of these impacts which influence arresting structure performance are under-defined. This paper emphasises the need to comprehend these characteristics, for effective design. Previous testing undertaken by Holmes Solutions [1] explored mooring line behaviour during impact events, refining theory and closing knowledge gaps. The research aims to describe critical behaviours to inform future design, thereby mitigating risks in maritime operations and enhancing safety, productivity, and mooring efficiency.

Keywords: Snapback, mooring lines, life safety, ports, arresting structures

Introduction

Assessing the impact severity resulting from a snapback event poses a multifaceted challenge. Various factors contribute to the magnitude and characteristics of these impacts, including the mooring line material, composition, and manufacturer, rupture location, breaking tension, and trajectory. Additionally, the way the line fails, often influenced by the mooring configuration, heavily influences the nature of the impact event. Sweeping failures (ref. Figure 1), prevalent in spring or breast lines, often travel along a three-dimensional trajectory, generating complex side-swiping impact events and unpredictable hazard zones, over expansive areas. This is discussed by Butler J, [2]. Meanwhile, direct line failures in head lines or stern lines often travel along a two-dimensional trajectory, at least initially, following the path of the moored line toward their termination point and generating concentrated impact events within confined areas. However, if the ruptured line collides with obstacles in its path, deflects off a surface, or is propelled off accumulated ruptured rope at the termination point, it can suddenly shift into a three-dimensional trajectory, resulting in impacts and hazard zones more like a sweeping failure.

Relying solely on conventional methodologies and parameters to gauge impact severity, risks oversimplification of the event, and may lead to ineffective arresting structures. For instance, the mere consideration of the weight and velocity of the tail section, or the deceleration of a ruptured line alone, fails to provide a comprehensive understanding of the impact dynamics. This approach, relying on analogies from neighbouring industries, may overlook crucial factors, potentially leading to inaccurate assumptions regarding the severity of impacts that result in over-engineered structures or unforeseen failures [3].

Even if a mooring line fails to penetrate an arresting structure, any resulting debris can pose a significant danger; a small metal segment broken from a structure due to an impact with a ruptured mooring line can travel at exceptionally high speeds. Examples below that were observed in testing illustrate the weight and velocities of debris from a broken structure (Table 1). A .22LR rifle projectile is included for comparison.

Table 1: Recorded Snapback debris - max velocity, weight and max energy [4]

Debris Code	Max Velocity (m/s)	Weight (g)	Max Energy (J)
1	57.7	53	88.3
2	152.5	46	534.9
3	143.7	52	536.9
4	76.6	38.5	113.0
5	110.5	101.5	619.7
6	67.7	46.0	105.5
.22LR Projectile	330.0	2.6	163.0

Moreover, while the instinct may be to design structures with unlimited strength and size to withstand any snapback event, practical considerations within environments such as commercial terminals, operating ports, offshore platforms, and vessels, present significant challenges. These constraints include the need to maintain visibility, allowing for personnel movement, limited space for installation, capacity restrictions, the need for quick installation to keep operations running, limited access for heavy equipment during installation, and dealing with harsh metocean conditions.

Distinct Loading events

When assessing the impact of a mooring line tail on an arresting structure, it is essential to recognise three distinct loading events (ref. Figure 1):

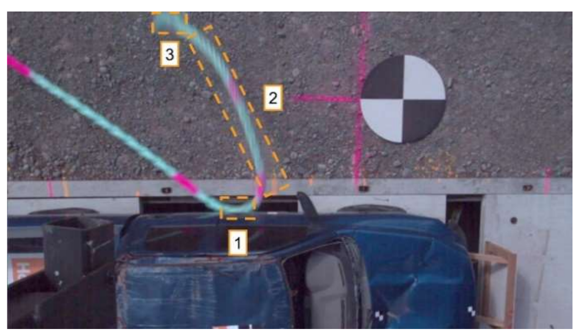

Figure 1: Distinct loading events during a snapback [4]

1. Elbow Impact: Initially, the mooring line elbow strikes the barrier, covering a length of approximately 300 mm.
2. Tail Impact: Subsequently, the tail of the mooring line exerts sustained loading on the barrier, with

the specific contact length dependent on length and trajectory of the tail.

3. Tip Impact: Finally, the tip of the mooring line makes contact, covering a length of around 200 mm.

Key Impact Characteristics

These distinct events vary in characteristics such as speed and impact location. Their sequential occurrence and diverse properties can lead to different loading patterns on the arresting structure. The performance of the arresting structure is heavily dependent on variations in these characteristics. Specifically:

1. Velocity of each critical impact event

When a mooring line fails under tension, it behaves like a series of stretched springs suddenly allowed to contract. As the line accelerates (due to force applied by the tension at rupture), its momentum, represented by:

$$p = mv \qquad (1)$$

Where p = momentum, m =mass, and v = velocity. p remains constant if there is no net external force acting on it (Newton's 2nd law). Considering mass, only the impacting tail section (measured from elbow to tip) matters. In sweeping failures, this section reduces in size as the line unravels like a whip, causing velocity to increase, until impact (conservation of momentum). Even when the elbow impacts the arresting structure, the velocity of the tip may continue to increase. (ref. Figure 2):

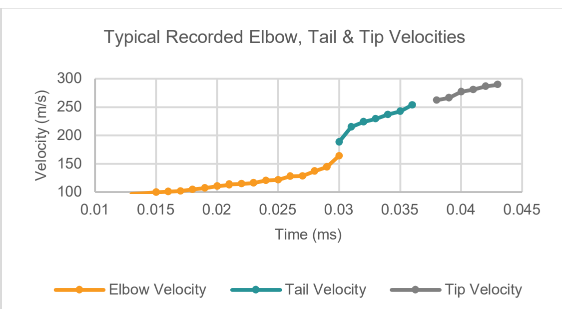

Figure 2: Recorded elbow Vs. tip velocity at arresting structure [4]

2. Duration between critical impact events

When struck by a ruptured mooring line, arresting structures face limited reaction time compared to traditional energy-absorbing designs. Snapback impacts occur rapidly, causing immediate changes in material states like strain hardening. This quick impact, akin to a bullet, can lead to penetration or rupture of the barrier and release of dangerous debris. The double impact of the elbow followed by the tip further heightens this risk, with shorter durations between events increasing the danger. Short tails result in rapid, high-loading impact events of millisecond duration, while longer tails result in more sustained loads (ref. Figure 3):

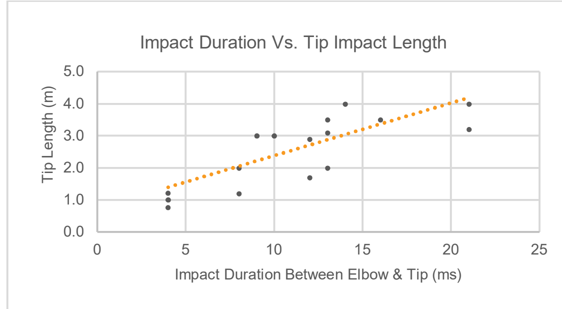

Figure 3: Impact duration between elbow and tip Vs. tip impact length [4]

3. Position of critical impact events

When a mooring line tail collides with an arresting structure, the positioning of each impact event may vary, leading to differing loading points. The overall impact size is a composite of the positions and sizes of all impact events—the elbow, tail and tip. The location of the initial impact (elbow) is determined by previously discussed variables. Conversely, the size and location of the second and third impact events depend on the tail's length and trajectory. A shorter tail leads to the tip impacting closer to the initial impact point. The tip's impact position on the structure may deviate to the left, right, or even overlap with the initial impact location in a smaller overall impact area and heightened concentrated loads. The successive impact events elevate the risk of material failure, as the impacted area is already stressed and damaged from the initial impact and may already be approaching capacity. Particularly, if the second tip impact occurs near the weakened area from the first event, compounded by shorter durations between impact events due to the truncated tail, it increases the likelihood of catastrophic failure.

Conclusion

Effective design of arresting structures to mitigate Snapback risks requires a comprehensive understanding of Snapback characteristics and their impact on structures. By identifying distinct loading events and considering practical constraints, this paper lays the foundation for developing practical solutions to enhance personnel safety and operational efficiency in maritime operations.

Acknowledgements

Holmes would like to acknowledge the team at BMA and Geobrugg for their input and collaboration.

References

[1] Hodgins K, (2023) Validating Snapback Risk. pp.1.

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[3] Smith A.S, (2021) BHP Mitsubishi Alliance Snapback Barrier System Validation Testing. pp.1.

[4] Keane R, (2024) BHP Mitsubishi Alliance Hay Point Ships Line Protection – Phase 2. pp.1-2.

Relevant UN SDGs

5 Understanding Marine Snapback Events **(https://www.youtube.com/watch?v=eXaDSO-a3lc)**

Automation, Technological and Digital Advancements to drive Decarbonisation.

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Summary

The aim of this paper is to highlight operational enhancements pivotal to the decarbonization of ports, this is achieved through the correct utilization of mooring automation, technological advancements, and digital innovations. These insights originate from first-hand data gathered throughout a working term within a towage operation spanning a 2-year period. This dataset encompasses measurements of tug fuel consumption, average durations for vessel berthing and sailings, and an examination of port logistics. Notable findings demonstrate a remarkable annual reduction in tug fuel consumption and CO_2 emissions, plus a time saving that directly contributes to more efficient throughput of vessels in a busy port.

Introduction

This paper presents a comprehensive analysis of the reduction in tug fuel consumption achieved through time savings facilitated by automated vacuum mooring systems for vessel berthing and sailing. Additionally, it delves into the advancements in automation and technology that are currently enhancing the efficiency of vessel berthing and sailing operations. These advancements include the utilization of machine learning to optimize equipment operation during the product transfer phase, and automated technologies for equipment preparation and berthing procedures. This paper is based solely on factual data, there is no speculation regarding fuel usage, mooring times, or the systems and technologies employed.

The study is centred around an Australian port in the state of Victoria subject to tidal constraints and navigation through a narrow channel with limited passing options. Fuel consumption data referenced in this study originates from tugs equipped with Niigata 6L25HX mains, commissioned in 2011. The data set has been meticulously collected by the author, alongside berthing and sailing times, which have been averaged over a two-year period. Furthermore, mooring and detachment data has been sourced from a live feed obtained from a working port in the Baltic Sea region operating 12 vacuum mooring pads.

Main body

Firstly, a comparison of the current operation compared to the vacuum mooring is made; this list, side-by-side, the difference in CO_2 emissions, fuel usage and berthing / sailing time figures, see Table 1. Following this, is evidence to support the data in Table 1.

Current vs Automated mooring data

	No Vacuum mooring	*Vacuum mooring*
Mooring time	*35 mins*	*2 mins (Figure 1)*
Sailing time	*15 mins*	*1 mins (Figure 2)*
Total	*50 mins*	*3 mins*
Per year @ 600 ships	*500 Hours*	*30 Hours*
Tug Fuel @ 600 ships	*124,500ltrs*	*7,500ltrs*
CO_2	*333.66 tonnes*	*20.1 tonnes*
CO_2 AND FUEL	*94% less fuel Consumed*	
REDUCTIONS	*94% CO_2 reduction*	

Table 1. Fuel usage = 2 Tugs at a ¼ power push or lift, total fuel burn rate for a pair of Niigata 6L25HX at 130 shaft revolutions (¼ power) comes out at ~ 124.5LPH, 2 Tugs @ 124.5LPH x 2 x 500hours comes to 124,500Ltrs

CO_2 = 2.68 (Average) x Litre of MDO consumed [2]

The present mooring and sailing durations are defined as follows: 'mooring' is the period from when the vessel assumes its position and is against the fenders, until the pilot dismisses the tugs, while 'sailing' entails the interval from when the pilot instructs the tugs to push up against the ship, to when they are directed to lift. In simpler terms, this refers to the time required to manage the vessel's lines.

To support the vacuum mooring and sailing times referenced in Table 1, Figure 1 and Figure 2 below are used. These are derived from working ports in the Baltic Sea region and support the time reduction stated in Table1.

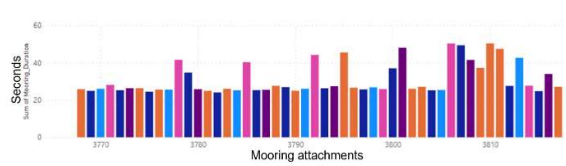


Figure 81. This shows vacuum mooring attach times consistently under 30 seconds, data source from a Baltic terminal. (12 vacuum pads)

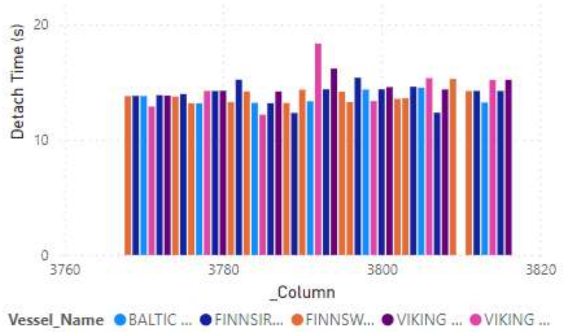


Figure 2. This shows vacuum mooring detach times consistently under 20 seconds, data source from the same dataset referenced in Figure1. (12 vacuum pads)

If we now add in CO_2 the vacuum mooring equipment contributes through energy consumption, we can compile the results.

AutoMoor CO_2 calculation

1 machine per vessel calculated at 400VAC.

Berthing	0.51	KWh
72 hours at berth	10.512	KWh
Departure	0.07	KWh
Total per vessel	11.092	KWh

8 machines per ship x 600 ships

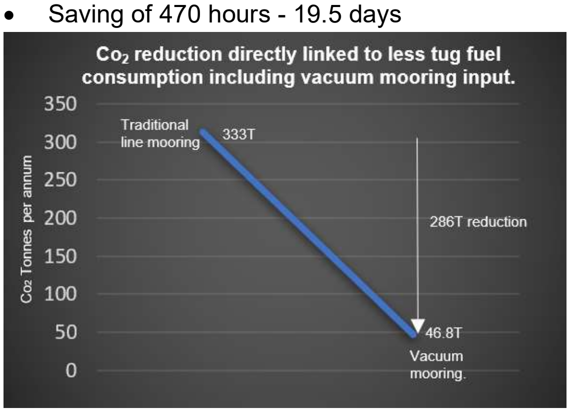
Total KWh for 8 units mooring 600 ships.
11.092 x 8 units = 88.736 x 600 ships = 53,241

CO_2 emissions are determined by multiplying energy consumed by carbon intensity of 503.18g CO_2 pe kWh [1]
(53,241 x 503.18g / 1000 = 26,789kg)

CO2 per year = 26.7 Tonnes

Outcomes and conclusions

- 117,000ltr reduction of MDO (marine diesel oil)
- 286T CO_2 reduction (117,000 MDO x 2.68 CO_2 produced per litre of MDO burnt) – 26.7T (CO2 contribution from vacuum units)
- Saving of 470 hours - 19.5 days



To further reduce our environmental footprint, cutting-edge technological and digital innovations can be implemented to harness and enhance the efficiency of this process, not only leading to significant reductions in CO_2 emissions, but also to optimize port operations and increase throughput. By employing machine learning techniques, various parameters such as pre-tension forces, the vessel's position relative to the fender line can be fine-tuned. Data used in this process is illustrated in Figure 3, which, when combined with vessel motions and meteorological oceanic inputs, furnishes us with a comprehensive data platform. This platform enables us to precisely calibrate each automated vacuum mooring machine's operations, ensuring it operates at optimal levels without exerting undue pressure.

Machine learning interface

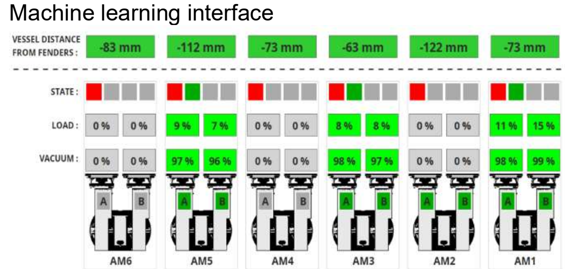


Figure 3. This is typical vacuum mooring interface, it displays load's, distances from fender to vessel and fender compression.

An invaluable outcome of vacuum mooring technology is the newfound independence from shore-based and vessel-based mooring crews. With systems designed for release by the pilot or pilot-endorsed master, upon clearance from VTS to proceed, this autonomy significantly aids in adhering to sailing schedules. Whether it's meeting a critical tidal window or navigating through narrow channels within the port, this autonomy proves vital. Moreover, it eliminates reliance on mooring crews, thus averting scenarios where vessels must wait for crew availability, thereby minimizing waiting times for tugs and reducing emissions generated by idling machinery during standby periods. Further CO_2 reductions can also be observed by the removal of lines boats from the mooring process.

References

[1] Carbon intensity
www.cencepower.com/calculators/kwh-to-co2-calculator

[2] CO_2 produced per litre of Diesel consumed in an ICE
https://www.econology.info/Emissions-co2-liter-fuel-gasoline-or-diesel-gpl/

Relevant UN SDGs (*https://sdgs.un.org/goals*)
9, 13, 14

Bulk Terminal Optimization with Simulation

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Summary
Event-based simulation is now recognized as an essential tool for terminal design and capacity enhancement. A key benefit of simulation is the ability to test outcomes quantitatively by varying a key variable, such as the number of equipment or their handling productivity, storage, service requirements, and other possible variables. In this paper, we will first demonstrate how simulation can assist in identifying and solving the technical and operational bottlenecks of a bulk terminal. The paper will then highlight how a more integrated simulation approach can provide additional benefits by providing a more balanced and optimal outcome. The paper is based on a representative terminal, but the original work was done for a real terminal.

Keywords: (bulk terminal, simulation, optimization, holistic approach)

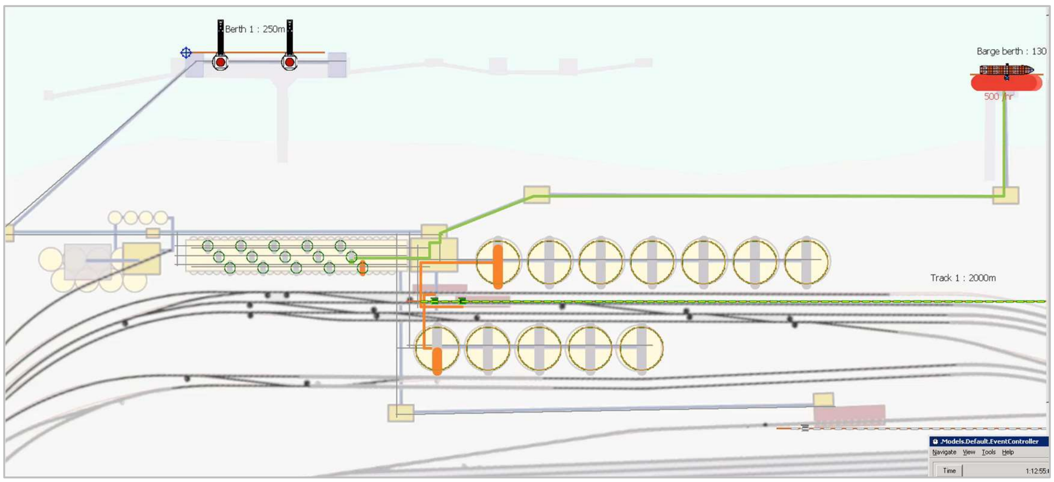

Figure 82. 2D simulation model integrates major parts, incl. trucks, storage, conveyors, (un)loaders of a bulk terminal.

Introduction

A case study based on a represented terminal highlights how capacity simulation was used to improve the operation of bulk terminals by focusing on identifying and solving the technical and operational bottlenecks based on objective quantified results.

In a bulk terminal various equipment, processes and components are often designed and configured independently from each other [1]. In this case study the benefits of an integrated simulation approach are emphasized.

Simulation key elements

The first step in simulation is collating data, inputs operating information, and operating scenarios. These are then used to configure the simulation. A key part of the simulation is validating the model based on test runs. See Fig. 2 shows illustrates the key steps.

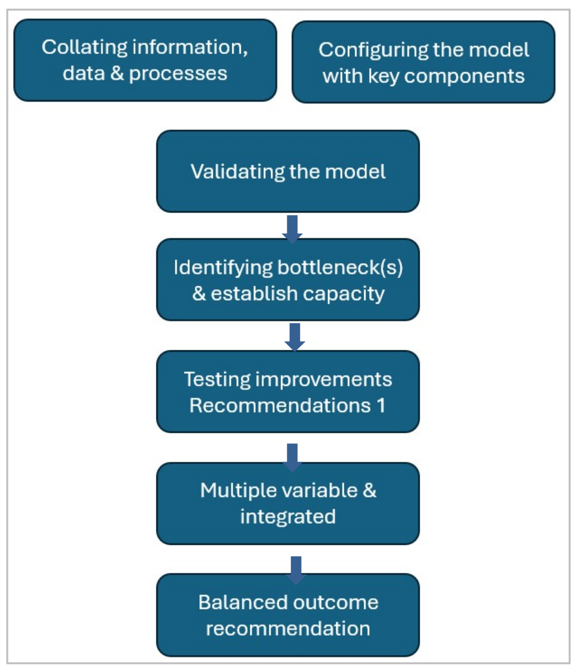

Figure 2. Key simulation steps and integrated modelling

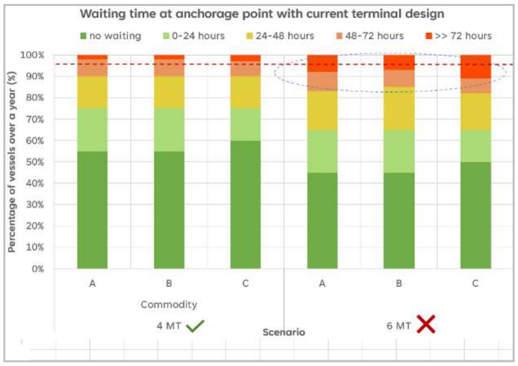

Figure 3. Simulation approach and integrated modelling

The terminal, in this study, intended to raise the total annual volume from 4 MT to 6 MT for all three commodities combined; however, the waiting times indicated that the terminal was already operating at full capacity, as vessels have to have a long waiting time for a berth (see **Error! Reference source not found.**). Waiting times become extreme with 6 MT for all three commodities handled at the terminal. This would lead to drastic demurrage costs.

The next step was to identify technical and operational solutions based on the existing bottlenecks. For instance, as shown in Figure 4, using optimised grabs for the crane and material properties of commodities A and B, the waterside operation can be improved. When it comes to commodity C, using a conveyor system instead of terminal trucks increases productivity.

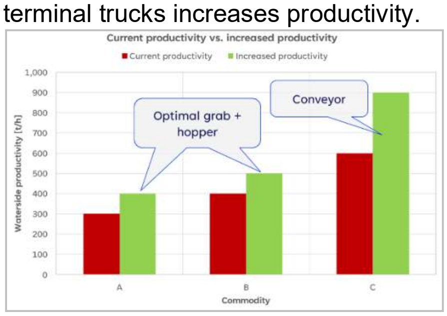

Figure 4. Impact of technical improvements on waterside productivity

Various improvement scenarios were then simulated to evaluate the proposed design solutions. The first scenario was the current situation, and three other scenarios waterside productivity or / and with increased storage. The effect of the improvement measures on the waiting times is shown in **Error! Reference source not found.**.

Figures 5 and 6 indicate that on the one hand, increasing only the waterside performance made the storage limit even more critical; on the other hand, increasing only the storage capacity does not help with the waiting times of vessels.

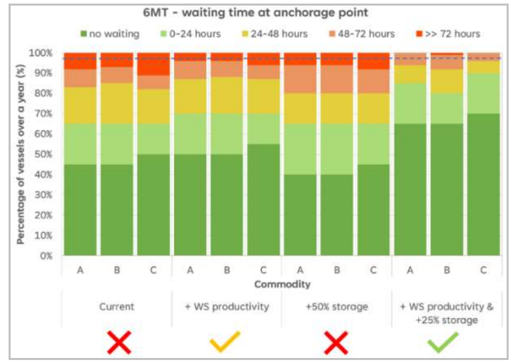

Figure 5. Waiting times with current terminal design as assessed by simulation

The final step was integrated modelling that showed that modifications must be considered in an integrated way, considering waterside, landside, and storage operations. Enhancing the waterside operation and increasing storage capacity by just 25% allowed the terminal operator to reach the target annual volume of 6 MT with acceptable waiting times, which lead to reasonable demurrage costs.

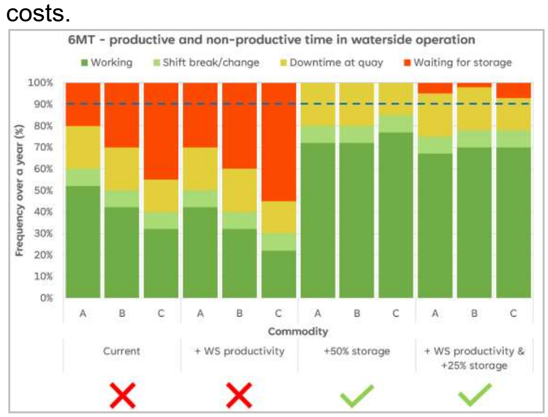

Figure 6. Waiting times of bulk vessels reduce with both WS productivity & storage changes. Simulation allowed to fin the right balance.

Summary Conclusion

The case study highlights how the simulation approach can be used to enhance bulk terminal operation & optimise operation:

- Identify design and operational bottlenecks.
- Assess technical and operational measures to enhance productivity.
- The benefits of an integrated approach for raising annual throughput & efficiency.

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SDGs Goal 9.

Harbouring Sustainability: Assessing Maritime Fender Systems' Carbon Footprint for Sustainable Ports

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Summary
There is unquestionably growing concern for the planet's health, especially centered on the effects of human-induced global warming due to its role in the overabundance of greenhouse gases - including CO_2 - in the atmosphere. This paper emphasizes the need for the maritime industry to minimize its carbon emissions. Firstly, it describes the current situation, outlining some measures available to all fender manufacturers to reduce their CO2 emission levels through design, components, shipping or maintenance. In a second section, it introduces a Carbon Footprint Assessment that provides product specific figures on CO2 emissions for each order of engineered fender systems upon request. In essence, it represents a notable step forward in encouraging sustainability in the maritime industry.

Keywords: Sustainability, transparency, fenders, CO_2 Emissions

Introduction: The challenge

The rapid deterioration of the environment and other negative consequences from resource exploitation have dramatically shifted companies' focus toward sustainability. Within the maritime industry, the impact of a growing population is evident, with increased cargo and passenger traffic highlighting this global challenge. Also, the rising consumption of natural resources, with their sourcing and their use in manufacturing posing a significant challenge.

Addressing them requires collective effort and puts the maritime industry facing increasing pressure to adopt sustainable practices to reduce its environmental footprint. In the next two chapters the following shall be discussed:

- Initiatives that all companies have at their disposal to reduce carbon emissions.
- A recently developed assessment that provides product specific figures on CO2 emissions.

The Current Situation

There are several initiatives available to focus on reducing carbon emissions on the operational side.

Design.
The Holistic Approach to fender system design, pioneered by ShibataFenderTeam in 2017 and endorsed by PIANC WG 211 Guidelines, ensures fender durability, extending their life cycle, reducing early repairs, and minimizing resource waste. This green design approach promotes sustainability by creating fender systems that withstand harsh conditions and use high-quality materials.

Components
Ensuring high-quality fender components through in-house manufacturing and sustainable sourcing is crucial. Natural rubber, ethically sourced and locally manufactured, reduces transportation emissions. Innovations in steel production have achieved up to 70% CO_2 reduction, offering significant sustainability improvements [1][2]. Recycled carbon black in rubber compounds and post-industrial recycled UHMW-PE contribute to lower environmental impact.

Distribution
Sustainable distribution involves choosing eco-friendly carriers committed to zero carbon goals and utilizing green fuels. Attention to eco-friendly transportation options, like LNG or eco-powered trucks and trains, helps achieve greener supply chains.

Maintenance
Regular maintenance and refurbishment extend fender lifespans, reducing resource waste. Planned inspections and refurbishment services, like foam fender reskinning, are vital for sustainability. This proactive maintenance approach prevents accidents and prolongs fender systems' operational life.

However, leading the way involves transparency and accountability. It is time to take a sept forward.

Transparency in the fender industry: carbon footprint assessment

The manufacturing of fender systems is a complex process; the rubber compound, only, involves many ingredients and various steps. Achieving visibility and accountability, which come hand in hand with complete control of the supply chain, is essential for a fender manufacturer to claim sustainability.

Under this premise, an independent consultancy analysed and mapped out each and every production process of a company with fully owned and controlled (from cradle-to-gate) supply chain for the rubber fender, ShibataFenderTeam, to develop a tool that provides product specific figures on CO2 emissions for each order of engineered fenders [3].

This carbon footprint assessment was developed by an independent consultancy based in Denmark, a country that is often considered a leader in sustainability and has implemented several laws and initiatives that support this reputation [3].

This assessment tool is based on ISO 14067:2018, an international standard for quantifying and reporting the carbon footprint of products [4].

Evaluating CO2 emissions from fender components reveals steel as the primary contributor due to high production emissions, though it is highly recyclable. In contrast, rubber is harder to recycle, posing sustainability challenges. Thus, this paper focuses on rubber.

Method

To calculate the CO2 emissions for this assessment, every fender system element and action in the manufacturing supply chain was meticulously dissected, from the sourcing of raw materials to transportation. This included considering the impact of each ingredient in the rubber compound mix and other raw materials used in the fender system. Additionally, the energy consumption associated with production processes, as well as the transportation of raw materials, intermediates, and final products, were thoroughly analysed.

The key to the study and therefore to the results, was the possibility to go into a fully owned and controlled supply chain and analyse the rubber compounding and mixing process.

The company identified every single of the 20+ ingredients that forms the compound of the rubber fender, naming and labelling every supplier.

The project included the analysis of CO2 emissions from the sourcing of ingredients, but also from their supply, which meant calculating the impact based on the distance between each supplier's factory and the ShibataFenderTeam workshop.

The company identified and labelled each of the 20+ ingredients in the rubber fender compound, analysing CO2 emissions from sourcing and supply, including distances from suppliers to the ShibataFenderTeam workshop.

The assessment also examined the mixing process and its energy consumption, evaluating different compound formulas for their CO2 impact. Further analysis included emissions from other fender components like steel and UHMW-PE, tracing their journey from cradle to gate.

This comprehensive approach ensures responsible management of high CO2 footprint components, crucial for true sustainability in fender manufacturing.

The result

The assessment provides CO2 emissions per order in kg CO2-eq, presenting the data in several ways: as total aggregated figure, divided into sourcing, manufacturing, waste, and distribution, and as percentage breakdown by components (fenders, steel panels, fixings, UHMW-PE).

It also offers a comparison between carbon footprints of as-built products with those made from 100% virgin materials and includes a lifetime analysis of emissions per year.

Conclusion

The figures offered by the tool provide transparency and accountability not seen before in the CO_2 emissions. The assessment approach empowers customers to demand more transparency from fender manufacturers and enables them to make informed decisions.

The paper outlines measures to <u>reduce</u> CO_2 emission levels and present a unique approach to <u>measuring</u> CO_2 emissions in the fender industry.

The focus is on the entire maritime community: engineering companies, port operators and port authorities. All are potential targets, as sustainability is the responsibility of society as a whole.

UN Sustainable Development Goals that are represented here are 12 "Sustainable Consumption and Production, and 13 "Climate Action".

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Enhancing Coastal Resilience: Beneficial Reuse of Dredged Material through Implementation of a Nature-Based Design Approach

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Summary
BMT was contracted to devise a comprehensive design for the stabilisation of Babbage Island Spit in Carnarvon, Western Australia. This encompassed detailed design development, project management and technical oversight of dredging and placement operations within Tegg's and the Fascine Channels. The project included intricate dredged material management in collaboration with the dredging contractor and collaboration with coastal revegetation specialist to design the built dunes, wind-blown sand management and revegetation implementation plan. The resulting design addressed the dynamic coastal environment by integrating considerations of project objectives and specifications, coastal processes, constructability, and geotechnical analysis. The outcome is an efficient and durable dune system that fulfills its intended function and fits into the surrounding natural environment.

Keywords: Beneficial reuse, Reclamation, Dredging, Working with Nature

Introduction
The Fascine in Carnarvon serves as a crucial entryway for tourism in the area and experiences substantial annual sediment movement from the Gascoyne River delta, rendering it a highly dynamic coastal environment. Over time, sediment movement in the region has posed a challenge to the functionality of the Fascine's entrance channel specifically. This challenge was particularly evident following a significant over wash event in 2017, which led to the closure of the Fascine due to increased sedimentation. Consequently, the spit and entrance channel underwent a dynamic process of reformation and evolution after this 2017 event. In response to community demand, the WA State Government initiated the Carnarvon Fascine Entryway and Boat Harbour Pen Project in 2020, aiming to re-establish the channel and ensure its long-term functionality by mitigating against recurrence of the over wash and channel closure. The Department of Transport (DoT) implemented a maintenance dredging project, utilising studies of coastal processes to strategically redredge the channel. This dredging effort also involved using the dredged material to mitigate future over wash events affecting the spit.

BMT undertook a comprehensive design process, focusing on reinforcing weak points vulnerable to cyclone type events and optimising channel alignment to mitigate sedimentation issues. Collaborating closely with Maritime Constructions (MC), the dredging contractor, BMT achieved a favourable outcome for the community by restoring the navigational link between the Carnarvon Fascine and the ocean.

The key coastal processes that drive the development of the spit are winds (aeolian processes), waves (longshore transport), currents (scouring of the channel) and water level (overtopping). The preliminary design was devised to account for these factors. The design of the dune at the initial stage (Figure 1) incorporated a foredune and primary dune with slopes of 1:3 to match the surrounding natural profiles. The dune field footprint was designed to allow space in the lee side along the Western shoreline where coastal processes are most active. The design seamlessly integrated into the surrounding ecosystem by incorporating revegetation methods such as sand drift fencing, brushing, and propagule collection.

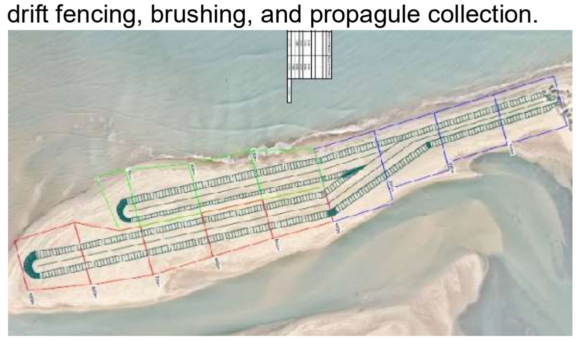

Figure 83 Preliminary dune design depicting the alignment and structure of the foredune and primary dune to provide suitable protection. Source: BMT

The initial channel alignment was design based on coastal modelling from Baird. The dredge design was then updated to optimise the alignment of the access channel along the natural 0m contour for ease of dredging and navigation. A silt trap was included on the western side of the channel near the end of the spit to allow for the natural accretion to continue the extension of the spit moving southeast. Likewise, the bend in the north of the channel was smoothed out and widened to 30m (2 x 15m cuts), thereby, allowing a silt trap in the inner northern corner to capture sediment. A bell mouth was proposed similar to the pre-breach channel design and to tie into Tegg's channel.

Further geotechnical, hydrological, and site-based data was sourced and informed the detailed design of both the access channel and dune. Notably, dredged material containing clay (~12% of cohesive material) posed challenges in retaining it on the dune. To address this, a bund and swale design was developed in collaboration with MC and incorporated along the spit during execution to capture additional material.

Figure 84 Detailed dune design depicting the alignment and structure of the foredune and primary dune to provide additional volume. Source: BMT

Throughout the execution phase, adjustments were made to optimise functionality and address site-specific challenges. Initially, an increase in dune height was necessary due to the close correlation between dredge and disposal volumes, prompting additional infilling of the middle section for increased volume capacity. However, subsequent revisions reverted the final dune height back to its original design, prompted by reductions in dredge depth and width to reduce the extent of dredging in clay layers encountered during the works. Furthermore, the entire dune underwent realignment towards the east to mitigate the impact of recorded onsite wave setups (Figure 2). Notably, the inclusion of a sacrificial berm on the west side of the dune was introduced to safeguard the northern section, recognised as pivotal to the project's success.

Figure 85 Drift fencing on the northern section of the dune trapping the fine particles of windblown sand. Source: BMT

Emphasising the beneficial reuse of dredged material, the final design aimed to restore navigation while simultaneously nourishing the dune and beach. The capacity requirements of the dune were increased to approximately 150,000m^3 to accommodate this dual purpose, with additional infilling and height adjustments. The design featured undulating profiling, extending approximately ±1m on each side of the designated height, matching the dune profiles observed just north of the spit and effectively reducing wind-blown erosion. Methods utilised during the construction of the dune system maximised the settling of fines in dredged material preventing excessive sediment plumes within return water and minimising impacts to nearby sensitive benthic habitats. Stabilisation measures, including drift fencing and revegetation, were implemented to further trap windblown sand and facilitate the establishment of native vegetation (Figure 3). Direct seeding provided an effective and efficient means of facilitating this establishment of native vegetation. While utilising a Hydromulch product was designed to provide stability to soils and adherence of seed in areas where wind / water is likely to mobilise seed before it can germinate.

Figure 86 Completed dune construction including revegetation and stabilisation works. Source: Maritime Constructions

In conclusion, the successful completion of the dune shown in Figure 4, integrating the reuse of dredged spoil, highlights the synergy between effective design and sustainable coastal management practices. By restoring navigation and utilising a nature-based approach, the project not only achieved its objectives but also set a precedent for environmentally conscious coastal development.

The dynamic nature of the spit presents a complex scenario wherein decisions must carefully balance the objectives of rebuilding it, augmenting sediment supply, and maintaining accessibility through the channel for the community. These considerations highlight the intricate trade-offs involved in managing this environment effectively.

Acknowledgements
BMT extends our sincere appreciation to Maritime Constructions and the DoT for their invaluable collaboration, which played a pivotal role in the successful delivery of the Carnarvon Maintenance Dredging project and the stabilisation of the Babbage Island sand spit.

Relevant United Nations Sustainability Development Goals: 14

Upgrade, Reinstate, or Retreat? A Comparison of Breakwater Asset Management Strategies

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Summary
Maintenance of the Port of Mackay breakwaters consists of reinstating their profiles to the design levels following a storm event. To assist North Queensland Bulk Ports (NQBP) understand whether the current strategy is optimal, Kellogg Brown & Root (KBR) was commissioned to undertake a high-level investigation of six alternative breakwater maintenance strategies. Using existing wave modelling output, KBR developed a synthetic storm timeseries and estimated the Net Present Value costs associated with each maintenance strategy. Recommendations were limited to 1) *reinstatement* where existing rock was sufficiently sized (e.g., around breakwater heads) and 2) *progressive upgrade* where the breakwater structure may benefit from larger rock. These high-level results confirm that NQBP's current strategy of reinstatement is optimal in most locations and that development of a partial rock overlay upgrade solution may offer better value at other locations.

Keywords: Asset Management, Breakwaters, Rock Stability, Cumulative Damage, Economic Assessment.

Background and Introduction
The Port of Mackay, located five kilometres north of the city of Mackay, comprises of four wharves and is one of the major servicing centres for Central Queensland mining and agricultural industries. The Northern Breakwater, Southern Breakwater, Middle Breakwater and Western Revetment (Figure 87) are rock armour structures that provide shelter and protection in and around Mackay Harbour. Since the original construction of the Northern and Southern Breakwaters in the 1930's, the structures have been exposed to their fair share of extreme events in the cyclone-prone North Queensland region, including TC Debbie (2017), TC Dylan (2014) and TC Ului (2010). To date, North Queensland Bulk Ports (NBQP) have been repairing damage to these rock armour structures by simply reinstating to the design profile, however, needed confirmation that this was the most efficient and economical approach to take.

Kellogg Brown & Root (KBR) was engaged by NQBP to conduct a high-level assessment to determine whether alternative maintenance strategies require further investigation. The objective of the study was to consider a broad range of potential maintenance strategies and identify which strategies were feasible in terms of cost, provided protection and public perception.

Methodology
The study used a total of eight representative cross sections from various locations along the rock armour structures (Figure 87). A synthetic timeseries of storms was developed based on offshore historic wave data from the Mackay Waverider Buoy. Storm wave parameters at the base of each cross-section were derived using previous wave modelling [1].

At each cross-section, the cumulative damage due to the series of storms was estimated using BREAKWAT [2] software, which adopts a similar approach to Van der Meer [3]. The costs associated with each of the maintenance strategies were then calculated using the volume of displaced rock and an indicative supply and install rate ($\$/m^3$) that accounted for the difficult access requirements which are typically associated with breakwater repairs. Costs were reduced to a Net Present Value for comparison between different strategies.

Additionally, a sensitivity analysis was also conducted using variations in wave height, rock size, and rock density, as well a comparing cumulative damage estimates to the Melby approach [4]. This methodology ensure that this high-level assessment was robust enough to draw suitable conclusions, while limiting the requirement for time-consuming modelling or analysis.

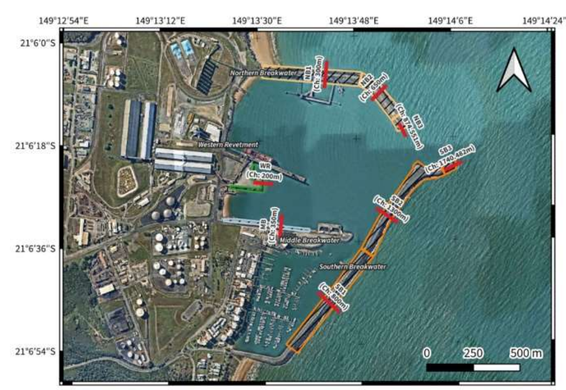

Figure 87 Plan of Port of Mackay rock armour structures including the Northern Breakwater, Southern Breakwater, Middle Breakwater and Western Revetment. Red lines indicate the cross-sections assumed to be representative.

Maintenance Strategy Options
A total of six maintenance options were considered for this assessment:

- *Reinstatement* of the breakwater to the design profile (see Figure 88 top)
- *Retreat* where the breakwater damage is not repaired and a breakwater is downrated.
- *Monitor* where the breakwater is allowed to reshape into its natural state over time.
- *Reprofile using existing rock* where damaged sections are repaired with rock from less critical sections.
- *Progressive upgrade* where repairs are conducted by locally filling damaged sections with new, larger rock (see Figure 88 bottom).
- *Full replacement* where entire sections of breakwater are replaced when damage occurs.

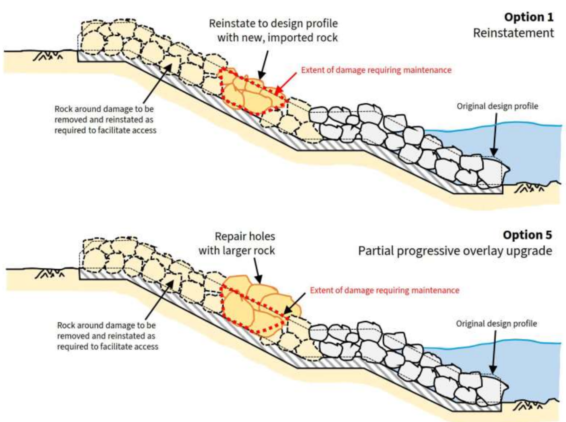

Figure 88 Two of the six maintenance options considered in this study, including *reinstatement* of existing design profile (top) and *progressive upgrade* (bottom).

Results and Recommendations

The assessment found that both *reinstatement* and *progressive upgrade* are recommended throughout the Port of Mackay (Figure 89). Importantly, there is also no economic justification for the full replacement (or rebuilding) of the rock armour structures.

Figure 89 Plan of Port of Mackay showing *reinstatement* and *progressive upgrade* as the recommended maintenance strategies for their respective structures.

Reinstatement of any damage to the design rock size and profile was generally recommended where the existing armour rock was sufficiently sized. Given the conservativeness assumed in the analyses, from the selection of synthetic storms to the tendency for breakwater design equations to somewhat over-predict observed damage in most situations, continuing the existing maintenance strategy for these areas is justified.

In some areas, *progressive upgrade* (using new, larger rock to repair damage) was recommended, indicating that there is some economic benefit of improving the resilience of the structure to future storm events. In order to formalise this strategy, however, the following aspects need to be investigated:

- Triggers for intervention need to be determined to allow incorporation into a formal asset management plan.
- Further analysis, design and optimisation of progressive improvement options which may include physical modelling.
- Detailed investigation to determine design events, including the impact of Sea Level Rise and the potential for wave overtopping.

The sensitivity analysis did not change the recommend strategies, however, did highlight that the costs associated with *reinstatement* have larger variability compared to *partial progressive overlay upgrades.* This is because the upgrade can be designed to accommodate larger waves and higher water levels, but the damage (and therefore cost) under a *reinstatement* strategy varies with the severity of the event. Additionally compared the Melby approach for damage accumulation [4], BREAKWAT and Van der Meer [2,3] appear much more conservative.

As a result of this high-level analysis, it is suggested that continuation of the *reinstatement* strategy combined with *progressive upgrades* appears to offer NQBP with an effective maintenance strategy for the rock armour structures at the Port of Mackay.

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Improved Port Planning and Risk Management using AIS and PPU Data

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Summary
Port planning, operations, and risk management are ongoing tasks for a port management team. In the digital age, an abundance of data is generated during port operations and this data has tremendous potential when applied to improve planning and risk management. Traditionally, this operational data is poorly managed, and the effort required to extract usable information and analyse it frequently prevents its use in routine planning and risk management decisions. This abstract describes a new operational data management tool which is gaining rapid adoption in ports in Australasia and presents two case studies which demonstrate how operational port data have been used to inform routine planning and risk management decisions.

Keywords: Port Planning, Risk Management, Big Data, AIS, PPU

Introduction

Port planning, operations, and risk management are essential ongoing tasks for a port management team and these tasks are interrelated. For example, the outcome of a risk assessment performed as part of risk management may inform changes in operations, as well as drive planning for new infrastructure. Accordingly, ports are seeking improved methods to perform these tasks more efficiently and thoroughly. This paper will, though a pair of case studies, describe how this has been achieved using routine analysis of automatic identification system (AIS) and portable pilot unit (PPU) data.

In the digital age, an abundance of data is generated. Much of this data is generated in operations but can have tremendous benefits for learning from experience to improve planning and risk management. In most ports, the AIS transmissions made by all large commercial vessels data and PPU data collected by marine pilots on their navigation computers, provide a high-resolution record of vessel positions and manoeuvres. An array of meteorological observations is also required for safe and efficient port operations.

In many ports these types of operational data are not managed in any systematic way and can be difficult to access efficiently, let alone routinely analyse for trends and patterns and identify poorly managed risks and learning opportunities. This is a lost opportunity as, when these data are readily accessible, they allow planners, trainers, and risk managers to efficiently make decisions informed by historical navigation practices.

This paper presents a series of examples which demonstrate how operational AIS, PPU and environmental data have been used to assist planning and risk management.

TransitAnalyst

TransitAnalyst is a tool that was originally conceived to empower stakeholders in port-scale navigation (pilotage) by providing an easy-to-use tool for visualising, analysing, and learning from historical port navigational data.

TransitAnalyst operates using a simplified digital twin of the port environment, with port areas, berths, channels, anchorages, pilot boarding grounds and other port features set up as objects in the system.

The system takes a live feed of AIS data, which can be supplemented by periodic PPU data uploads, to automatically identify transits of vessels through the port. When a transit is identified and completed it is augmented with simultaneous metocean data and information on other vessels and small craft operating at the same time including pilot boats and tugs. Algorithms categorize the transit and generate analytics against predefined criteria before all this information is stored in a transit database.

Port operators and maritime pilots have access to this database through an online web interface. This enables them to search for and view one or many transits, and all associated data, based on a wide variety of search filters.

The implementation of TransitAnalyst as a digital twin of the port, continuously and automatically collecting, processing, and organising data into a common database with qualitative insights from pilotage, significantly simplifies data collection and analysis and lowers the threshold for including sophisticated data analysis in port planning and engineering decisions.

Case Study 1: iReX Berthing Velocity Analysis

Wharf structure and fender design requires an understanding of the forces exerted by berthing vessels and the expected velocities and angles of approach of design vessels are required. Typically, this would be informed by design criteria from PIANC guidelines and similar publications however, for the redesign of an existing operational berth and in this case, for structures with short life spans, this information can be more accurately gathered from actual transits.

Use of AIS data for this purpose is limited by inherent uncertainties and limitations which limit the resolution and accuracy of the data. However, in this project, these limitations were overcome by temporarily installing PPU units on the ferries arriving at No 1. Wharf. Further, as road and rail ferries must berth at a consistent position relative to the landside infrastructure the final berthed position of the ferries is known within centimetres. This information was used to calibrate the vessel's position information received from AIS and PPU data.

Aggregating all transits from September to November 2023 allowed the extraction of the distribution of speed over ground (SOG) of the vessels at 10 m intervals along the wharf (Figure 1).

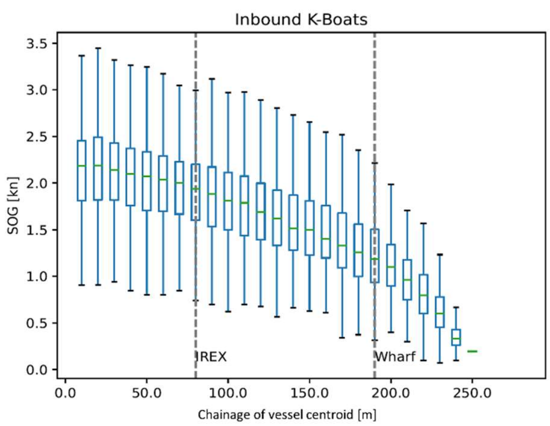

Figure 1 – Distribution of approach velocities of ferries at Picton No 1 Wharf.

The value of analysing actual vessel data alongside historic wind data, allowed the designers to refine the design cases for various berthing manoeuvres, reducing the overall capital infrastructure costs for two separate temporary marine structures, this included reducing demand on fenders, and sub/super structure elements.

Case Study 2: iReX Construction Zone Analysis

As a provider of a critical infrastructure linking New Zealand's North and South Islands, KiwiRail ferry operations must continue during the construction of the new iReX Berth. However, this presented a clear risk to be managed. As part of their risk management approach KiwiRail undertook ongoing monitoring of the ferry transits taking place in Picton harbour. This study quantified the proximity of the ferries to the planned construction zone as a function of prevailing wind conditions. This monitoring and analysis assisted decision making for environmental limits and other risk control measures to be placed on operations during the construction period.

In order to adequately assess this risk of the ferry operations entering the proposed construction zone in various manoeuvring cases, the client needed to determine if the ferry Masters could stay clear of this exclusion zone and its temporary protection structures, which was a series of mono fender piles and a single end dolphin, installed between the active berth and the construction zone.

To assist meet this objective, TransitAnalyst was configured to automatically identify and tag any transits which entered a virtual exclusion area, along with the environmental conditions at the time (Figure 2). This information was reported to KiwiRail monthly and was fed back to ferry Masters.

Figure 2 – Example plot of the swept path of a vessel that entered the iReX exclusion zone on arrival with identifying vessel and transit data obscured.

Utilising TransitAnalyst and PPU data, the client was able to review the incursions and investigate why they occurred. This was completed for multiple months leading up to construction commencement. The target was to get down to 0 incursions through means of adequate training and continual improvement. At the end, this data was essential in supporting the client with defining and setting risk controls, including the need for temporary fender protection structures and wind limits for the use of tugs, during construction.

Conclusions

Routine analysis of the operational data available in most ports today can support improvements to operational decision making, port planning, and risk management. As more ports adopt tools such as TransitAnalyst to assist their operational quality assurance, additional benefits can be obtained by taking advantage of the improved access to historical data in port planning, engineering design, and risk management decisions.

Acknowledgements

The authors thank KiwiRail for the opportunity to work with them in these projects, and for their support in sharing this work with a wider audience.

Planning for Offshore Wind Port Infrastructure on the U.S. West Coast

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Summary
In the United States, the Federal Government and the State of California established ambitious floating offshore wind deployment goals. This abstract summarizes the steps taken to establish consistent port planning approaches, design criteria, and methods to identify, select, and develop port sites to support the offshore wind industry on the U.S. west coast.

Keywords: Floating Offshore Wind, Port Infrastructure, Renewable Energy, Clean Energy

Introduction

The U.S. Department of the Interior, Bureau of Ocean Energy Management (BOEM) administers exploration and development of energy and mineral resources in U.S. federal waters. This includes the responsibility of issuing a lease, easement, or right-of-way for offshore energy and mineral resources in federal waters [1].

The U.S. west coast region, consisting of the area off the coasts of California, Oregon, Washington, and Hawai'i, is characterized by rapidly increasing water depths that exceed the feasible limits of traditional fixed offshore wind (OSW) turbines. Floating offshore wind technology is more suitable for this region, which requires the use of ports to construct the floating offshore wind turbines. Existing port infrastructure on the U.S. west coast is not adequate to support these activities and significant port investment is required to develop offshore wind port facilities [1].

The U.S. established deployment targets of 15 gigawatts (GW) of floating offshore wind by 2035, 30 GW of offshore wind by 2030, and 110 GW by 2050. The State of California established a target to deploy 25 GW of floating offshore wind by 2045 and to date has leased areas off Central and Northern California with an approximate capacity of 4.6 GW. Off the Oregon coast, BOEM designated two wind energy areas with a total estimated capacity of approximately 2.4 GW. Future planning may identify additional offshore wind deployment opportunities off the coasts of Washington and Hawai'i.

To meet the deployment targets in California and Oregon, approximately 1,400 turbines (assuming 20 MW systems) will need to be installed. For the capacity of turbine system envisioned on the U.S. west coast (>15 MW), the components are so large that the only feasible way to transfer them from one location to another is by waterborne transit. Therefore, the offshore wind industry coalesced around an approach to use waterfront facilities at ports to manufacture components and transport them to another port site for complete integration of the floating offshore wind turbine system. Once assembled, the fully integrated turbine system will be towed out to the offshore installation site [2].

To ensure adequate port sites are available for industry use, a comprehensive program was developed to define the type of port sites required, establish port planning design criteria, and identify the best port sites for industry use considering both existing and potential greenfield port sites.

Floating Offshore Wind Port Site Types

To allow for the development of consistent design criteria, the following definitions of offshore wind port site types were established. A Staging and Integration (S&I) site will receive, stage, and store offshore wind components and assemble the floating turbine system for towing to the offshore wind area. A Manufacturing/Fabrication (MF) site receives raw materials via road, rail, or waterborne transport and creates larger components in the offshore wind supply chain. An Operation and Maintenance (O&M) site is a base of wind energy area operations and supports vessel provisioning and resupply during the operational period of the offshore wind energy area. A Construction Support Site is a home base to support the fleet of construction vessels necessary for construction and commissioning of the offshore wind energy area. Mooring Line, Anchor, and Electrical Cable Laydown sites receive and stage mooring lines, anchors, and electrical cables to support the installation of the offshore wind energy area [3].

Port Design Criteria

The offshore wind industry identified that U.S. west coast port infrastructure should be designed to accommodate up to 25 MW turbine systems with semi-submersible or tension leg platform foundation technologies and dimensions as shown in Figure 1. Based on this turbine size and offshore wind industry input, port infrastructure design criteria (see Tables 1 and 2) were developed to provide consistent criteria for port infrastructure planning.

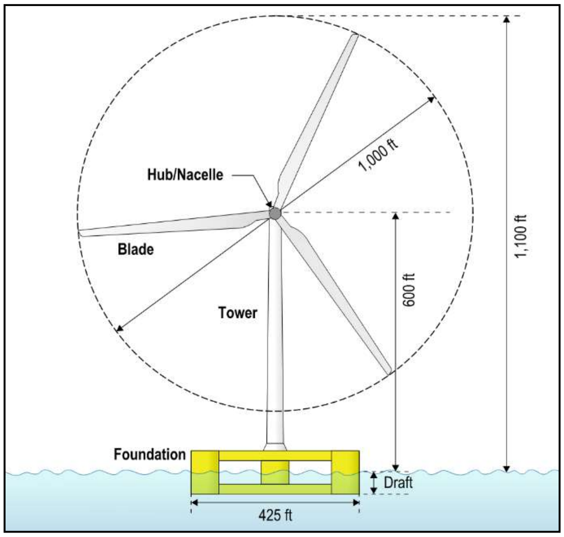

Figure 90 Turbine Dimensions for U.S. Port Planning [2]

Identifying and Selecting Port Sites

A primary objective is to establish the required number and size of each type of port site that is needed to support the deployment targets. For example, in California it was determined that approximately 4 S&I sites (80 acres each), 4 foundation assembly sites (100 acres each), 2 blade manufacturing sites, 3 tower manufacturing sites, and 1 nacelle assembly site would be needed to support a deployment goal of 25 GW by 2045 [2]. After the quantity of port sites was established, existing port sites were evaluated to determine if they could be redeveloped to meet the Table 1 criteria or if new greenfield sites need to be developed. In California it was determined that existing ports have adequate space to support the offshore wind industry and new ports would not be needed as developing a new port would be more costly, environmentally impactful, and may not be ready in time to support the industry [2], [3], [4], [5].

Table 12 Floating OSW Port Criteria for S&I and MF [2], [6]

Design Criteria	S&I Sites	MF Sites
1. Acreage	30 to 100 acres	30 to 100 acres
2. Wharf Length	1,500 ft	800 ft
3. Minimum Draft at Berth	38 ft	38 ft
4. Wharf Loading	> 6,000 psf	> 6,000 psf
5. Uplands / Yard Loading	2,000 to 3,000 psf	2,000 to 3,000 psf
6. Air draft	>1,100 ft	~100 ft

Table 2 Floating OSW Port Criteria for Other Sites [2], [6].

Design Criteria	O&M, Mooring & Anchor Storage, & Construction Support Sites	Electrical Cable Laydown Sites
7. Acreage	O&M: 2 to 10 acres Others: 10 to 30 acres	20 to 30 acres
8. Wharf Length	300 ft	500 ft
9. Minimum Draft at Berth	20 to 30 ft	30 to 35 ft
10. Wharf Loading	O&M: 100 to 500 psf Others: 500 psf	1,000 psf
11. Uplands / Yard Loading	O&M: 100 to 500 psf Others: 500 psf	1,000 to 2,000 psf
12. Air draft	~100 ft	~100 ft

Conclusion

Following the approach outlined, the State of California identified preferred port sites for offshore wind development. Sites in the Ports of Humboldt and Long Beach are far into the planning and design phases for use as S&I sites. Other port sites in California, Oregon, Washington, and Hawai'i will also be considered to support the development of the supply chain and deployment of offshore wind on the U.S. west coast.

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Relevant UN SDGs (*https://sdgs.un.org/goals*)

7 Affordable and Clean Energy, 9 Industry, Innovation, and Infrastructure, 11 Sustainable Cities and Communities, 13 Climate Action

Where the nuclear mindset meets maritime engineering

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Summary
As the Royal Australian Navy commences the journey to acquire and operate its own fleet of nuclear powered (conventionally armed) submarines, the planning and engineering required to support the optimal pathway to achieving this outcome is well underway. With plans to build, sustain and maintain our own fleet by 2040, and support homeported nuclear-powered submarines from 2027, new and upgraded maritime infrastructure is required that meets international standards for nuclear safety. This paper examines the evolution of the project from siting through to decommissioning, with a nuclear safety-led design and justification philosophy.

Keywords: nuclear engineering, nuclear safety, maritime engineering, port planning, site evaluation.

Introduction

The potential harmful health and environmental effects from exposure to nuclear and radiological material requires an approach to design and construction such that it can be demonstrated that the risks are minimised so far as is reasonably practicable (SFAIRP) and radiological doses are as low as reasonably achievable (ALARA). To achieve such demanding performance requirements, design is led by a structured safety case that considers all credible hazards and outcomes, and provides layers of engineering solutions enhanced by procedural excellence. Proven technologies from reputable suppliers provide confidence in the performance of equipment, which is underwritten by rigorous inspection and maintenance.

To successfully deliver facilities and infrastructure with nuclear and radiological safety implications, it is necessary to ensure that the risks are understood, relevant safety functions have been identified and met by the installed design, and properly evidenced with sufficient defence in depth. This requires all normal, accident and extreme hazards and emergencies to be assessed in the design.

This paper will examine the following:

- Safety Standards
- Site evaluation process
- Nuclear safety-led design

Safety Standards

In line with the International Atomic Energy Agency (IAEA) Fundamental Safety Principles [1], the fundamental nuclear safety objective is to protect people and the environment from harmful effects of ionising radiation. This means protecting people and the environment without unduly limiting the operation of facilities or the conduct of activities that give rise to radiation risks.

IAEA Safety Standards reflect an international consensus on what constitutes a high level of nuclear safety. These standards serve as a global reference for protecting people and the environment.

They comprise a series of :

- Safety Fundamentals
- Safety Requirements
- Safety Guides

Australia has aligned with the IAEA Safety Standards to develop world class best practises. Additionally, Australia is in the fortunate position of being able to work closely with our experienced AUKUS partners to assist with the journey to becoming the eighth country to own and operate nuclear-powered submarines.

Site evaluation process

A key measure to achieving the fundamental nuclear safety objective is selecting a site which is suitable for a nuclear installation including consideration of:

- External events occurring at the site including those of natural origin or human induced.
- Characteristics of the site and its environment that may affect the behaviours of radioactive material if it was to be released.

IAEA Site Survey and Site Selection for Nuclear Installations Specific Safety Guide No. SSG-35 [3] provides recommendations and guidance for the siting process for a nuclear installation. Whilst this approach is considered international best practise, a tailored application of the IAEA siting criteria should be applied to consider:

- Natural hazards
- Man-made hazards
- Emergency response feasibility.

IAEA guidance is not specifically developed for mobile nuclear reactor plants like submarines, therefore operating considerations also need to be considered.

The process covers the operating lifetime of a nuclear installation as shown in Figure 1.

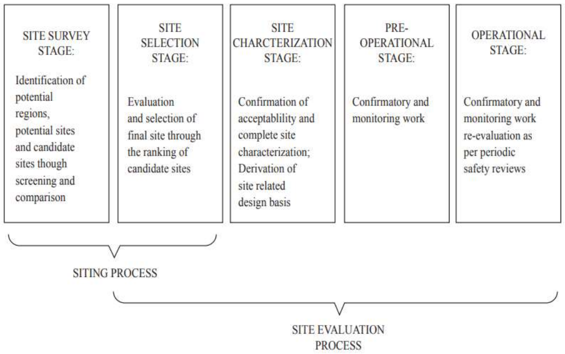

Figure 91 Stages in the siting process and site evaluation process in the operating lifetime of a nuclear installation. (Source: [3]).

Once a site is selected, the site characterisation stage commences, which includes a series of detailed studies to define the site-specific design basis events and hazards that need to be considered in the design process. Unknowns are reduced as far as possible and conservative assumptions are made to offset any remaining uncertainties.

Nuclear Safety Led Design

A nuclear safety case is a "collection of arguments and evidence in support of the safety of a *facility or activity.*" It is a logical and hierarchical set of documents with the purpose of demonstrating safe operability by providing a link between high-level safety claims and the facility detail throughout design, construction, operation and forethought of decommissioning. This is achieved through clearly defined management procedures, evidenced in hazard assessments and documented decision-making – the nuclear safety led design process.

In accordance with the applicable regulatory framework, the safety case sets safety goals and defines requirements for demonstrating compliance. It remains; however, to develop a design and substantiation process to provide evidence to support compliance. The design process and safety case process must work together as the design iterates through successive stages of development.

Whilst there are international standards that address the design of maritime structures and nuclear power stations, there is not clear international guidance on how to design maritime infrastructure to support nuclear reactors; however, the same principles apply to developing a nuclear safety led design, and there are precedent national examples developed by our AUKUS partners.

Safety functional requirements (SFRs) are defined and the systems, structures and component (SSCs) responsible for meeting these functions are identified and categorised based on the significance of their postulated failure. Items that are most critical to nuclear safety will require a high level of collaboration with the safety team during the design development.

Figure 2 illustrates how the design process and safety approach are interrelated to demonstrate a SFR has been met.

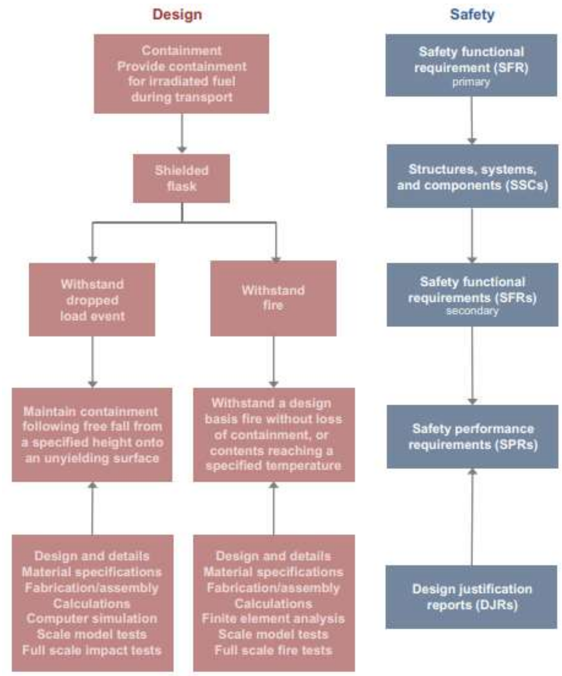

Figure 92 Integrated Safety-led Design Process

Discussion and Conclusion

The outcome of the above assessments and nuclear safety led design approach may result in a need to deviate from traditional maritime structures design and design processes to adequately address the hazards identified and provide the required design substantiation to achieve the fundamental nuclear safety objective. The Claim-Argument-Evidence (CAE) philosophy requires that any claim is justified for safety and is supported by evidence.

Australian engineers now need to consider and learn a new way of thinking; the nuclear mindset.

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U.S. Navy's Ambitious Infrastructure Upgrade: Dry Dock 5

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Summary
The United States Navy's comprehensive, 20-year plan to modernize its four U.S. naval shipyards through the Naval Sea Systems Command's Shipyard Infrastructure Optimization Program (SIOP) has as its objective to replace its aging graving dry docks as part of this program. Most of these graving docks were constructed in or before the first half of the twentieth century with only two new graving docks constructed in the last 55 years. With new dry docks designed to be sustainable and resilient, the Navy can maintain its ships and submarines, while reducing maintenance costs associated with inefficient and obsolete facilities.

Keywords: resilient, sustainable materials, dry dock, submarine, Hawaii, DD5, U.S. Navy

Introduction

The Dry Dock No. 3 Replacement Project is constructing a concrete dry dock, the first dry dock at Pearl Harbor Naval Shipyard (PHNSY) since 1943, and it will address resiliency areas of concern at PHNSY including flooding, seismic, utility resiliency and environmental impacts. This dry dock, designated as Dry Dock 5 (DD5), will be located northwest of the existing Dry Dock No. 3 (DD3) and sited over the existing decommissioned Marine Railway.

Design Criteria

Design criteria used for the Project includes requirements from the Unified Facilities Criteria (UFC), which apply to the U.S. Department of Defense:

- UFC 4-213-10, Graving Dry Docks, 18 May 2020
- UFC 4-152-01 Design: Piers and Wharves
- UFC 3-301-01 Structural Engineering
- UFC 3-201-01, Civil Engineering, with Change 4, 28 Sept 2020 and
- MIL-STD 1625D(SH) Safety Certification Program for Drydocking Facilities and Shipbuilding Ways

Dry Dock Characteristics

The dry dock, designed by MNDPI JV and NAVFAC Pacific between 2021 and 2022 and currently under construction, will be a soil-supported, non-relieved gravity dry dock with superflooding capability. The dock is roughly 206 meters long by 30 meters wide and 17 meters deep to accommodate submarine maintenance. The cross-section is typical of a non-relieved gravity dry dock with vertical thick concrete walls and floor. The dock has utility galleries and crane rail track along both sides and mooring hardware for operational use.

A steel flood-through caisson is used for dry dock closure. The caisson is 36 meters long by 7 meters wide and 17 meters tall, consisting of a steel beam superstructure overlaid by steel plating. A steel-reinforced rubber seal system is designed to sit against stainless-steel-faced concrete. The caisson is designed to be reversible and sit in one of two seats to allow for maintenance.

Flooding and Dewatering Systems

Pumping and flooding systems control the emptying and filling of the dry dock and must be done in a gradual and controlled manner to allow the vessel to seat slowly down on the blocks and to prevent movement of the blocks during inrush of water.

The DD5 caisson has flood-through pipes and pumps used for flooding the dry dock. The Dewatering Pumphouse handles all dewatering and drainage for the dock basin. The structure is configured as two identical rectangular wet wells aligned perpendicular to the dock basin. Two wet wells are provided for improved system resilience, allowing for an individual wet well to be removed from service for repair while the other wet well remains operational, and maximizes the separation of clean stormwater from seepage and process flows. Each wet well is connected to the dry dock with a dedicated dewatering tunnel and dock floor sump pit. The water is processed through a basin water treatment facility before being discharged.

Figure 93.Rendering of New Dry Dock 5. Project. Shows graving dry dock No. 5 in forefront. This dock is capable of supporting maintenance and repair of naval vessels. Source: Moffatt & Nichol

Resiliency Areas of Concern

To help inform the Project's design criteria and to address the resiliency areas of concern, numerous studies were conducted including sea level rise and coastal analysis to address flooding, ground motion studies to address seismic activity, and environmental impact assessment to address environmental concerns.

Coastal and Flooding

The coastal engineering report documented the metocean conditions (water levels, winds, waves, currents, hurricanes, and tsunami) that govern the design of the project elements. It also included determining detailed design criteria for design flood elevations, wave runup and overtopping, and wave and tsunami loads. Wave modelling was conducted using MIKE 21 Spectral Wave Model for nearshore and offshore waves. Tsunami modelling was conducted using Mike 21 Flow Model FM 2-D Hydrodynamic Model. These coastal models were used to determine the design ground elevation for the 100-year design.

Seismic

The ground motion study informed site-specific earthquake ground motion and soil structure interaction criteria.

The performance of the dock after a seismic event is governed by MIL-STD-1625D(SH). For Level 1 (475-year return period) seismic event, the dry dock must be undamaged. For Level 2 (2,475-year return period) seismic event, all damages must be repairable. Additionally, the vessel must be allowed to safely undock after the Level 2 event. The safe undocking requires critical utilities to be operational while there is no uncontrolled flooding. The full operation of critical utilities is enforced through the support design and accommodating the expected movement of the dry dock. Uncontrolled flooding of the dry dock is prevented by making sure that the cracks that are formed are not excessive and do not allow water to infiltrate in an uncontrolled manner. Additionally, the dry dock entrance walls cannot deform excessively so that the walls pinch the caisson.

Three-dimensional (3D) non-linear response history analysis (NLRHA) is performed to evaluate the dry dock seismic performance under the Level 2 seismic hazard using ABAQUS. A two-dimensional fully coupled dry dock seismic finite element analysis was conducted using PLAXIS analysis software and determined the dry dock seismic response due to the transverse and vertical earthquake ground shaking.

Environmental

Environmental assessment and best management practices (BMPs) are being used in accordance with the multitude of State and Federal environmental permits. Water quality and turbidity monitoring, above- and below-water noise monitoring, terrestrial and marine mammal surveys and monitoring, coral relocation, and mitigation are among the BMPs being incorporated into the project.

Dredge material characterization and best reuse and disposal practices are used to determine which, if any, material can be reused for land reclamation areas to support the dry dock.

Utility Resiliency

Investing in infrastructure upgrades, improving grid resilience, and ensuring that critical equipment is protected from flooding and other natural hazards is mandatory to improve the reliability and safety of the utilities' operations. The project provided the chance to improve the aging infrastructure of a pre-World War II military base. A new telecommunications and electrical backbone was designed, including a new electrical substation from the Hawaiian Electric Company to support the power needs of the new dry dock and surrounding facilities. An upgraded, more efficient sanitary sewer pumping station system, potable and fire water systems, and an efficient stormwater capture system meeting low-impact development requirements were designed to make the project more resilient.

Sustainable Design

Several design strategies were used when considering sustainable design. The most common strategies included concrete mix design optimization, selection of reinforcing steel based on corrosion performance, and low life-cycle costs. Each of these strategies influence the design in a unique way. A combination of these strategies will be used to gain advantage from their synergistic relationship and will allow for the design of a 100-year service life while keeping material and labor costs low. Additionally, aggregate selection and concrete mixture components will be controlled to help prevent alkali silica reaction (ASR). Concrete temperatures during placement and curing will be controlled to help prevent delayed ettringite formation (DEF) and to minimize shrinkage and thermal cracking.

Conclusion

DD5 was designed for 100-year service life with consideration for resiliency and sustainability including climate change and sea level rise with specific focus on flooding, seismic, utility resiliency, historic and environmental impacts.

References

Relevant UN SDGs (*https://sdgs.un.org/goals*)
9, 11,14.

Digital Twin Technology for Intelligent Monitoring and Maintenance of Port Infrastructure

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Summary
In this study a Digital Twins (DT) technology has been developed to automate monitoring of port infrastructure. By integrating Internet of Things (IoT), Finite Element Modelling (FEM) and Artificial Intelligence (AI), a digital twin of a port structure located in Dalrymple Bay Coal Terminal (DBCT) was created. The DT was able to visuals the structural integrity of a steel structure within the port infrastructure, which needed to be in service 24/7. This innovative technology enables remote and automated monitoring and maintenance of port infrastructure, eliminating the need for regular visual inspections.

Keywords: Digital twin, Internet of Things, wireless sensors, structural integrity assessment, real time monitoring

Introduction

Port infrastructure are of the utmost economic and social importance to Australia. Our country relies on sea transport for 99 per cent of exports, and the nation has the fifth-largest maritime freight volume in the world. Every day, $1.2 billion of trade moves through Australian ports [1]. Port infrastructure is critically dependent on the availability, reliability and capacity of the operating structures. Maintaining port structures, especially those located offshore, can be challenging due to exposure to harsh environmental conditions such as salinity, cyclical waves, strong winds, and tidal forces. This complexity distinguishes it from maintenance for structures built on land.

The failure at Port Hope Harbour in Ontario Canada, 2018, raised serious human health and safety concerns due to potential spread of nuclear contaminations [2]. More recently (in June 2021), a massive structural failure of two container cranes in Kaohsiung port (Taiwan) led to serious human injuries and more than $21M in failure costs [3]. When a structure within port infrastructure fails, the resulting problem often is not just the cost of repair but also the forced downtime. A port standing still may cost thousands of dollars every minute. For the West Coast Port in US, the estimated shutdown cost (forced by protestors in memory of George Floyd) was $2B a day [4].

Monitoring and maintenance of structural assets are primarily qualitative, and prediction of maintenance actions based on these is subjective. The current methods of monitoring ports and identifying structural defects rely on periodic site inspections to assess structural health. This process is inefficient, expensive, time consuming, prone to human error, and disruptive to port users.

This presents the steps taken to develop a sophisticated digital twin technology for automated monitoring and proactive maintenance of a port structure at DBCT.

Digital twin of Dalrymple Bay Coal Terminal

The port structure used for this study is DBCT, situated at the Hay port, Queensland, Australia. It is known as one of Australia's largest coal terminals. This port is an interconnector to a number of ports worldwide which mined, thermal and metallurgical coal for nearly 40 years (since 1983). The port structure consists of three rail receival stations and a stockyard covering approximately 67 hectares. According to reports from DBCT, the terminal contributed 13% of global coal mining in 2021. It is projected that production will reach to 99.1 Mtpa by 2028 (Infrastructure, 2022).

The port structure is continuously in operation where the coals are transported to the rail receival stations and stored in the stockyard. Subsequently, the conveyor system is used to transport coal from the stockyard along a 3.8 km jetty to the wharf or ships for direct loading. Hence, the conveyor plays a vital role in this process. In this study, a typical gallery of the Jetty Conveyor that extends 4 km towards the offshore area at DBCT is considered. **Error! Reference source not found.** shows the approximate location of the selected jetty conveyor gallery at DBCT.

In this project the digital twin of part of the jetty conveyor was created as a prototype which can be extended for the whole infrastructure.

Figure 94 Approximate location of the selected jetty conveyor gallery at DBCT

Technology integration to create digital twin

Developing digital twin technology will involve advancing and integrating the IoT, FEM, AI, and 3D visualization (Fig 2). This knowledge will transform reactive and subjective visual inspection into a proactive and objective planned approach based on real-time data collected remotely through wireless sensors. The industry will benefit from knowledge and technology development in: (1) dealing with uncertainties inherent in the exchange of data between different systems (i.e., physical vs digital) over a port life cycle; (2) decreasing the significant costs and risks involved in Structural Health Monitoring; (3) creating a real-time FEM of deteriorating port infrastructure in situations where significant uncertainties on material properties and loadings exist; (4) developing accurate, reliable and verified techniques for simulating what-if scenarios that support maintenance decisions

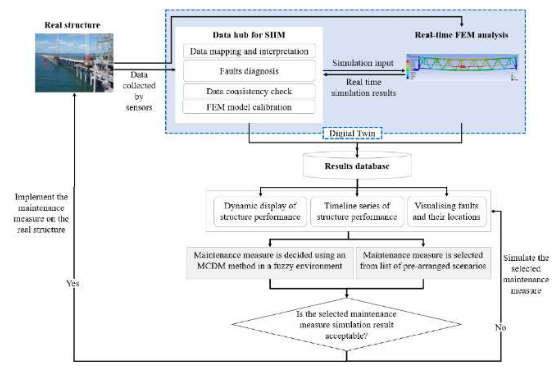

Figure 2 Developed methodology to create digital twin of port infrastructure [5]

The selected structure at DBCT was instrumented with 3 wireless sensors, including one strain gauge and two tilt meters. Then, an inverse finite element model was created using Artificial Neural Networks. This model could utilise sensor data to predict loading on the structure and conclude stress distribution and deflection for all structural components. This will then be visualised in 3D (Fig 3). A Machine Learning algorithm was also developed, enabling the asset owner to predict structural integrity of the infrastructure in the future. That will help to determine when and where failure might occur in the future.

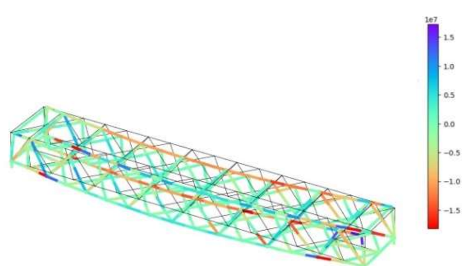

Figure 3 Real-time visualization of the stress variation of the selected jetty conveyor at DBCT port structure

Discussion and Conclusion

FE-based digital twins can play a vital role in the structural integrity assessment of port infrastructure. This study developed a novel digital twin solution that incorporates artificial neural network algorithms for a port structure in Australia to assess its real-time structural integrity. The port structure at DBCT was considered as the case study, and the digital twin model of that structure was successfully implemented.

The structure was instrumented with sensors (one strain gauge and two tilt meters) to measure the structural response. An artificial neural network-based model was used as a surrogate for real-time FE modelling. The developed digital twin for this port structure could visualize the stress distribution through individual members of the 3D structure, enabling asset owners to observe the structural integrity of the infrastructure in real-time, and make timely and optimal maintenance decisions. The DT will equip port asset owners with an advanced practical tool for inspection and maintenance management, thereby increasing their competence for the whole life management of infrastructure.

Acknowledgements

The authors would like to acknowledge the contribution of Sanduni Jayasinghe, Amir Sidiq, Tisal Nanayakkara, Azadeh Alavi, Farham Shahrivar and Zhiyan Sun in this research.

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Relevant UN SDGs (***https://sdgs.un.org/goals***)

This project addresses the following UN SDG: 9, 11, 12 and 13.

Nature of Cross currents at River confluence

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Summary
Cross-currents at river confluences pose a significant challenge for inland navigation, causing lateral drift, reduced manoeuvrability, and increased travel times. This study investigates the effectiveness of T-head spur dikes to improve navigability at confluences. Experiments were conducted using various configurations, such as spur dike length (L_{eff} = 0.1 – 0.3 W, where W is the width of channel), location (L_d = 2 – 8 L_{eff} from junction corner), orientation (θ = 30° – 90° to the bank) and flow rate (discharge ratio, Q_r = 0.2 – 0.8) to assess the extent of the cross-current influence zone. The T-head spur dike with L_{eff} = 0.2W, θ = 90°, and L_d = 6L_{eff} is found as the optimum configuration. This optimal configuration reduces the extent of the high-velocity zone by up to 100% laterally and 125% longitudinally compared to the uncontrolled confluence. These findings suggest that T-head spur dikes can be a valuable tool for enhancing navigability and safety at river confluences across a range of flow conditions.

Keywords: Cross current, River confluence, Inland Navigation, T-head spur dike.

Introduction

Rivers typically exhibit dominant longitudinal currents with relatively weak transverse (cross-currents) and vertical currents. However, specific sections, such as confluences, bends, and outfalls, experience significant cross-currents that can significantly challenge safe navigation. When an inland vessel encounters a region with strong lateral forces, the sudden increase can cause the vessel's bow to deflect upon entry (Ross, 1984). This deflection can lead to a rotation that intensifies as the vessel progresses further into the cross-current zone. Additionally, persistent cross-currents concentrated around the vessel's center of gravity can cause significant transverse displacement, potentially reaching up to twice the vessel's width (Ross, 1984). This lateral shift creates a risk of collision with other nearby vessels. Consequently, mitigating the influence of cross-currents is crucial for ensuring the operational safety of vessels navigating river confluences. River training structures such as spur dikes can be used to alter the flow field and reduce the extent of cross-currents. This paper investigates the effectiveness of T-head spur dikes in improving navigability at river confluences.

Experimental methodology

Experiments were conducted in a 90° river confluence model. The flume inlet consisted of a stilling tank, a gravel bed, and honeycomb panels positioned between baffle walls. This configuration, combined with a sufficiently long channel, effectively dampened flow disturbances induced by the pump and ensured fully developed flow entering the junction point. An adjustable tailgate was placed at the outlet to set the flow depth (h), measured by a point gauge. The horizontal flume had a negligible slope of 0.002. The bed was composed of a 0.25m layer of non-uniform sand with size d_{50} = 0.6mm. The flow was recirculated using a pump-pipe network controlled by an automated SCADA system that adjusted a valve based on data from electromagnetic flow meter.

Experiments were conducted with and without spur dikes to evaluate the effectiveness of spur dike on navigability. Initially, experiments without spur dikes were conducted to establish baseline hydro-morphological characteristics at the confluence. Subsequently, various spur dike configurations with varying length (L_{eff} = 0.1, 0.2, and 0.3 W), and orientation (θ = 30°, 60°, and 90° relative to bank) and location (L_d = 2, 4, 6 and 8 L_{eff} from the junction corner) were tested. The velocity measurements were taken only for the optimum spur dike configuration (L_{eff} = 0.2 W, θ = 90°, and L_d = 6L_{eff}) with the least scour depth and blockage ratio. The spur dike length (l = 6–12 cm) was within 20% of the flume width (W) to ensure no contraction scour [1]. The orientation (θ) was selected based on literature [2, 3]. Four discharge ratios (Q_r) of 0.2, 0.4, 0.6, and 0.8 were investigated. Experiments were conducted under a steady subcritical flow regime with a high Reynolds number to minimize scale effects. Also, both the flow (R_e) and particle (R_e^* = 4.8 > 4) Reynolds numbers are sufficiently high to neglect the viscous and scale effects [4, 5].

Experiments were conducted by gradually releasing the Water to establish steady flow. Flow discharges were maintained using the SCADA system. Scour depth was measured using an Ultrasonic Ranging Sensor positioned at maximum scour location. A quasi-equilibrium condition (characterized by variation in scour depths less than 2mm for 4 hours) [3], was achieved within three to five hours after the commencement of the experiment. The experiments continued for another 2 hours, after which velocity measurements were conducted. Following the velocity measurements, the flow was stopped, and water was drained to facilitate the measurement of bed elevation using a Laser Distance Meters.

Results

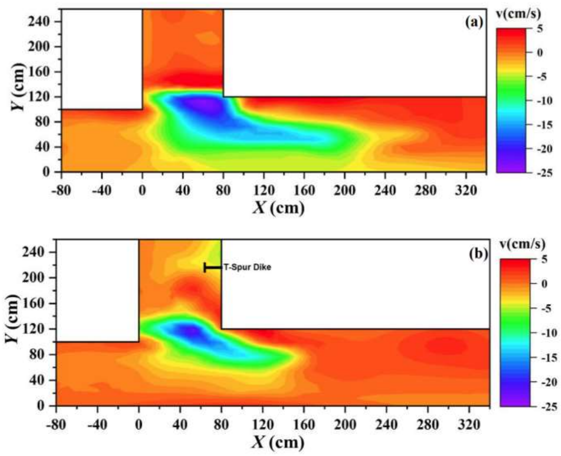

Figure 95 Cross current distribution at river confluence with discharge ratio (Q_r) of 0.8 (a) without spur dike and (b) with spur dike.

Figure 17 illustrates the influence of a T-head spur dike on cross-current distribution at the river confluence with a Q_r = 0.8. The plot shows that lateral inflow from the tributary significantly increases cross-stream velocities in the main channel. Velocity increases are most pronounced near the scour zone (within 60 cm of the bank, approximately half the channel width), reaching values exceeding 15 cm/s. The presence of the T-head spur dike effectively confines these strong cross currents to a narrower region (around 40 cm from the bank), with velocities gradually decreasing towards the outer bank.

Table 13 Variation of cross current influence zone at river confluence

Q_r	Without Spur dike		T-head Spur dike	
	W_c/W	L_c/W	W_c/W	L_c/W
0.8	0.58	2.61	0.29	1.16
0.6	0.42	1.83	0.26	0.92
0.4	0.38	1.24	0.24	0.70
0.2	0.32	0.86	0.19	0.57

The cross-current influence zone, defined as the area exceeding a critical velocity of 10 cm/s [6], was significantly reduced by the optimal T-head spur dike configuration. Table 1 presents the normalized dimensions (width, W_c/W; length, L_c/W) of this zone for various Q_r values with and without the spur dike. The results demonstrate a clear improvement in navigability at the confluence due to the spur dike. At the highest flow rate tested (Q_r = 0.8), the width of the cross-current influence zone was reduced by 100% (from 0.58W to 0.29W), and the length was reduced by 125% (from 2.61W to 1.16W) compared to the scenario without the spur dike. This translates to a significantly larger area within the main channel with more uniform flow patterns, facilitating safer navigation for barges and other commercial vessels. The effectiveness of the spur dike was maintained across all tested flow rates. Even at a lower flow rate (Q_r = 0.2), the width reduction was substantial (68%, from 0.32W to 0.19W), and the length reduction remained significant (51%, from 0.86W to 0.57W).

Conclusion

This study investigated the effectiveness of T-head spur dikes in enhancing navigability at river confluences. Experiments conducted in a laboratory flume demonstrated that using an optimized T-head spur dike in the lateral channel significantly reduces the extent of the cross-current influence zone. This zone, characterized by velocities exceeding a critical threshold for safe barge movements, poses a significant challenge. The optimal spur dike configuration, effectively confines strong cross currents to a narrower region. Spur dikes maintains similar performance across various flow rate conditions. These reductions translate to a broader area within the main channel with more uniform flow patterns, facilitating safer navigation for commercial vessels.

Acknowledgements

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Relevant UN SDGs (*https://sdgs.un.org/goals*)
9, 12, 13, 14.

Reviewing the effectiveness of Climate Change Adaptation outcomes in the Cook Islands: Insights into Mangaia Harbour Development Project

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Summary
Climate change is a major concern for the Cook Islands. The Mangaia Harbour upgrade aimed to combat these climate change effects. With similar projects are planned for the country, understanding the project's direct and indirect outcomes and effectiveness against its intended objectives were deemed necessary. Fourteen in-person interviews and a focus group revealed that economic, health, community, and lifestyle benefits were only partially achieved. This research underscores that community understanding and acceptance are crucial for project success in similar projects, requiring community-driven planning and implementation sensitive to cultural practices to maximize benefits and minimize maladaptation losses.

Keywords: climate change, climate change adaptation, project outcomes, port projects, Mangaia, Cook Islands.

Introduction
Mangaia is the second largest island in the Cook Islands (CI). Its harbour serves the purpose of bringing in resources, fuel, and goods/services to the island. Cyclones in the recent past had left the harbour damaged, The CI government and the Asian Development bank (ADB) co-funded the upgrade project which had a main focus on combatting climate change (CC) impacts. As similar donor-driven climate proofing port projects are planned across the island, the Government and key stakeholders were determined to evaluate the effectiveness and implications of the Mangaia harbour upgrade project. This research intended to understand and explore project outcomes more deeply in order to assess the direct and indirect outcomes on the local community.

Material studied
The main objectives of the project were:

- *Objective 1* related to the harbour operations/functionality: To increase the number of ships for berthing and enable unloading and loading of cargo during 15 knot winds.
- *Objective 2* related to lifestyle: To reduce the number of people and time taken to launch and retrieve fishing vessels by fishermen under adverse weather conditions.
- *Objective 3* related to health and wellbeing: To reduce the number of accidents at Mangaia harbour.
- *Objective 4* related to health and wellbeing: To increase the number of days per annum where the harbour can be accessed safely.
- *Objective 5* related to the community: To increase the number of people and communities benefiting from Mangaia Harbour project.
- *Objective 6* related to the community: To deliver community satisfaction at the end of construction.

Literature
Previous research has underscored the importance of adopting a context-specific and inclusive methodology, encompassing both intended and unintended social consequences, to assess post-completion project performance [1]. This approach highlights the necessity of integrating considerations of other place-specific development goals to ensure positive social impacts. Without a comprehensive understanding of existing localised approaches to addressing specific climate change impacts and community resilience strategies, adaptation mechanisms may inadvertently yield adverse outcomes [2]. Interestingly, a gap persists in the literature concerning ex-post evaluations of climate-related government decision-making and broader post-completion assessments [3-6].

Methods
The project and case study selection was co-developed with key local organisations involved with CC adaptation and infrastructure in CI. Data was collected through 14 in-person interviews and a focus group. Participants included Climate Change Cook Islands (CCCI), Infrastructure Cook Islands (ICI), Ports Authority, National Environment Service (NES), harbour users and community for a well-rounded data gathering approach. The interview and focus group data were validated using photographic evidence, transect walks and other related project documents.

Results
The results of the study are presented in graphical form in Figure 1 below.

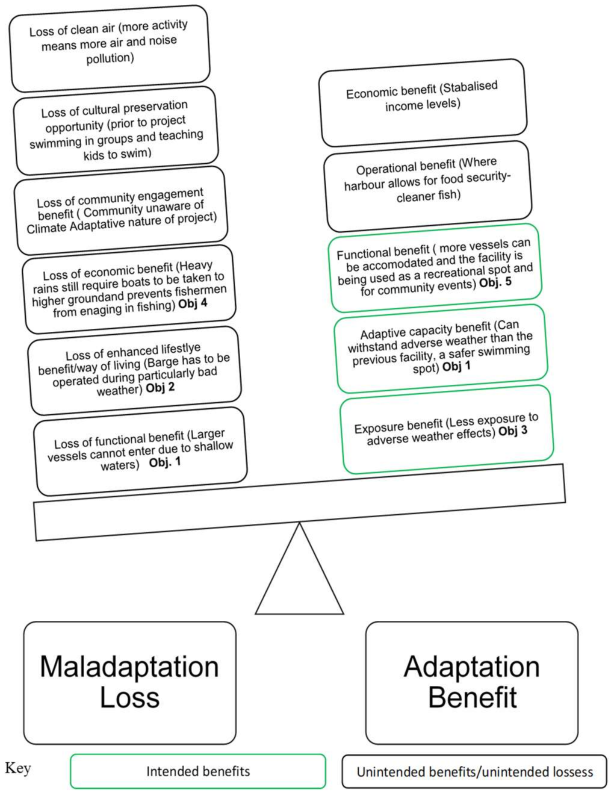

Figure 96: Maladaptation Losses and Adaptation Benefits of Mangaia Port development project in the Cook Islands (Source: Authors)

The findings revealed that the Mangaia Harbour upgrade project resulted in two types of outcomes related to adaptation: maladaptation losses and adaptation benefits. The majority of outcomes were unintended, with a significant portion resulting in maladaptive losses, as illustrated in Figure 1. Based on the findings, Table 1 below provides a review of findings against objectives stated under the section ‘Material Studied’.

Table 14 Mangaia Harbour development project objectives (obj.) versus project outcomes (Source: Authors)

Obj.	Project Outcome
1	*Partially achieved* The wind speed inside the harbour has reduced due to the design adopted. Larger vessels cannot enter the harbour due to shallow waters.
2	*Partially achieved* A barge still has to go out when the sea is rough/during high tide for larger vessels that cannot enter the harbour due to shallow waters. The boats need to be moved into higher ground during adverse weather conditions.
3	*Achieved* The new harbour design at the start caused a couple of drowning incidents but changes meant that the current design provides a safer swimming and fishing spot for the users.
4	*Partially achieved* The harbour can be accessed safely than prior to the upgrade however, it has not provided a complete solution as the harbour is still inaccessible during adverse weather conditions.
5	*Achieved* Unintended benefits by way of a recreational venue means the project has touched a wider community of people.
6	*Mostly unachieved* The users feel that the project has not been entirely successful in mitigating climate change impacts. The ramp needed to be moved to get the best out of the intended benefits which resulted in a subsequent remedial works. Some feel that it has caused a loss of biodiversity The project needs to be in line with other town plans already in place. The project was not positioned and promoted as a climate change adaptation project.

Discussion and Conclusion

The findings of this research confirm that for a project to be considered successful, it needs to be understood and accepted by the community it was targeted to serve. This requires projects to be planned and implemented with the help of the community while being sensitive to their cultural practices [1, 2]. A community-driven approach will ensure a wide array of direct and indirect benefits can be achieved minimising maladaptation losses. Consideration of and connection to existing local/town plans will ensure a more integrated approach to climate change adaptation projects planned for small, tight-knit communities.

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Relevant UN SDGs (*https://sdgs.un.org/goals*) 13

Mutual risk awareness between construction works and live port operations – Seaview Wharf Renewal Project

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Summary
The paper explores the process from concept ideas to how successful procedures were developed, looking at the types of risks involved and how they could be mitigated to best suit the contractor (Brian Perry Civil), the client (Centreport) and the shareholders (The Fuel Industry). The paper focuses on how the H&S, Programme, and Budget are managed so that the contractor can deliver a successful project, the fuel industry can continue to discharge fuel and the client gain an asset built to the highest quality.

Keywords: Progamme, Budget, Safety, Risks, Controls, Seaview Wharf - Wellington

Introduction

Ideally, construction projects run from start to finish with minimal delays ensuring programme, cost and quality are maintained throughout. However, when port operations continue throughout the duration of a project this could create issues. This paper presents how Seaview Wharf Renewal Project has successfully implemented critical controls to allow construction works to proceed alongside berthing of ships, fuel discharge and various other port operations. The project includes heavy civil works to upgrade and extend Seaview wharf in Wellington, New Zealand, rated as the region's second critical lifeline asset [1]. The upgrades are significant to maintaining and extending the lifetime of the structure, which suffered damaged from the 2016 Kaikoura Earthquake.

The complexities of simultaneous construction and fuel discharge on Seaview Wharf

Seaview wharf is an operational fuel wharf, supplying over 1 Million tonnes of fuel in recent years [3] therefore, considered one of Centreport's most valuable assets. Due to it's age and damage suffered in the 2016 Kaikoura Earthquake, Seaview Wharf is currently undergoing major upgrades and repairs to ensure it is as resilient as possible and meets international standards for ship berthing and bulk fuel discharge. Brian Perry Civil (BPC) are the specialist contractor completing the infrastructure works. The scope involves constructing new pile cap structures around the wharf and reinforcing the existing wharf to enhance structural integrity and seismic resilience.

Seaview Wharf's exposed location in Wellington leads to weather-related delays, particularly due to the area's strong, gusty winds and challenging sea conditions. Its position opposite the harbor entrance (Figure 1) emphasis these conditions during southerly winds, impacting the work progress.

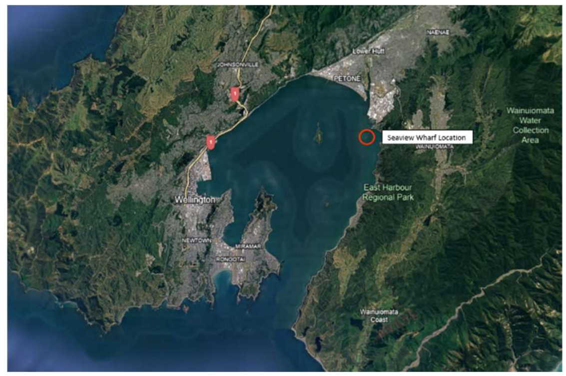


Figure 1 - Location of Seaview Wharf within Wellington Harbour, showing how the Southerly winds significantly effects the construction works.

Before project commenced, it was clear that both the construction works and shipping discharge had to be uninterrupted throughout. Due to the high-risk nature of fuel discharge BPC, Centreport (Client) and the fuel industry had to create robust procedures to maintain operations and safety. At first, it was uncertain how the project risks could be managed and if the shipping operations would delay the programme and overall the budget of the project.

Figure 2 – Tanker berthed in Seaview while construction team is working on the barge.

The Matrix of Permitted Activities

Centreport and BPC both have a rich history on their commitment to safety and it was clear that, for this project to succeed, the safety procedures set at the start of the project had to be robust. However, with so many different construction activities throughout the life of the project a Matrix of Permitted Operations (MOPO) was developed, shown in Figure 3.

During the document development, safety guidelines from the asset owner (Centreport) [2], Fuel industry and contractor (Brian Perry Civil) were consulted.

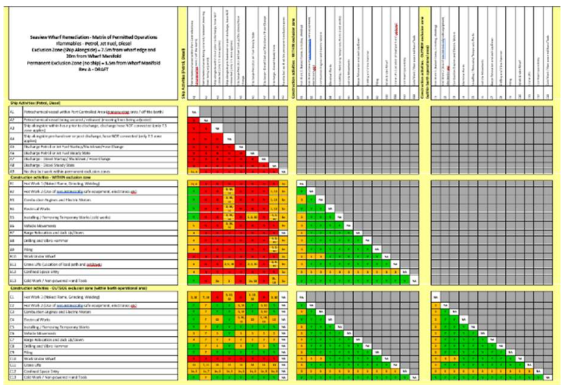
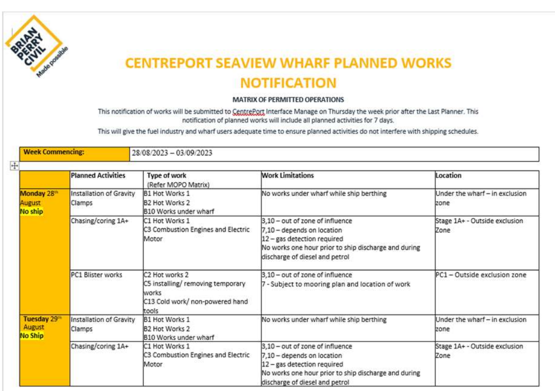


Figure 3 – Example of The Matrix of Permitted Operations (MOPO), showing the complexity of simultaneous activities involved.

While the matrix provided a starting point for discussions, the fuel discharge authority sought visibility into BPC's planned construction activities to ensure that the controls were adequate for the hazards involved. BPC developed a detailed document (Figure 2) outlining day-by-day construction activities, associated hazards, risks, controls, and locations to communicate effectively with the discharge authority.



CENTREPORT SEAVIEW WHARF PLANNED WORKS NOTIFICATION

MATRIX OF PERMITTED OPERATIONS

This notification of works will be submitted to CentrePort Interface Manage on Thursday the week prior after the Last Planner. This notification of planned works will include all planned activities for 7 days.

This will give the fuel industry and wharf users adequate time to ensure planned activities do not interfere with shipping schedules.

Week Commencing:	28/08/2023 – 03/09/2023

	Planned Activities	Type of work (Refer MOPO Matrix)	Work Limitations	Location
Monday 28th August No ship	Installation of Gravity Clamps	B1 Hot Works 1 B2 Hot Works 2 B10 Works under wharf	No works under wharf while ship berthing	Under the wharf – in exclusion zone
	Chasing/coring 1A+	C1 Hot Works 1 C3 Combustion Engines and Electric Motor	3,10 – out of zone of influence 7,10 – depends on location 12 – gas detection required No works one hour prior to ship discharge and during discharge of diesel and petrol	Stage 1A+ - Outside exclusion Zone
	PC1 Blister works	C2 Hot works 2 C5 installing/ removing temporary works C13 Cold work/ non-powered hand tools	3,10 – out of zone of influence 7 - Subject to mooring plan and location of work	PC1 – Outside exclusion zone
Tuesday 29th August No Ship	Installation of Gravity Clamps	B1 Hot Works 1 B2 Hot Works 2 B10 Works under wharf	No works under wharf while ship berthing	Under the wharf – in exclusion zone
	Chasing/coring 1A+	C1 Hot Works 1 C3 Combustion Engines and Electric Motor	3,10 – out of zone of influence 7,10 – depends on location 12 – gas detection required No works one hour prior to ship discharge and during discharge of diesel and petrol	Stage 1A+ - Outside exclusion Zone

Figure 4 - Example of the planned works notification document, showing the detail of the planned work while working under MOPO conditions.

BPC and the fuel discharge agent conduct a pre-start meeting to ensure mutual understanding of concurrent activities and confirm safety measures and emergency procedures.

During construction, momentum and moral of the workforce are important factors to weather activities are completed on schedule. They work hand in hand, if progress is being made this generates momentum and therefore, the moral of the workforce increases. Alternatively, if the project experiences a lot of delays, no momentum is generated and in turn the workforce feels disappointed with their efforts. Great supervisors understand this, and BPC's supervisors highlighted their concern with Centerport at the start of the project. The fear was that the shipping activities would delay the construction works to the point where the workforce would not be motivated, and the snowball effect would drive the programme out by years.

To address this, a compromise was made: BPC would have uninterrupted work periods for two weeks each month (shipping outage), allowing focused progress without interruptions from ship berthing. The remainder of the time the MOPO conditions would be in effect. This in turn generated a culture on site where the workforce become incredibly motivated trying to achieve as much as possible within the two weeks, and on occasion, getting well ahead of schedule.

In conclusion, the implementation of the Matrix of Permitted Operations (MOPO) significantly reduced delays caused by tanker fuel discharges at the wharf, resulting in a reduction of several days in project timelines. This project not only achieved its goal of minimizing disruptions but also established a valuable precedent for safely managing construction activities around tankers. Moving forward, lessons learned from this initiative can inform future projects and contribute to more efficient and secure operations in similar environments.

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Relevant UN SDGs (*https://sdgs.un.org/goals*)

3, 8, 9

Innovations in Shiploader Technology for Wharf Environmental Management – QAL Case Study

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Summary
This paper focuses on the replacement of the Alumina shiploader at Queensland Alumina Limited (QAL) in Gladstone, which faced the critical issue of generating high levels of Alumina dust. Failure to address this problem could have led to environmental non-compliances and impact to the local community and waterways. Advanced dust suppression mechanisms, including cascade chute system, dust extraction systems and air slide conveyors, minimized dust emissions throughout the loading process without increasing loadings on existing wharf. Concurrently, design improvements on the feed conveyors streamlined material handling to further reduce dust generation. Despite implementation challenges, QAL successfully achieved their objectives, setting a precedent for sustainable port engineering practices worldwide.

Keywords: Dust suppression, Shiploader replacement, Environmental sustainability, Alumina loading

Introduction
In the ever-evolving landscape of port engineering, the optimization of operations and environmental stewardship are key considerations. Queensland Alumina Limited (QAL) in Gladstone, Australia, faced a pressing need to upgrade their ship loading systems, not only to tackle dust emissions but also to safeguard the longevity of their aging wharf infrastructure, which, due to its age and exposure to marine elements, had experienced deterioration. This paper describes the innovative ship loader technology that achieved these twin objectives by enhancing dust suppression capabilities on the new shiploader without increasing loading on the existing wharf.

Problem Definition
Alumina, a white, odorless, crystalline powder used for producing aluminum metal, poses a significant challenge in handling due to its easily aerated and airborne dust-prone nature. Prior to its replacement, QALs original Shiploader and conveying system were the source of high alumina dust emissions., As part of a 5-Year Environment Strategy, QAL had committed to reducing these emissions by 2024. The primary causes of these emissions included:

- *Inadequate Containment* **–** Despite the conveyors being typically enclosed, the shiploader's loading boom required intermittent "luffing" (rotation about a horizontal axis) during hatch changes or vessel berthing, which compromised the conveyor seal, resulting in substantial dust emissions.
- *Dust Generation and Collection Issues* - Outdated conveyors and transfer chutes prone to entraining excess air, coupled with undersized or improperly commissioned belt cleaners and dust collectors, allowed alumina product to bypass containment measures and be released as dust.
- *Lack of Flow Control* - Inconsistent feed control to the Shiploader from upstream storage sheds exacerbated dust generation by overwhelming existing materials handling and dust collection systems.

Proposed Solution
In 2021, in alignment with its environmental and community commitment, QAL initiated a program to identify and implement a solution to address the root causes of thesedust emissions. After evaluating available technologies, a solution encompassing the installation of a replacement "slewing" style Shiploader with modern dust control technologies, upgrades to upstream conveyor transfer chutes and dust collectors, and enhancements to automation/control systems of the reclaim systems at the upstream storage sheds was chosen.

The use of a slewing style Shiploader eliminated the need to luff the boom to the same extent for hatch changes as previously, meaning that the conveyor seal at the landward end of the boom could be maintained continuously and the material remain contained. Furthermore, the selected Shiploader incorporated several state-of-the-art dust control features:

- Enhanced "airslide" or "air-gravity" conveyors utilizing low-pressure air to fluidize alumina, facilitating sealed downhill flow with no moving parts to ensure comprehensive containment of product and resulting dust.
- Utilization of a Cleveland™ Cascade loading chute, maintaining consistent slow flow speed through a sequence of inclined cones within a dust containment shroud, preventing air entrainment and dust generation [1].
- Implementation of state-of-the-art self-cleaning dust collectors generating negative pressure within the system to prevent dust escape.
- Improved belt cleaning at the tripper discharge point onto the Shiploader, including primary and secondary cleaners, and “air-knife” cleaners.

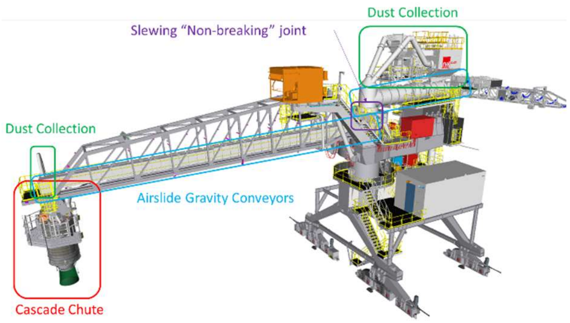

Figure 97 Replacement Shiploader Design (Source: [1] [2]) highlighting key features such as the Slewing "Non-Breaking" Joint, Airslide Conveyors, Cascade Chute, and Dust Collection System.

Project Outcomes and Learnings

In early 2022, the detailed design and supply of the Shiploader and upstream dust control upgrades was awarded to Reel Alesa, a specialist Alumina materials handling supplier. Following design, fabrication, off-site erection and pre-commissioning, the machine was transported to the QAL site via Heavy Lift Vessel (HLV) and delivered, fully assembled, in November 2023 for tie in works and commissioning. In December 2023, the machine commenced full operations with negligible dust emissions, marking a significant success. However, several key learnings emerged from the project:

Firstly, the existing wharf condition was aging and require weight limits to be enforced to reduce risk.. Although a remediation programme was in place, it was critical that the Shiploader wheel loads did not exceed acceptable limits. The use of a low profile, light machine, in combination with modern load limiting control systems and a focus on weight management ensured that the wharf was not overloaded.

Secondly, it was extremely difficult to define measurement and acceptance criteria for the tolerable level of dust post upgrade. This highlighted the need for more quantifiable criteria (e.g. dust 24 hr levels below PM_{10} 150µg/m^3).

Thirdly, constraints posed by the slewing machine's manoeuvrability, especially when loading geared vessels, necessitated comprehensive pre-arrival manoeuvrability and hatch loading studies. This ultimately proved crucial to the development of appropriate vessel load plans and the smooth operation of the shiploader.

Finally, the offshore fabrication and full assembly of the shiploader proved successful in minimizing berth operation disruptions, though stringent third-party quality inspections were essential to rectify significant defects which were identified prior to delivery to site.

In summary, operation to date of the project components achieved its core environmental objective of "zero-visible dust," showcasing the prowess of the project team while operating within the constraints of wharf load limits, geometry, existing operations, time, and cost.

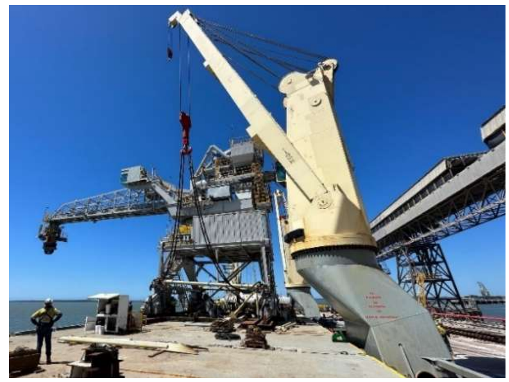

Figure 98 New Fully Assembled Shiploader Unloaded from Heavy Lift Vessel (HLV) and placed onto wharf rails in Gladstone, Queensland (Source: [3]).

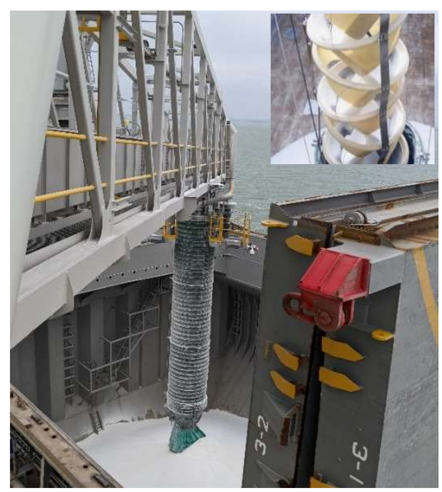

Figure 99 Dust-Free Operation of New Shiploader in Gladstone, QLD, showcasing its close proximity to ship hatches and the innovative Cleveland™ Cascade Chute, featuring a cutaway view illustrating the internal inclined cone concept (Source: [1], [4]).

References

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[3] Small, C (2023) Photo of Shiploader HLV Unloading

[4] Mayers, A (2023), Photo of Shiploader Operations

Structural Health Monitoring System Considering Challenges in Managing Port Assets

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Summary
Port authorities and operators face multifaceted challenges in assessing the structural condition of maritime infrastructure. A primary challenge under scrutiny is the inspection and maintenance of waterborne transport infrastructure, often located in remote and inaccessible areas. This emphasises the pressing need for a more efficient, cost-effective, and technologically advanced approach to these critical areas. This paper, while introducing structural health monitoring system with implementing smart technologies, tries to address these challenges by presenting some examples leveraging PIANC InCom report WG 199.

Keywords: Structural Health Monitoring System, Asset Management, Structural Condition Assessment, Maritime Infrastructure, Dalrymple Bay Terminal.

Introduction

Port authorities and operators serve as vital conduits for global trade. Effective port management presents unique hurdles necessitating innovative solutions. Health Monitoring of Ports and Waterway Infrastructure can be ground-breaking solutions for preserving the condition and health of these essential assets.
A primary challenge under scrutiny is the inspection and maintenance of waterborne transport infrastructure, often located in remote and inaccessible areas. The intricate logistics involved in the condition inspection where the framework is depicted in Figure 100, necessitates advanced techniques, such as the creation of supplementary infrastructure for access and the deployment of divers for in-situ inspections of underwater sections. These methods require careful coordination to minimise economic impact due to temporary infrastructure shutdowns.

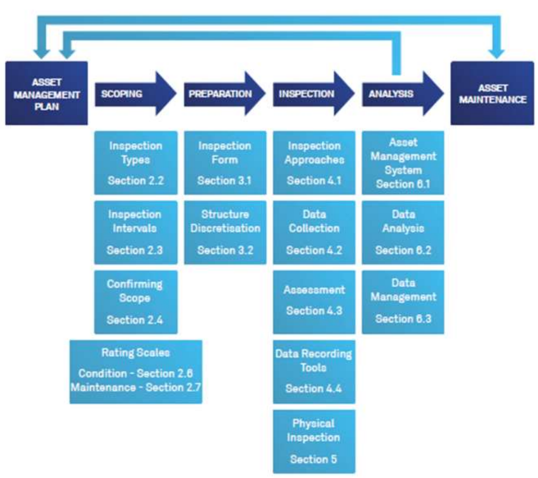

Figure 100: Condition inspection framework [1]

Additionally, the irregularity of these inspections, driven by substantial initial costs and potential economic consequences can be underscored. This emphasises the pressing need for a more efficient, cost-effective, and technologically advanced approach to these critical tasks. Smart technology can reshape these procedures. Innovations like remote sensing, autonomous inspection vehicles, data analytics, and predictive maintenance are at the forefront of transforming inspections into more streamlined, efficient, and sustainable processes.

Structural Health Monitoring System (SHM)

SHM is traditionally defined as a process of detecting damage and characterising the state of a structure by periodically observing the structure via collecting measurements from an installed sensor system [2]. The economic significance of waterways infrastructure, coupled with the difficulties of inspection and maintenance, has led to a growing interest in SHM. This method offers the potential to detect damage, determine its location and extent, assess its severity, and predict the remaining safe service life of structures.

To implement an effective SHM system, proper planning is crucial. This includes identifying the target issues for monitoring, selecting appropriate sensors to measure relevant structural behaviour changes, managing data acquisition and storage, and conducting data processing and analysis. Each step must be meticulously considered to ensure a successful SHM program. The first step after identifying a problem that needs to be monitored, is to align the location of the sensors with the knowledge of the structure leveraged to understand expected structural behaviour. Then, by compiling the expected sensor signals with the measured sensor signals, damage threshold criteria need to be determined. This can be done by utilising various tools, such as data processing, statistical methods, ANN, machine learning algorithms, and AI systems. Data interpretation is a critical aspect of SHM, as sensors alone do not detect damage. Extracting meaningful features from the data and comparing them to known acceptable values are key steps in assessing structural health. The impact of environmental factors, such as temperature variations, on data must also be considered. With this information, proper action can be triggered based on the interpretation of the measured sensor signals against the defined damage threshold criteria. Figure 2 simply depicts this process. It should be noted that data acquisition and management, discussing parameters such as sampling rates, signal conditioning, power supply, and data communication play important roles in a successful implementation of an SHM system. Additionally, the need for robust data storage solutions and considering cybersecurity implications should be considered.

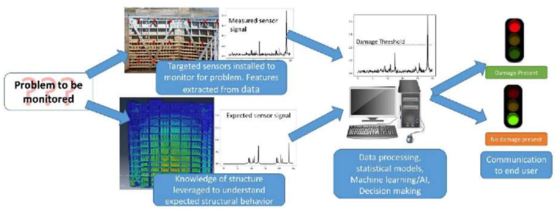

Figure 101: Overview of an SHM system [1]

Practical Examples

1. Condition Assessment of LT Rail Girders on a Wharf Structure: The rail girders of a wharf structure, which provide Long Travel facility for the tripper of the shiploader, consist of two 900WB175 continuous beam profile on the seaward and landward sides, with a rail beam placed on their top flanges and a typical 13 m supports. After being in service for a long-term under dynamic loads and being prone to harsh tropical environmental conditions, reassessing these girders' capacity and structural behaviour against extreme live loads considering their current structural condition was required. For this purpose, the structural behaviour including the section utilisation of rail girder against extreme load cases, was studied through Finite Element Analysis (FEA) modelling. Additionally, the frequency analysis of the shiploader long travel system was employed by collating data from the last five years to identify which spans were experiencing the highest number of cyclic loads. Based on this, three consecutive spans were selected for further assessment and monitoring. Twelve wireless sensors were chosen and installed on the top and bottom flanges in the mid-span of these nominated consecutive spans (Figure 102).

2. Condition Assessment of Jetty Conveyor Truss Section: There are more than 150 truss galleries with a typical 24 m span, facilitating the transit of bulk material over 4 km jetty structure from onshore to offshore loading systems. It is important to understand the structural behaviour of these hollow member truss sections considering their current profile under the actual and extreme loads. For this purpose, two tilt meters, one strain gauge, and one vibrometer were considered and installed on various locations of a nominated typical gallery, as shown in Figure 103. The structural behaviour was monitored, analysed, and assessed against an FEA model. Section utilisation and maintenance strategy were two targeted outcomes from such a monitoring system. Additionally, these sensors were used to develop a concept for a digital twin system.

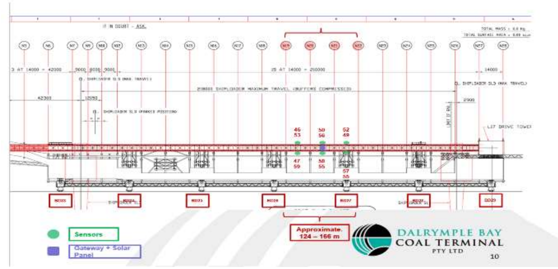

Figure 102: Location of wireless sensors on LT Rail Girders

3. Snapback Risk Management & Quick Release Hook Condition Assessment: For better risk assessment of snapback hazards, monitoring of online loads on mooring ropes has been considered through the installation of load cells on each Hook of a quick release mooring system.

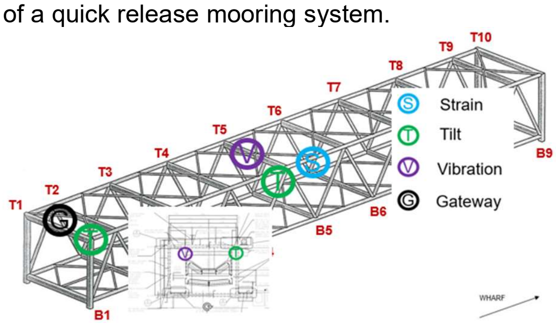

Figure 103: Location of sensors on a nominated typical jetty gallery

Concluding Remarks

In this paper, while addressing some of the key challenges that exist in the condition assessment of port and maritime infrastructure, an attempt has been made to present a successful framework of a structural health monitoring system leveraging PIANC InCom Report WG 199. Additionally, it has been demonstrated through a few practical examples how the implementation of a proper SHM system can contribute to a better and more seamless assessment of structural condition.

References

[1] Ports Australia (2022). Wharf Structures Condition Assessment Manual, Ports Australia.

[2] PIANC InCom WG 199 (2023). Health Monitoring of Port and Maritime Structure,

Relevant UN SDGs (*https://sdgs.un.org/goals*)

This paper addresses SDGs No. 9 and No. 17.

Risk and Resilience in Port Design Option Assessments

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Summary

Resilient port infrastructure is essential to achieve continuity of operations in the event of disasters. Port infrastructure development usually involves a basis of design developed together by port engineers and the port owner, followed by a multi-criteria analysis to identify the preferred option. However, more resilient infrastructure usually comes at a cost. A rigorous assessment of risks to infrastructure, the consequence of such risks being realised, and the level of resilience the asset owner can afford needs to be agreed as part of the option selection process. This will ensure the balance between resilience and cost is understood before detailed design is undertaken.

Keywords: Risk, resilience, climate change, disasters.

Introduction

This paper examines the importance of identifying and understanding all risks to infrastructure, likelihood of such an event occurring, and the consequence of such an event. The costs associated with mitigating such risks can then be assessed against the impact to ongoing operations to enable the right development option to be selected.

Ports often provide the only point of access for goods entering and leaving a region. In the event of large scale natural disasters, the port may also provide the only emergency access to a region. Therefore it is important to ensure port infrastructure is sufficiently resilient to withstand disasters.

It is important that the asset owners are fully informed of the resilience of the proposed infrastructure such that the right balance of risk and mitigation is achieved to ensure the most cost effective option is selected. A risk assessment process involving the asset owners, where risk and consequence can be discussed and understood, and nature and cost of mitigations can be discussed and agreed, will assist in the selection of the appropriate development option.

Main body

It can be costly to ensure that port infrastructure is resistant to large scale events, hence the need to ensure that all risks to the infrastructure and ongoing operations are understood. The level of resilience required can then be identified in order to achieve a balance between the capital cost of achieving resilient design, the likelihood of the event occurring, and the consequence of such an event.

Port infrastructure development usually involves a basis of design developed together by the port engineering consultant and port owner, followed by a multi-criteria analysis to identify the preferred option. However, more resilient infrastructure comes at a cost. A rigorous assessment of risks to infrastructure and the level of resilience the asset owner can afford needs to be undertaken and agreed as part of the option selection process. This will ensure the balance between resilience and cost is understood before detailed design is undertaken.

Typical examples of risks influencing design of port infrastructure include:

- Seismic events affecting the wharf type selected;
- Seismic events affecting the amount of ground improvement required for breakwaters, reclamation and wharves;
- Storm events damaging breakwaters, revetments and beaches;
- Sea-level rise inundating infrastructure;
- Floods restricting site access; and
- Vessel navigation error resulting in impact with infrastructure.

The consequence of a seismic event can include:
- significant damage or loss of wharves,
- slumping of breakwaters and revetments,
- settlement of reclaimed areas, and
- damage or loss of buildings.

Such impacts can result in a reduction or halt to operations for significant periods of time. However, the risk of such events occurring can be very low. Therefore it may not be appropriate to invest significant capital expenditure to eliminate the risk of damage, but rather reduce impacts with some repair required following an event.

The consequence of storm events, sea level rise and flooding on breakwaters, revetments, beaches, reclamation and transport corridors may be relatively minor, but the frequency and intensity of such events occurring are likely to increase with climate change. The preferred mitigation may be to undertake ongoing repair over time rather than upgrade infrastructure to avoid damage.

Ongoing operations of port infrastructure following a disaster may not only affect port revenue. Ports often provide the only point of access for goods entering and leaving a region. In the event of large scale natural disasters, the port may also provide the only emergency access to a region. Therefore it is important to ensure port infrastructure is sufficiently resilient to withstand disasters.

It is important that the asset owners are fully informed of the resilience of the proposed infrastructure such that the right balance of risk and mitigation is achieved to ensure the most cost effective option is selected. A risk assessment process involving the asset owners, where risk and consequence can be discussed and understood, and nature and cost of mitigations can be discussed and agreed, will assist in the selection of the appropriate development option. Such assessments should involve workshops with engineers, asset owners and operators, with sufficient information presented at the workshops to ensure the risks, consequence to ongoing operations, mitigation options, and costs associated with mitigations are tabled and understood by all involved in the option selection process.

Discussion and Conclusion

Through thorough risk-based assessment of infrastructure risks and resilience, the right balance of risk and mitigation can be achieved to ensure the most cost effective option is selected. This will avoid the development of unnecessarily expensive or insufficiently resilient infrastructure.

Marine Drilling and Blasting, and Social Licenses to Operate

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Summary
In today's landscape, there is a growing expectation for sustainable practices to be adopted as standard. Countries, the public and communities are increasingly advocating for transparency, adherence to higher environmental standards, and meaningful involvement in decision-making processes, particularly on proposed projects involving Drilling and Blasting (D&B) in marine environments. This paper discusses marine D&B projects and restoring D&B's Social License to Operate (SLO) by gaining community and public trust.

Keywords: Marine, Drilling and Blasting, social license to operate, environment

Introduction

Marine D&B has not been utilised as much as in the recent past, with the commonly perceived reason given being its poor social license in an increasingly environmentally aware public.

However, the main reason for the decline in marine D&B projects is economic rather than perceptions of environmental destruction. D&B is expensive and adds around a tenfold increase to dredging costs.

Much of today's D&B experience and technical refinement was acquired during projects to expand and deepen post-war ports, in line with the rapid growth in the transport of bulk cargos and a rapid increase in ships' size and draft.

Initially, port expansions remained within the capacity of existing ports and their urban centres. However, this required the excavation of previously avoided bedrock, which lead to the introduction of marine D&B projects.

Over time the demand for port expansions lessened due to stability in cargo vessel sizes and pressure on terrestrial infrastructure within urban centres. However, global south economic growth and the emergence of new industries continued the demand for new ports. This demand brought with it more opportunities for port design alternatives and options for avoiding costly rock D&B projects.

At the same time social priorities changed, and so potent has the term "marine blasting" become that it is a much sort after trigger term to be included in any anti-development campaign.

Marine D&B Overview

Because of this prevalent emotive community reaction to marine D&B, restoring D&B's social license has become a herculean task. The emotive reactions mainly centre on an instant perception of marine fauna deaths and injury, particularly in dolphins and whales. It can, for those with only a general interest in the subject, become a simple modern-day allegory of good versus evil.

Yet when executed competently, D&B keys in nicely with typical dredging environmental requirements. It is rare for D&B to be carried out without dredging and is usually a pre-treatment for the material to be dredged.

D&B fragments rock in situ without cratering. It uses drill patterns, charge sizing and initiation delays to limit ground vibration and other deleterious effects. Consequently, benthic habitat destruction is normally limited to the dredging envelop. The same applies to water quality, sedimentation and plume generation.

The exception is damage caused by the blast itself, which produces seismic ground waves and mid-water shock waves. Seismic waves, if not controlled, threaten damage to man-made structures and buildings, including any vulnerable indigenous heritage structures, while in-water shock waves can, and will, kill or injure marine fauna.

Both these types of waves are manageable. However, mitigating them adds to D&B costs. This is especially true for in water shock waves, as their mitigation necessitates greater safe blasting radiuses and often involves long delays and interruptions if fauna strays into the non-safe zone.

Marine D&B's Social License to Operate

Sociologists Thomson and Boutilier [2] proposed that the key to obtaining SLOs was to identify any parties (i.e., stakeholders) affected by, or with an interest in, the project and getting their approval for it. They added that although obtaining all regulatory licenses, such as environmental approvals, was a necessary step, mutual trust was required to gain stakeholder approval for environmentally sensitive projects.

To this end, Thomson and Boutilier [2] developed their "Four Factor Model", which distinguishes between Project Legitimacy and Trust. This was adapted by Biernaux and Miller [1] in their definition of a "Responsible Project". Their adapted model is provided in Figure 1 below.

FOUR FACTOR MODEL				
Level & Label		Description	Role in Determining SLO Levels	Legal Licences
TRUST LEVEL	4 Institutional Trust	Relations between stakeholders and proponents are based on regard for each other's interests.	Without this, psychological identification with the project is unlikely.	Stakeholders and the wider community can clearly see that the approval conditions are being met and maintained during the construction and operational phases. This applies in particular to environmental approvals.
	3 Interactional Trust	Proponents listen and respond to stakeholders, keep promises and engage in dialogue and reciprocity.	Without this, stakeholder approval is less likely. If both 2a and 2b are lacking, stakeholder approval would be rare. If both are present, approval is likely.	Environmental and other approvals including conditions, have been clearly communicated to stakeholders.
LEGITIMACY LEVEL	2 Socio-political Legitimacy	Proponents contribute to the well-being of the region and respect the local way of life. Meets stakeholder expectations of their role in the community and acts according to stakeholders view of fairness.	Without this, stakeholder approval is unlikely.	Environmental and other approvals have been obtained.
	1. Economic Legitimacy	The project offers a clear economic benefit to the community.	Without this, most stakeholders will withhold or withdraw the SLO.	

Figure 1 Boutilier and Thompson's Four Factor Model as adapted by Biernaux & Miller (Source: [1]).

Biernaux and Miller [1] also developed the graph in Figure 2 below of all stakeholder community types and their likely percent interest in such projects. They state that it is important to involve all below community types in all marine D&B projects.

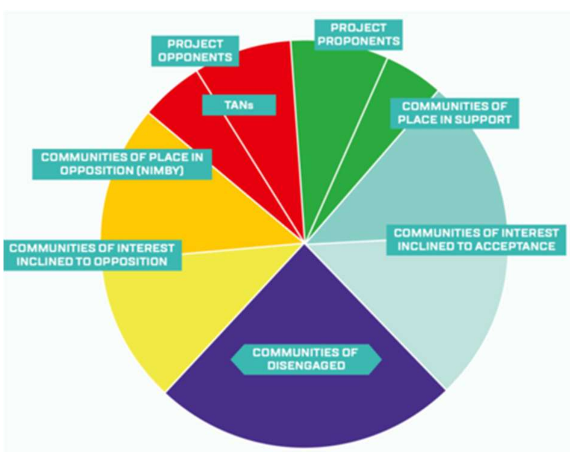

Figure 2 Stakeholder community types by Biernaux & Miller (Source: [1]).

D&B Controls and Gaining Stakeholder Trust

Obtaining regulatory D&B licenses is seen as part of gaining Project Legitimacy. Apart from environmental approvals, there are also strict controls around handling explosives. However, to gain stakeholder Trust there must be honest and informative dialogue without spin.

Communities' and activists' objections originate in the perception that D&B recklessly injures marine fauna and damages community assets. Therefore, a responsible D&B project must start with honestly informing stakeholders of project risks and controls.

All previously mentioned blast shock waves vary depending on the size of the instantaneous charge and their decay over distance. Finding the safe relationship between charge and distance is a critical control for these risks and ensures the safe management of marine D&B works.

This is achieved through a program of non-lethal test blasting undertaken to identify ground factors and shock transmission factors. Furthermore, devices such as air curtains should also be trialled as part of this program.

To gain stakeholder trust, they need to be informed of site controls in place, especially of controls to safeguard fauna, such as those mentioned above. It is necessary for owners and contractors to invest in avoiding fauna death or injury, which involves undertaking baseline studies of local marine fauna behaviour, carrying out continuous marine fauna surveillance during projects and patrolling the safe distance perimeter prior to blasting.

Finally, to develop and maintain mutual trust, proponents must share their findings and projects' progress with stakeholders. They must demonstrate that promises are being kept.

References

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Relevant UN SDGs (*https://sdgs.un.org/goals*)

9, 12, 14

Mandorah Marine Facility – Alternative Design

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Summary
The Mandorah Marine Facility is being developed to not only provide an essential link between Cox Peninsula and the city of Darwin but also to provide a safer, DDA compliant and lower maintenance ferry berthing facility, compared to the existing Mandorah jetty, which is exposed to all prevailing and extreme metocean conditions and has reach the end of its service life. WGA partnered with experienced marine contractors, SMC Marine, to develop an Alternative Design for the Facility which delivered a number of benefits compared to design that was originally developed. This paper describes the main features of the Alternative Design and discusses how partnerships between designers and contractors can result in an improved engineering outcome.

Keywords: Maritime facilities, breakwaters, dredging, design and construct, Northern Territory.

Introduction
The Department of Infrastructure, Planning and Logistics (DIPL), Northern Territory, is planning to develop a new marine facility to service the Mandorah and Cox Peninsula communities.

The key project objectives for DIPL were that the design of the ferry berthing facility should:

- Minimise construction and whole-of-life costs;
- Allow for uninterrupted ferry service operation during construction;
- Provide a safe and enjoyable passenger experience; and
- Address existing issues faced by the Mandorah Jetty and boat ramp. This includes the highly exposed nature of the site, Disability Discrimination Act (DDA) compliance, passenger safety issues and siltation of the existing boat ramp.

An Original Design was developed by Cardno in 2022[1] which provided a design for the infrastructure at different levels of detail, namely:

- Breakwaters, dredging, and boat ramp: Issued for Construction (100% level of design); and
- Pontoons, gangways, and onshore civils: Issued for Design & Construct (30% level of design).

During the tender process, WGA partnered with experienced marine contractors, SMC Marine, to develop an Alternative Design for the Mandorah Marine Facility which aimed to improve constructability and reduce volumes of offshore dredging and breakwater materials. SMC submitted a tender based on this Alternative Design and was awarded the contract to deliver the project. Subsequently, SMC commissioned WGA to develop a detailed design for the works.

Project Background
The site for the Mandorah Marine Facility (MMF) is located near the eastern tip of the Cox Peninsula, approximately 6km to the west of Darwin, as shown in Figure 104.

The existing Mandorah ferry jetty and boat ramp are located to the immediate south of the Site, with both facilities sharing a common onshore carpark facility.

Figure 104 Location of the Mandorah Marine Facility (MMF)

Metocean Conditions
Mandorah has a tropical climate with distinct wet and dry seasons. During the wet seasons, the dominant wind direction is from the west and north (270-360°N), whilst during the dry season, easterlies and southeasterlies are prevalent.

The wave climate at the site is dominated by sea waves generated locally by local winds and swell waves are typically small. Sea waves typically approach the site from the north-north-west to north-north-east during wet season and from the north-north-east to south-east during the dry season, and. Waves are typically lower than 0.5m, but occasionally exceed 1.0m. The largest waves that reach the site are associated by tropical cyclones, and mostly approach the site from the north-east.

Facility Layout

The MMF involves the establishment of a purpose-built harbour to host a ferry terminal (floating pontoon) and a public boat ramp. It is proposed to establish the harbour by constructing breakwaters and undertaking capital dredging. Figure 105 presents a conceptual layout for the facility.

Figure 105 Conceptual layout of proposed Mandorah Marine Facility

Two breakwaters are proposed, namely a Northern Breakwater and a Southern Breakwater, a dredged entrance channel, turning basin and berthing area, a new ferry terminal (floating pontoon) as well as a new boat ramp and associated parking areas.

Design Studies and Investigation

Several additional design studies and investigations are currently underway, as noted in Table 1. The results of these studies and investigations will be presented at the Conference.

Table 15 Additional Design Studies and Investigation for the Alternative Design

Study / Investigation	Detail and Purpose
Development of Geological Model	Offshore boreholes and investigations will be used to create a 3D geological model (using Leapfrog software). This will allow a better assessment of the breakdown in materials to be dredged and for any slope stability assessments.
Nearshore Numerical Modelling	A further program of hydrodynamic, spectral and wave penetration modelling to be undertaken for the Alternative design.
Desktop Vessel Simulation	Using a vessel closely matching the design vessel(s), to test entry to the facility, turning and berthing of the vessel to ensure that the harbour area is sufficient for the design purpose.
Physical Modelling	Both 2D Flume and 3D Basin modelling will be undertaken for the updated Alternative design layout.
Optimisation of Pontoon Structure	The reduced size of pontoon (compared to Cardno, 2022 design) will be further investigated and assessed.
Onshore Test Pits and Investigations	To obtain relevant geotechnical information for the design of the pavements as well as any required onshore excavations areas.

Comparison to Original Design

In comparison to the Original Design, the Alternative design:

- Has achieved a reduction by around 50% in rock volumes required for the construction of the breakwaters;
- Results in much better operational conditions at the ferry berths for both user experience and less physical impact on the facility and, hence, is anticipated to achieve reduced long term maintenance requirements;
- Separates the dredging activities from the breakwater construction activities, which means that breakwater construction can progress independently from the bulk of the dredging works which may be constrained by availability of suitable dredging equipment;
- Similar or reduced sediment transport impacts, especially the fate of dredge plumes which will be better controlled during more adverse periods for the dredging works; and
- Avoids adverse impacts on existing ferry operations during construction and eliminates the potential for future conflict of ferry and boat ramp users.

These changes resulted in considerable saving of the capital cost of the project in comparison to the Original Design.

Discussion and Conclusion

A new marine facility is being developed for the Northern Territory to service the communities of Mandorah and Cox Peninsula as well as to replace aging and outdated infrastructure. An Alternative design developed by WGA and being delivered by SMC Marine will provide much needed long term maritime infrastructure to the local community.

References

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The Feasibility of Onshore Power Supply in Australian Ports

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Summary

Onshore power supply is gaining momentum globally as port operators and vessel owners pursue decarbonisation and sustainable goals. This paper examines the feasibility of onshore power supply, with assessments of the technical and commercial aspects of implementation in Australia across different vessel types. The technical findings illustrate a proven method for implementing shore power at various ports with global shore power standards forming the basis for connecting the vessel to the local grid. The commercial findings examine the capital and operational expenditure required for shore power. This includes challenges with ownership models and relatively high capital investment for shore power.

Keywords: Shore Power; Decarbonisation; Energy; Port electrification

Introduction

Onshore power supply (OPS) is an emissions control measure of enabling a vessel to connect to the landside electricity grid whilst at berth, thereby reducing its emissions and improving air quality. OPS is gaining prominence in Australia with several port authorities exploring initiatives as part of its ESG policies. Certain port authorities are currently in active implementation stages for OPS. This paper examines the feasibility of implementing onshore power supply, challenges and opportunities faced by various port authorities. The objective of this study is to examine and assess the infrastructure requirements to enable the provision onshore power supply, energy demand and electricity grid constraints, and conduct a preliminary commercial analysis of the capital and operational expenditure for shore power, along with the marginal cost of abatement when considering the reduction of Scope 3 emissions. This study utilises findings from a recently completed shore power assessment for the Port of Melbourne.

Technical assessment of OPS

Onshore power supply is a technologically mature concept where a vessel at berth is connected to the landside electricity grid. This ensures that the vessel is able to reduce its greenhouse gas emissions and pollutants. As electricity grids around Australia decarbonise, low carbon energy is supplied to vessels, enabling them to switch off their auxiliary engines when plugged into the grid. providing significant carbon emissions reduction. Whilst there has been steady improvement in implementation of shore power globally, there are concerns by a number of ports on OPS becoming a stranded risk as alternative fuels are developed and used by vessels at berth.

Requirements for shore power should adhere to the requirements of IEC/IEEE 80005-1:2019 for high voltage connections above 1MVA of power demand. Integration and compatibility for OPS connections depends on several factors such as the onboard vessel electrical system, connection location, vessel parameters such as age, size and type and additional power demand considerations for operations or storage of refrigerated containers.

The challenges with integrating shore power between the vessel and landside infrastructure can be generalised, however, every port has specific constraints that will need to be addressed to successfully implement shore power. The compatibility between vessels and shoreside connections requires consideration and early engagement with stakeholders. As shown in Figure 106, the shore power electrical infrastructure consists of three main elements that provides the power supply route from the electricity grid to the vessel when connected to shore power.

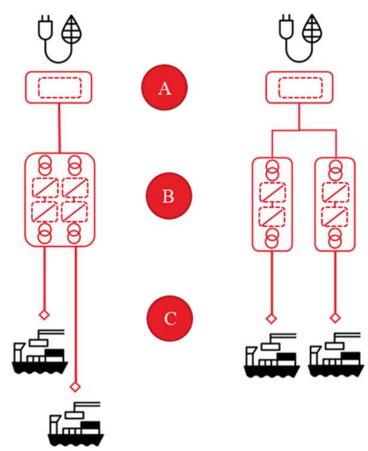

Figure 106 Shore power infrastructure topology

Supply side constraints to meet anticipated power demand introduces additional challenges as the port becomes a significant energy consumer. The electrification of other assets in the port adds an additional dynamic to the port energy mix. This requires early engagement with relevant distribution network operators and key stakeholders to ensure that forecast planning.

Commercial assessment of OPS

OPS has various asset ownership models that can be utilised with port authorities and terminal operators. This is differentiated by three principal methods of ownership where the port authority, the terminal operator, or a third party owns and operates the OPS infrastructure. Implications for the ownership models differs based on the capital expenditure investment source, operation and maintenance and commercial mechanism. Depending on the commercial arrangement agreed for the operation of OPS and funding, different ownership models can be arranged.

The commercial assessment of OPS involves capital expenditure and operational expenditure estimation. This involves network augmentation costs for the increase in power demand for the utilisation of OPS. The estimated costs within the port boundary for various terminals differs based on the infrastructure provided. Implementation costs for each terminal or dock studied can then be categorised based on four elements: OPS equipment, civil and electrical works, staging and preliminaries and others. OPS equipment often contributes the largest section of the capital expenditure, and this is because of the equipment required to support OPS operations such as frequency converters and associated HV switchgear.

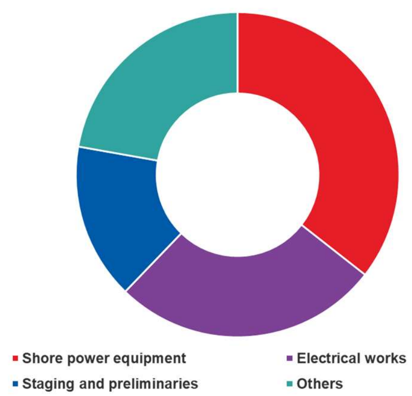

Figure 107 OPS CAPEX breakdown

From a vessel operators point of view, one of the principal reasons that vessels will utilise OPS is the cost of electricity vs fuel. The charging mechanism' for OPS includes the cost of electricity, infrastructure levies and port charges for the use of OPS and contributions to periodic operation and maintenance costs.

Utilising preliminary cost estimates, the cost of abatement can be estimated to determine the cost effectiveness for removing a tonne of CO2 via the implementation of OPS. Current comparative carbon pricing locally from global reference points towards a higher cost of abatement, which also varies across the various precincts studied. It is important to note that these costs are unlikely to be the sole criteria used in decision making. Other criteria include social licence to operate, the emphasis on air quality standards in international projects and meeting corporate or regulatory objectives.

Discussion

The findings based on the case study shows that the technical requirement for OPS is mature with existing methods and technologies. There are many examples globally of successful implementation and in-operation OPS systems. The capital expenditure required for implementing OPS are heavily impacted by specialist electrical components and construction at operational sites. The funding for OPS initiatives in Australia is currently limited and therefore this limits the ability for port authorities and operators to raise adequate external funding or grants for implementation.

At present, the likelihood of shore power becoming a stranded asset is low, primarily because the cost of alternative low carbon fuels is expected to remain higher than electricity. This cost disparity is attributed to the fact that electricity is utilised in the manufacturing of these fuels.

Conclusion

In the case study explored, the implementation of shore power is technically achievable with a phased approach across various precincts. However, the capital expenditure of OPS necessitates external funding as there are limited government commercial incentives. A well-defined commercial strategy is required to enable revenues to be generated. The cost of abatement for OPS indicates that there is a higher cost associated with the removal of C02 as compared to other benchmarks in an unregulated carbon pricing market within Australia.

Acknowledgments

References

Relevant UN SDGs (*https://sdgs.un.org/goals*)
9 , 11, 13

40m Unrestricted Single-Span Aluminium Gangway Design & Fabrication

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Summary
Gangways play a crucial role in providing safe access to various transportation modes, including trucks, railcars, and marine vessels. Functionality can be improved with innovative engineering that pushes the boundaries to achieve a more practical design. In this case, the end user was Mackay Regional Council and Superior Jetties had a contract with SMC to design and fabricate a 40m aluminium gangway for the Pioneer River in Mackay. This river has a significant flood and tidal range, where shorter gangways would only be suitable if a floating mid-landing platform was built. This paper highlights advantages of building a much longer single span aluminium gangway and the innovations implemented to make this possible.

Keywords: Engineering; Decarbonisation and Climate Change Adaption; Working with Nature, Technological Advancements; Pioneer River Mackay.

Introduction

Conventional bridge & gangway structures haven't changed much in the last century, where designs utilise standard build practices and materials to offer a seemingly straightforward solution at the inception stage, but with costly flow on effects through the product lifecycle. This is especially the case in marine structures. The purpose of this paper is to highlight five design strategies implemented on this Mackay project for a contemporary result.

1. 40m Single Span Design

The conforming tender design of this Mackay project was two short gangways, with a floating mid-landing platform that rested on a stop frame mid tide. This allows the gangway to be usable across the full 8.8m tidal range that this region exhibits, whilst meeting DDA & AS3962 [5] compliance.

The Tender design is shown in Figure One, with the constructed design shown in Figure Two. Advantages of the constructed longer gangway design is that it saves additional site work as extra piles and landing platforms aren't required. The cost of these elements significantly impacts a project, where in this case, the landing platform was designed as a floating steel structure. This would've been significantly more expensive and requires ongoing maintenance to keep in operation.

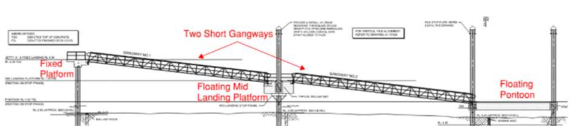

Figure 1: Tender design with two short gangways and a floating mid-landing platform resting on a stop frame.

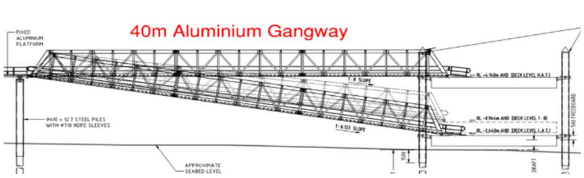

Figure 2: Construction 40m single span design with <1:8 slope @ >80% of use.

2. Material Selection

The original tender document specified steel as the material of choice, with the relevant post processing to meet the saltwater exposure classification. Aluminium 6000 series was selected for construction with it being a proven performer in marine applications, structural components and is much lighter than steel. Steel variants of the design were >25t, where the aluminium design was 8.5t and gained efficiencies in transport and cranage onsite (dual 200t crane lift shown in Figure 3). Aluminium is fully recyclable with minimal ongoing maintenance, helping to decarbonise the industry and reduce waterway contamination (post processing steel galvanisation & paint systems).

Figure 3: Dual 200t crane lift to install gangway from land only possible with the material choice being aluminium.

3. Loading Conditions & Incorporating Stress Relief in the Structure

A gangway system differs to that of a bridge with it being a connection at each end for land and sea; both of which respond differently to external loads. Three main loading conditions to consider and their respective results on this project are:

A. Dead load (gangway weight: 8,500kg)
B. Live load (Public, cargo & equipment: 3kPa)

C. Dynamic load (wave, flood & wind)

For a gangway the combination of the above loading conditions plays a pivotal role in the success and lifespan of the system. On this project, the combination load conditions as per AS1644 [2], AS1170 [3] & AS4997 [4] are extreme and resulted in design that minimised stress buildup at each end of the gangway. At the fixed platform end, the use of a hanging design is ideal to stress relieve the gangway under dynamic loading. To ensure stability of the structure, wishbone hangers were incorporated into the design, allowing the structure to 'swing' in either direction underneath the fixed platform whilst remaining stable under its own dead weight. This is shown in Figure Four.

Figure 4: Gangway wishbone hanger connection to fixed platform.

At the pontoon end, we explored options to isolate the pontoon rolling action from the gangway. With further research [1] and modelling, single 'C channel' sections for the gangway chords offered enough stress relief across the gangway structure, when working together with pontoon end rollers and the wishbone hangers on the fixed platform. A combination of these strategies prevents side to side racking with wave actions and a HDPE guide track on the pontoon end prevents the gangway 'walking' across the pontoon deck.

4. Preventing Torsion Failure

One of the first discussion topics was how to prevent torsion failure that so many of these long gangway spans suffer from in FEA. The use of channel as described above was one such strategy to mitigate stress concentrators in the truss lattice. The use of a taller gangway (deeper truss), a 4-sided design (roof lattice structure above clearway) and outriggers were additional strategies to prevent torsion failure and keep the gangway mass to a minimum (low dead weight creating efficiencies in the overall structure design). Conventionally thicker or doubled up members are used for the top and bottom cords, which have aesthetic advantages but are inefficient in adding dead load, additional material costs, and extra labour to fabricate.

5. Three-Section Gangway Design & Connection Detail

All long gangways need to be joined to allow for economic transport options. In this case, breaking up the 40m length in three sections was a simple choice, removing a join from the highest deflection point (centre of gangway). Once on site, the challenge is to rejoin the sections without impacting the strength of the structural members. Generally, a bolting perimeter flange the full face of the joining surface is preferred by designers as it's a 'safe' option and works well. However, this perimeter flange can be unsightly, offers no flexibility in joining (think welding shrinkage) and is inherently expensive (material, fabrication & site labour). More recent innovative designs include fishplates let into the sections to transfer the stresses of the joint back into the structural member. This was implemented as shown in Figure Five.

Figure 5: Three section gangway connection detail at each chord connection.

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Relevant UN SDGs (*https://sdgs.un.org/goals*)
9, 10, 12 & 14

A Resilient Assessment Case Study of a Deep Sea Port in Vietnam

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Summary
In response to the evolving risks posed by climate-related and natural hazards such as storms and sea-level rise ports in Vietnam, require an approach towards building resilience and climate adaptation. This paper presents a climate-related risk assessment applied to Gemalink International deep sea port project located in Southern Vietnam, which focused on identifying climate-related risks, evaluating the port's strategies, and recommending climate-adaptation measures. The paper then recommends a broader adoption of the climate assessment for ports and maritime infrastructure in Asia-Pacific. It suggests leveraging existing frameworks and tools for climate adaptation and resilience development to address this critical need effectively.

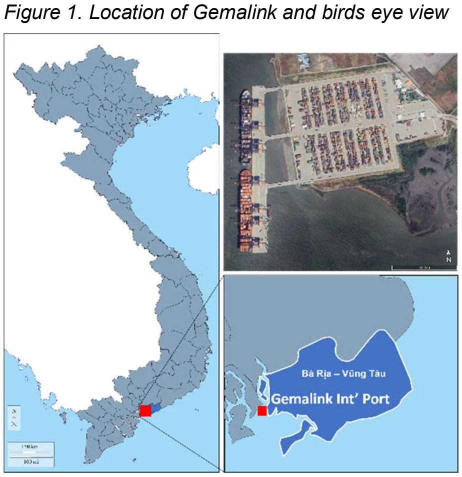
Keywords: Climate-adaptation Seaport, Resilient Maritime Infrastructure, Resilient Ports

Introduction

Disruption caused by climate change impacts can lead to severe damage to global shipping, trade, and supply chains.[1] While various tools have been introduced to support the building of smart and green ports,[2,3] they often lack robust climate-resilience features. In addition, an increasing number of studies have highlighted substantial risks faced by ports in Asia-Pacific due to climate change impacts[4,5].

Aimed at setting an example for smart and sustainable port development, Gemalink International Port located in Southern Vietnam [5], is the largest deep-sea port in the country. The first phase area of Gemalink project covered 330,000 sqm (see Figure 1), with an investment cost of 330 million USD[7]. To evaluate its resilience to climate-related hazards, an assessment was conducted for the Gemalink site using Building Resilience Index (BRI) framework developed by the International Finance Corporation.[8] The assessment focused on the identification of hazard risks to the Gemalink site and proposing mitigating climate and disaster risks.

Figure 1. Location of Gemalink and birds eye view



Source: RHDHV and Google Earth

Techniques and Material Studied

The resilience assessment drew upon a detailed review and assessment conducted, by the Royal HaskoningDHV (RHDHV) on behalf of Gemalink. The RHDHV team consisted of experts in climate change, hazard risk assessment, and structural engineers. Information provided by Gemalink's Private Developer including architectural design, structural design, electro-mechanical design, fire-fighting plan, geotechnical survey, and other relevant specifications were utilized in the assessment. All the submitted documents adhered to Vietnam building regulations applicable to the site.

Under the BRI [9], 71 risk mitigation measures falling under the four hazards against Wind, Water, Fire, Geoseismic hazards, and Operational Continuity measures were evaluated.

Results

The design of the Gemalink was found to have some resilient practices across the onshore assets on the site. This indicates that Gemalink has incorporated some recommended adaptation and resilience practices, making its ability to withstand applicable hazards of wind, water, fire, and geoseismic at a moderate level.

Discussion and recommendations

The rating method by BRI is determined based on metrics related to the physical integrity of a building when facing hazards including Water (tsunami, storm surge, and flood) , Wind (tornado, downburst, and cyclon), Fire (local fire), Geoseismic (subsidence and earthquake). However, many tools, such as U.S port resilience index[10], or UNCTAD toolbox for port risk management,[11] and including BRI, often apply global empirical best practices, setting severity levels above those typically assumed or required by local building codes. Despite the requirement for buildings to comply with national regulations, these tools may not fully align with local contexts.[12] It is critical to recognize these limitations so that tools, such as BRI, can be customized to suit different regions and localities more effectively.

The experience gained from the assessment on Gemalink highlights the importance of context-specific adaptations. While resilience assessment tools can offer a comprehensive framework for resilience assessment, their effectiveness can be improved by tailoring them to diverse geographical and regulatory contexts. Conducting resilience assessments for ports and maritime infrastructure in various countries and locations will facilitate better identification of region-specific vulnerabilities. This, in turn, will enable the refinement of climate adaptation strategies to address the specific needs of different regions more accordingly.

Another key insight derived from this study is the essential role of resilience assessment in informing design decisions for more effective adaptation impacts. This view is also supported by other case studies, such as those conducted on ports in China[13] and Spain[14].

Nonetheless, it is crucial for the maritime industry to consider extended risks and prepare for more advanced adaptation measures. This cruciality is also emphasized in other studies such as in the work by Monios[15]. Furthermore**,** stakeholders involved in adaptation and resilience assessment, including engineers, planners, policymakers, and community members, should also undergo training and capacity-building[16] support to effectively utilize adaptation tools and implement mitigation measures.

Conclusion

In conclusion, the case study of Gemalink project, employed a structured approach to assess and mitigate risks across wind, water, geosemic and fire hazards. The study showed that localised and accurate hazard data is important for determining risks, this is a limitation in Vietnam. Additionally maintaining operational continuity measures are also critical to enhance an assets physical integrity and reflect the improvement of the infrastructure's resilience. The project demonstrates the potential and importance of applying climate-adaptation and resilience indices to port and infrastructure design in Asia-Pacific. Looking ahead, it is essential to prioritize the widespread adoption the climate assessment for ports and maritime infrastructure. This can be achieved by leveraging existing frameworks and tools applied in climate adaptation and resilience development. The journey toward building climate adaptation infrastructure is an ongoing process that requires continuous improvement, innovation, and robust international collaboration.

Acknowledgment

The authors acknowledge the contributions of Gemalink Private Developer for providing data and documents for this case study. We also thank the International Finance Corporation for providing the BRI tool for a test run. We especially thank the RHDHV project team with engineers and experts for the contribution of their expertise and insights into this project.

Relevant UN SDGs: Goal 9, 13, 1

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Verification of a Probabilistic Coastal Erosion Hazard Line Assessment against Cyclonic Weather Events: Coromandel Peninsula

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Summary
Results verification, undertaken as part of the Thames Coromandel Shoreline Management Pathways project by Royal HaskoningDHV, of probabilistic coastal erosion hazard line model results against real-world coastal erosion at a number of nominated locations along the east coast of the Coromandel Peninsula, New Zealand - following the extreme weather events that affected the area in January (ETC Hale) and February (ETC Gabrielle) 2023 - showed good agreement between predicted erosion hazard lines and actual erosion.

Keywords: Coromandel, cyclone, erosion, Monte Carlo, hazard lines.

Introduction

In April 2019 Royal HaskoningDHV (RHDHV) commenced the Thames Coromandel Shoreline Management Pathways (SMP) project for Thames Coromandel District Council (TCDC). In September 2022 the Coastal Adaptation Pathways (CAP) Report, including 138 adaptive pathways covering the entire coastline of the district, was adopted by TCDC.

TCDC are now developing an SMP Implementation Plan, that includes the prioritisation of actions. To inform this, and in light of recent weather events (including cyclone Hale in January 2023 and Gabrielle in February 2023) the process needed to include a review of the signals, triggers and adaptation thresholds (STATs), set as part of the SMP, within the 89 "active" pathways to determine if the criteria for action have been met.

As part of the STATs assessment, a review of the 1% exceedance coastal erosion hazard lines resulting from a probabilistic coastal erosion hazard line assessment undertaken as part of the SMP, and comparison to coastal erosion due to subsequent extreme weather events was undertaken at locations that were affected by these weather events and where data was available, i.e. (also refer Figure 108):

- Whangapoua Beach;
- Simpson Beach;
- Brophys Beach;
- Bufallo Beach; and
- Whangamatā Beach;

Results of the verification of modelled probabilistic coastal erosion hazard line data against real-world shoreline erosion data at two nominated beaches are presented herein.

Figure 108 Coromandel peninsula study area

Probabilistic coastal hazard assessment

Traditionally, coastal erosion hazard line assessments have been undertaken under a deterministic approach, whereby each potential hazard is assigned a single value (e.g., 'design' storm demand, sea level rise projection, etc., with generally conservative estimates applied). A probabilistic approach has been applied to the TCDC SMP CHA, which accounts for the interaction between the forcing parameters. In this way, rather than present only a "worst case" scenario, acceptable risk can be considered when examining predicted coastal hazard extent from a probabilistic perspective. The probabilistic approach allows each of the contributing coastal hazard parameters (e.g., sea level rise, underlying coastal recession and storm events) to randomly vary according to appropriate probability distribution functions. The randomly sampled parameters are repeatedly combined in a process known as 'Monte Carlo simulation' (refer Figure 109). All outputs from the Monte Carlo simulation are collated to develop a probability curve for shoreline retreat over the planning period (refer Figure 110).

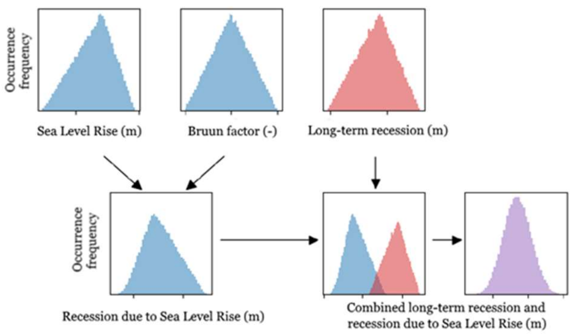

Figure 109 Methodology for combining random values to estimate shoreline movement (based on [1])

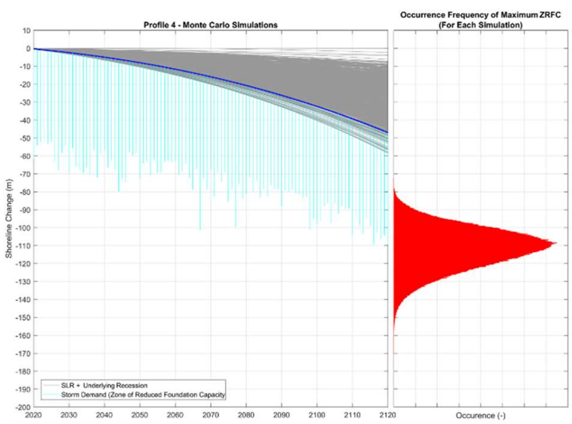

Figure 110 Example of simulated storm demand superimposed on background shoreline change due to combined recession

Extreme weather events

During summer 2023, New Zealand was impacted by two ex-tropical cyclones. Cyclone Hale was the first tropical cyclone of 2023 in the South Pacific, interacting with the New Zealand mainland in January. Exhibiting heavy rain and strong east to southeast winds, Hale caused havoc across the North Island, and particularly affected the Coromandel and Gisborne areas.

The worst storms in modern history in New Zealand occurred in February 2023, by way of cyclone Gabrielle (refer Figure 111), which exposed much of the island to extreme rainfall and river flooding, catastrophic wind damage, and substantial storm surge, causing shocking impacts to the North Island [2] [3].

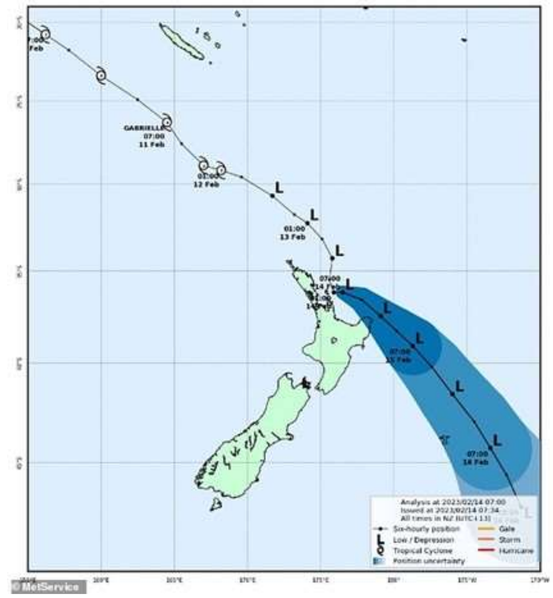

Figure 111 Cyclone track map showing the forecast path of Gabrielle as at 13 February 7am along with track at the time [2].

Methodology

Photographic data and drone imagery taken within a few weeks after cyclone Gabrielle were reviewed. Images that both clearly showed the coastal erosion line and were located within the 1% exceedance hazard line sections for the years 2020, 2040, 2070 and 2120, were then selected for further assessment. The coastal erosion line after the cyclones, shown on the selected images, was then compared against the 1% exceedance hazard lines for the years 2020, 2040, 2070 and 2120 in GIS. Results of the hazard lines review for all suitable post-cyclonic imagery for Whangapoua Beach and Whangamatā Beach is outlined below.

Whangapoua Beach

At Whangapoua Beach six post-cyclonic images were identified as suitable for the 1% exceedance hazard lines review. A spatial overview of those images is shown in Figure 112, while the selected site and a snapshot of the corresponding hazard line section using the LINZ Aerial Imagery Basemap as background map is presented Figure 113.

Figure 112 Coastal erosion images location overview – Whangapoua Beach (WP1 to WP6)

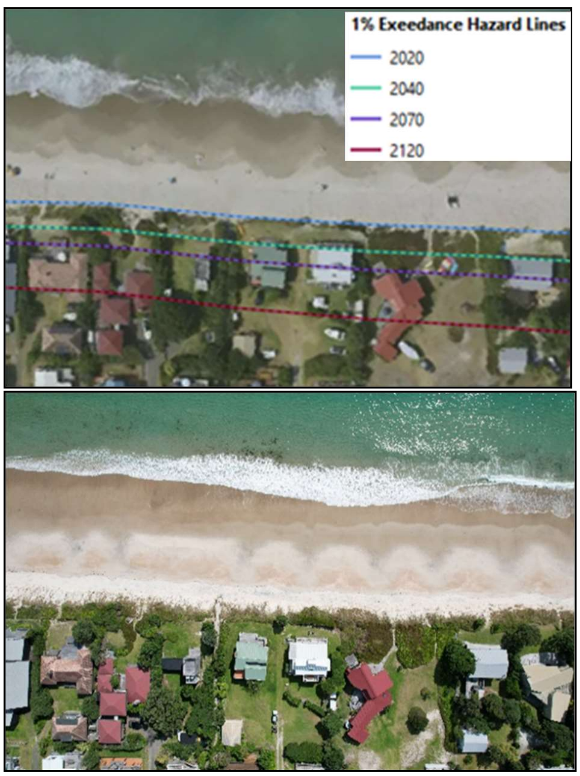

Figure 113 Current 1% exceedance hazard lines (top pane) vs coastal erosion line after cyclones Hale and Gabrielle (bottom pane) - WP5

Whangamatā Beach

At Whangamatā Beach 12 post-cyclonic images were identified as suitable for the 1% exceedance hazard lines review. A spatial overview of those images is shown in Figure 114, while the selected site and a snapshot of the corresponding hazard line section using the LINZ Aerial Imagery Basemap as background map is presented in

Figure 114 Coastal erosion images location overview – Whangamatā Beach (WM1 to WM12)

Figure 115 Current 1% exceedance hazard lines (top pane) vs coastal erosion line after cyclones Hale and Gabrielle (bottom pane) - WM2

Discussion and Conclusion

The outcomes of the 1% exceedance hazard lines and STATs review for Whangamatā and Whangapoua are discussed below. It is noted that it could not be confirmed how much of the erosion was caused by cyclone Hale or Gabrielle individually, or by previous conditions, as no detailed information about the exact capture date of the post cyclonic imagery was provided by TCDC. It was therefore assumed that all images were taken within a few weeks after cyclone Gabrielle.

Whangapoua Beach

Overall, the hazard line review indicates that the coastal erosion line post cyclones Hale and Gabrielle in the Southern section of Whangapoua Beach lies between the 2020 and 2040 1% exceedance coastal hazard line. There is no tidal gauge station found in close proximity to the beach. However, with a north-eastwards facing beach orientation, Whangapoua Beach was relatively unsheltered from the dominant east and south-east wind directions and storm surge.

Whangamatā Beach

Overall, the hazard line review indicates that the coastal erosion line after cyclones Hale and Gabrielle along the lower southern section of Whangamatā Beach corresponds best to the 2020 1% exceedance coastal hazard line. The post-cyclonic coastal erosion line along the upper southern section of Whangamatā Beach slightly lies below the 2020 1% exceedance coastal hazard line. This is likely due to the fact that this section of the beach is slightly more sheltered from powerful waves and the dominant easterly and southeasterly wind directions and associated storm surge that occurred during the cyclones, due to its proximity to the Hauturu Island, Maukaha Rocks, Whenuakara Island and Rawngaiti Island (refer to Figure 114).

The northern section of Whangamatā Beach westwards of Hauturi Island is characterized by a coastal erosion line that lies between the 2020 and 2040 1% exceedance coastal hazard line.

There is no tidal gauge station located in close proximity to the beach, however the south-eastwards orientation (southern beach section) and north- eastwards orientation (northern beach section) of the beach indicate that Whangamatā Beach was quite exposed to the dominant east and southeast wind directions and storm surge.

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Relevant UN SDGs (*https://sdgs.un.org/goals*)

9, 13, 14.

Fender Design. Changes after PIANC WG211 2024

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Summary
The recent publication of PIANC WG211 in 2024 for fender design introduces significant changes relative to the previous guideline PIANC WG33 published in 2002. This paper analyses the need for updated guidance, the changes proposed and their effect on fender design and selection through a detailed comparison with previous guidelines. While the intent and methodology of both publications remain largely consistent, the main changes are found to be higher berthing velocities, lower berthing angles and specific guidance on multiple fender contact.

Keywords: berthing energy, fender design, PIANC WG211, new guidelines

Introduction

Marine fenders are the interface between a vessel and a berthing structure. The main purpose of fenders is to transform the berthing energy from the ships into a reaction on the berthing structure without causing any damage to the vessel, the structure or the fender. The characteristics of the design vessels and the environment determine the berthing energy and fender selection. To date, PIANC WG33 [1] was the main guideline used for fender design around the globe. However, PIANC WG211 [2] has been recently released and fully supersedes [1] while allowing for a 2-year transition period for fender manufacturers to update their catalogues accordingly.

This paper analyses the changes in fender design introduced by [2] relative to the previous guideline [1] and outlines the new pathway for fender selection in the coming years.

Need for Updated Guidelines

The update was primarily driven by the availability of more reliable velocity data gathered in publications such as PIANC WG145 [3], as well as doubts over the validity of [1].

Characteristic Berthing Energy

[2] proposes that the berthing energy that is to be absorbed by the fenders and the supporting structure can be calculated as shown in Equation 1:

$$E_c = \frac{1}{2} M V_B^2 C_e C_m \qquad (1)$$

where
E_c = characteristic berthing energy;
M = vessel displacement;
V_B = berthing velocity;
C_e = eccentricity factor;
C_m = added mass factor.

The changes introduced in [2] relative to [1] include the removal of the softness factor C_s since the elastic contribution of the vessel hull is considered negligible, and the removal of the berth configuration factor C_c as this effect is already included in the berthing velocity recordings used to determine the characteristic berthing velocities and partial energy factors.
[2] also corrects an error in [1] in the formula to calculate the eccentricity factor C_e -by replacing the radius of gyration K with the distance from the centre of mass of the vessel to the resultant fender reaction force r_f-.

Berthing Velocity

Berthing velocity, due to its uncertainty, is the dominant factor over all other factors for fender design. The velocity is to the square in Equation 1 which results in an exponential increase in the berthing energy.

[1] used the Brolsma curves that estimate berthing velocities based on deadweight tonnage and the ease of the berthing conditions at the port. In turn, [2] simplifies the classification of the difficulty of the berthing conditions -favourable, moderate and unfavourable- and replaces the vessel size with vessel type. Guidance for navigation conditions is provided when no site specific information is available and shall be agreed with the asset owner prior to commencement of the fender design.

[3] found berthing velocity is not linked to vessel size as opposed to the Brolsma curves. Hence the largest design vessels will generally govern the fender selection. However, it shall be noted that both [1] and [2] recommend using data measured on site if available as the tabulated velocities are based on global datasets and, therefore, tend to be conservative. Using site specific information will typically result in slightly smaller fenders than those determined using [1]. Unfavourable navigation conditions could result in higher berthing speeds and thus higher berthing energies compared to [1].

Berthing Angle

The berthing angle is defined as the angle between the longitudinal axis of the vessel and the berthing line and is used to calculate the eccentricity factor C_e in Equation 1.

[1] assigned an angle of 6° for vessels larger than 50,000 DWT, which are usually assisted by tugs. However, [2] proposes a maximum of 4° angle for tug-assisted ships. This is in line with [3] which concluded that berthing angle can be controlled by pilots more easily than berthing velocity and found no strong correlation between angle and vessel size. Both [1] and [2] encourage again the use of site data first if available. The impact of berthing angle on the berthing energy is limited.

Design Berthing Energy

The design berthing energy accounts for uncertainties in energy calculation such as berthing frequency and variations in displacement using a partial factor γ_E as indicated in Equation 2:

$$E_d = \gamma_E E_c \qquad (2)$$

where

E_d = design berthing energy;

γ_E = partial energy factor.

[1] discussed risks to be considered in choosing partial factors and provided a range varying from 1.25 to 2.0 depending on the vessel type and size (smaller vessels are assigned higher partial factors to account for their potential greater velocities). [1] used these global safety factors to incorporate safety. It is unclear whether this approach results in an appropriate reliability level.

[2] further elaborates the partial factor as a multiple of various factors as shown in Equation 3:

$$\gamma_E = \gamma_{E,ref}\gamma_n\gamma_p\gamma_c \qquad (3)$$

where

$\gamma_{E,ref}$ = reference partial energy factor for 100 berthings per year;

γ_n = correction factor for alternative annual berthing frequencies;

γ_p = correction factor for berthings without pilot assistance;

γ_C = correction factor for correlations between design variables.

The reference partial factor $\gamma_{E,ref}$ depends on the ease of the navigation conditions, the range of vessels using the berth and its consequence class. Consequence class shall be defined by the asset owner based on how critical the failure or malfunction of a fender would be. Different factors for single and multiple fender contact are provided given that the probability of characteristic berthing velocity and angle occurring simultaneously at multiple fenders is lower. The number of vessels berthing in a year and the consequence class determine the factor γ_n. The factor γ_p accounts for those berthing manoeuvres without pilot assistance. Finally, γ_C considers whether there is any correlation between vessel size, berthing velocity and berthing angle. [3] found no strong evidence of correlation so [2] recommends that γ_C is taken as 1.0 in the absence of local data.

It shall be noted these partial factors are only considered for new structures, as they are generally too conservative for the assessment of existing structures.

Multiple Fender Contact

Large vessels are likely to impact multiple fenders sharing the energy as shown in Figure 116. [2] provides specific guidance on multiple contact which can lead to smaller fender sizes or larger vessels accommodated on the berth.

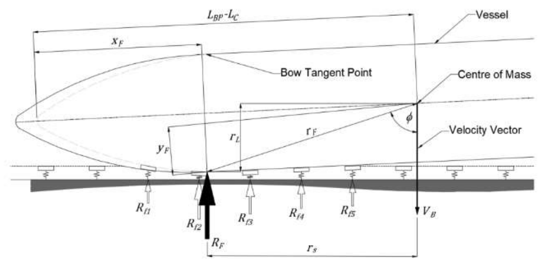

Figure 116 Illustration of multiple fender contact and sharing of berthing energy (Source: [2]).

Discussion and Conclusion

PIANC 2024 fully supersedes PIANC 2002 and introduces significant changes in fender design, - namely higher berthing velocities, lower berthing angles and specific guidance on multiple fender contact- while remaining largely consistent in intent and methodology. The new guidelines provide a more refined method of determining the berthing energy via a reliability-based method and strongly recommend the use of local data.

New sections include fender selection under moored conditions, manufacturing, testing and sustainability.

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Relevant UN SDGs (*https://sdgs.un.org/goals*)

8, 9

Electrochemical Chloride Extraction: Re-injecting Sustainability into the Australian Market

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Summary
The presence and ingress of chlorides, particularly when exposed to aggressive wet/dry cycles of tropical and marine environments, is one of the main factors responsible for the deterioration of steel reinforced concrete structures. Electrochemical Chloride Extraction (ECE) is one of the resources available that can interrupt the initiation and progression of corrosion in this scenario through an electrochemical process which draws chloride ions already present in the concrete away from the reinforcing steel towards a temporarily surface-mounted anode. This process not only prevents chloride-induced corrosion of steel by extracting chlorides, but it also alters the concrete properties in the concrete cover and at the steel surface, including a measurable increase to the pH, and subsequently supporting the re-formation of a protective passive layer on the steel.

Keywords: Electrochemical Chloride Extraction, Cathodic Protection, Sustainability, Durability, Design Life.

Introduction

Marine structure durability design has improved in recent decades with relevant codes of practice specifying deeper concrete cover depths for high exposure classes, the inclusion of specific materials that inhibit chloride migration, or the installation of cathodic prevention systems in new builds. However, the number of existing reinforced concrete structures without durability considerations or that are coming to the end of their service life this decade but are still necessary parts of existing infrastructure is enormous. Electrochemical protection systems are effective treatment options for such conditions.

The construction industry is facing immense pressure to improve sustainable practices with targets being set to lower emissions and reduce waste generation. It is therefore expected that non-destructive techniques will be encouraged in asset maintenance programs, which introduces more opportunity for electrochemical chloride extraction to be chosen as a preferred maintenance system.

History of Electrochemical Chloride Extraction in Australia

Early research on electrochemical chloride extraction began in the United States in the 1970's [1]. Studies were funded and operated by government transport agencies Kansas Department of Transport (KDOT), the US Federal Highway Administration (FHWA), and the US Strategic Highway Research Program (SHRP) as there was huge potential for electrochemical chloride extraction to solve their costly maintenance problems. In the 1980's field trials were introduced and a Norwegian patent for ECE became commercially available.

Since the initial research studies and trials, most electrochemical chloride extraction projects have been conducted in North America and Europe on inland highway bridges and overpasses where continuous exposure to sea spray is not a concern, yet still have high levels of chloride contamination. The source of chlorides for many of these structures is de-icing salts applied to roads to prevent ice-related vehicle accidents. Car tyres carry the de-icing salts onto concrete structures, such as car parks for example, where they accumulate on entry ramps and other high-traffic areas.

The technology would have certainly been considered for coastal structures exposed to sea spray, however, was likely dismissed due to the method of application. Typically, ECE has been conducted by installing a sacrificial metallic mesh temporarily mounted to the concrete surface as the anode, and encapsulated by spraying an absorbent cellulose fibre to carry the electrolyte. This method is not practical for exposure in the tidal range or splash zone, and therefore has not seen widespread use in Australia where chloride contamination appears particularly in coastal environments rather than from de-icing salts. Although a few ECE projects have been conducted in Australia, use the technology faded since the traditional application method did not provide the same benefits as today's innovative application techniques.

Figure 1. Typical ECE installation on a wharf pile from suspended access decks

Technology profile

ECE utilises a temporary anode applied to the concrete surface. From there, a direct connection to reinforcement is established from a small concrete breakout pocket and the system is connected via cables to an external power source and control unit. Through the presence of the electrical circuit, chlorides are repelled with ECE treatment and the steel is re-passivated in the active stage of application. One key design benefit when compared to alternative systems, however, is that since the temporary anode is applied to the external concrete surface, as shown in Figure 1, chlorides are drawn completely out of the concrete structure rather than accumulating inside the cover concrete.

An ECE system is designed to extract chlorides to acceptable concentrations whereby corrosion does not initiate.

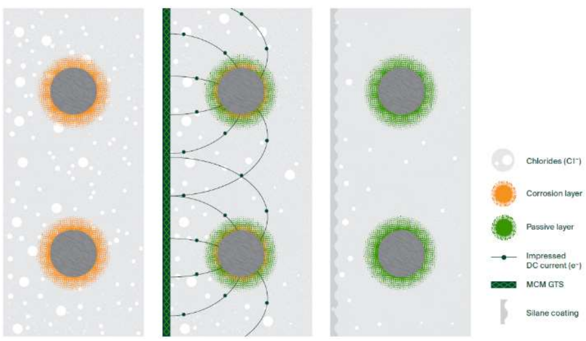

Figure 2. Electrochemical Chloride Extraction Process

The innovation introduced in Australia via Marine & Civil Maintenance's 2020 patent is related to the method of ECE application rather than the proven technical theory behind the technology. By using a prefabricated system in which the anode, electrical components, and electrolyte dosing equipment are held together, it is not affected by high winds or waves. It can be applied by two people inside a boat, pinned to the wall or soffit or strapped around piles, and subsequently removed in the same manner eliminating the need for scaffolding or other large-scale access installations. Since the prefabricated components are modular, quantities can be scaled up or down to suit various geometries and power supplies can be run in parallel depending on the area being treated. ECE can now be applied in less than half the time as an equivalent hybrid system, so is an attractive solution for asset owners wanting to minimise disruption to their operations.

ECE as a Sustainable Approach

It is widely accepted that maintaining a concrete structure to extend its service life is a much more sustainable practice compared to rebuilding once it no longer meets the required performance. The generation of new steel and cement contributes to the highest global CO2 emissions of all building materials [2] so there is an increasing call to the construction industry to reduce the demand of those new materials.

Out of the various Electrochemical Protection methods available, ECE treatment can be considered the most sustainable of the available options. Since the prefabricated system can be reused, waste generation could be limited to the reinforcement electrical connections, quality compliance tests, intermittent water to keep the system saturated, and consumables that can be expected for any construction sites. Compared to alternative electrochemical protection systems, ECE produces less waste and a drastically reduced project duration.

Economical and Commercial Aspects

Waste generation, emissions, and project duration are all correlated with project cost. Where ECE is a viable option technically, it would most certainly be the most attractive option for asset owners, allowing for more area to be protected within the same budget. Since a typical application time for ECE is around eight weeks, most of which is spent monitoring remotely without labour on site, operations can continue with minimal downtime. This optimisation allows concrete structures to operate at a high capacity for more of their service life.

Conclusion

Electrochemical Chloride Extraction can be an effective treatment for reinforced concrete structures affected by chloride contamination and has a proven history globally. Through innovation of the technology, ECE now enables service life extensions for more structures within equivalent budgets, while at the same time reducing waste, emissions, and application time.

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Relevant UN SDGs (https://sdgs.un.org/goals)
9, 12, 14, & 15

Concrete Repair of Concrete Ports and Harbours

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Summary
Inaccurate and inadequate data can have profound consequences in repair assessment. Building pathology offer systematic approaches to investigating structural failures and identifying underlying causes which help, in guiding effective remediation strategies. The success of concrete repairs is influenced by various factors, including construction practices, material selection, and workmanship. The paper outlines some important issues for investigation, repair selection and quality assurance, including patch repairs and cathodic protection.

Keywords: Inspection, Corrosion, Repair, Cathodic Protection,

Introduction

Due to the severe exposure of coastal structures, concrete repair can be a frequent issue. This paper outlines some key strategies for successful repair.

Investigation

For investigations to meet the objective of determining an appropriate repair strategy they must have:

a) a clear and appropriate process (Figure 1),
b) sufficient testing to give confidence in the diagnosis and extent of each condition.

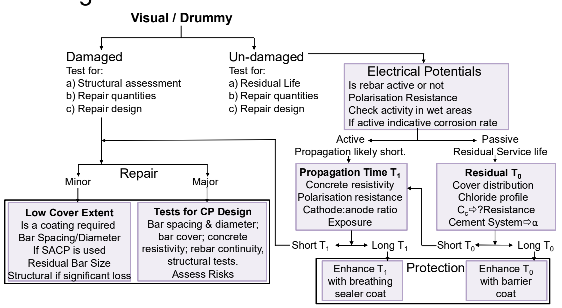

Figure 117: This process for corrosion assessment provides logical steps to ensure the appropriate information is obtained depending on apparent visual and electro-chemical state to define the spread of residual life. The process can be applied to representative areas initially but that also points to appropriate tests during repair.

Repair Reliability and Risk Assessment

It is likely that some repairs will fail during their life. For each repair type there will be one or more principal mechanisms that bring about the failure. For example, assume a patch repair design life is determined by the age at which the pull off load exceeds bond strength. These parameters are not discrete numbers but variables with a distribution. As shown in Figure 2, a probabilistic model, gives a useful assessment of life but the bond strength distribution must be known.

This assessment shows that there are some complex issues that require consideration. Where there is limited data on the distribution, suitability of repairs can be determined by risk analysis.

The form of risk analysis of different patch repair types, and applications is shown in Table 1.

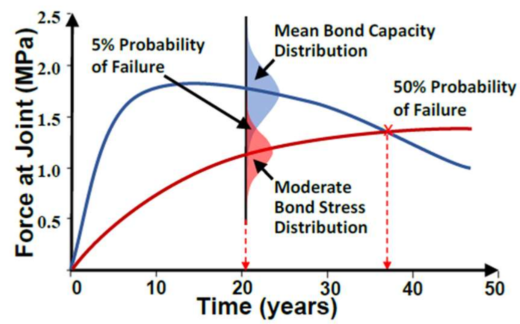

Figure 2: Comparing the overlap of bond strength and pull off load distributions over time shows the rate of bond failures.

Table 16 Risk analysis for bond failure of different interface arrangements for different patch applications.

Patch Repair Type	Key Factors	Risk Analysis		
		Likeli-hood	Conse-quence	Risk
Shallow, small, good prep.	Good bond strength	Rare	Low	Neg.
Shallow, small, poor prep.	Low bond strength.	Poss	Low	V.Low
Shallow, large, no anchors	Mortar's poor expansion restraint	Walls Poss	Walls: Mod	Mod
		Soffit: Likely	Soffit: V.High	Ext
Shallow, large with anchors	Eliminates the issue of bond.	Walls Rare	Walls: Mod.	V.Low
		Soffit: Rare	Soffit: V.High	Low
Moderate depth, no rebar	Well matched/placed.	Un-likely	Low	Low
	Not well matched or placed.	Poss	Low	V.Low
Deep repairs, include rebar	Rebar anchors & distributes strain.	Rare	Neg.	Neg.

Poss=possible; Neg=negligible; Ext-extreme; Mod=moderate

Table 1 indicates large shallow repairs can have a high risk of failure as the bond is stressed as the patch expands in the first day unless there is good restraint. Conversely deep repairs can be one of the least risky repairs because they incorporate the reinforcement. In general patch repairs that have been properly designed (Figure 3), and where workmanship is good, then the risk of failure is below the normally accepted level of moderate.

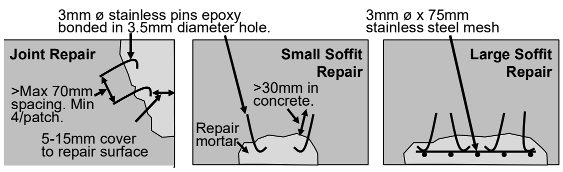

Figure 3: Mechanical bonding methods for patch repairs

For new structures the owner has the right to expect that repairs will be undertaken with the objective that the repairs will provide the same service life as the rest of the building. That is a 5-10% probability of failure at the end of the design life for SLS situations. For existing structures, the design life and reliability might be reduced by agreement.

Patch Repairs

Compatibility of Repair Material and Substrate.
Where repairs involve breakout and patching it is important that the thermal and elastic moduli are matched to the parent concrete, particularly where dynamic conditions apply.

Incipient Anodes
A major failure mechanism of repairs has been corrosion adjacent to patches when the anodic area protecting the reinforcement changes to a cathode. The repair must cater for this by extending the patch to remove potential incipient anodes, isolation of the patch reinforcement or by anodes to provide corrosion protection.

Testing
As debonding is a principal failure mechanism it is reasonable to verify:

a) that the processes leading to good bond are enforced,
b) the bond strength for the materials, method of application and curing is assessed.

It is also important to verify the protective performance of the repair materials as applied on site. The quantity of quality assurances tests typically allows for a gradual reduction in testing as results verify the performance. Ultimately if there are no failures the interval between tests is quite long.

Cathodic Protection

Cathodic protection stops corrosion.

Impressed Current
A current is passed from reinforcement to an inert anode placed on or in the concrete. Mixed metal oxide (MMO) is the common anode material. It is typically applied as strips grouted in groves, discrete anodes grouted into holes, or pinned to the concrete surface and covered with a concrete layer. Its principal benefits are a 50 year design life and sufficient polarisation to meet cathodic protection criteria (so only loose concrete has to be removed). They are also economic on large projects where the design and electronics cost can be spread.

An issue with MMO ribbons in slots is that local wetting causes a sink for the current which causes acidification that destroys the grout. On one structure failure occurred in under 10 years. Methods to overcome this have been applied but long-term performance in splash areas is still to be proven.

For Impressed Current Cathodic Protection (ICCP) systems electrical connections have a high risk of failure unless they meticulously exclude the environment, e.g. using potted connections.

An alternative anode system, ideal for wharf superstructures, is to fix MMO anodes in a holder to the concrete surface. The inert holder (‘Cassette’) eliminates acidification issues. The simple attachment process drastically cuts installation time. The system is unproven in regards potential for mechanical damage from solid object in wave impacts. Another variant is MMO precast inside and inert grout. It is then bonded to the concrete surface.

Sacrificial Anodes
Sacrificial anodes are connected to the reinforcement. The potential difference provides corrosion protection. Two anode types, as described in Figure 4, are:

a) Low polarisation – To prevent incipient anodes. Require breakout behind the reinforcement to remove chloride contamination.
b) High polarisation – Cathodic protection criteria are met. Only damaged concrete is removed.

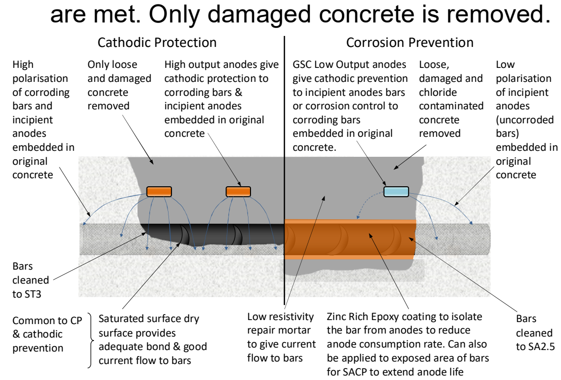

Figure 4: Difference between cathodic protection and cathodic prevention sacrificial anodes. SACP is that it can be applied to small areas at low cost.

Conclusion

Keys to successful repairs are appropriate investigation, open assessment of client needs for all repair options and appropriate detailing and testing.

Relevant UN SDGs: 9, 11, 12, 13.

Sustainability and Durability for Concrete Ports and Harbours

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Summary
Concrete, as a fundamental component of modern infrastructure, plays a pivotal role in ensuring the longevity and resilience of structures. fib MC2020 emerges as a groundbreaking international standard, addressing the design of new structures, as well as the assessment and repair of existing ones. Compiled by subject matter experts worldwide, MC2020 serves as a comprehensive source document intended for national code writers. This paper delves into the core principles outlined in MC2020, with a particular focus on sustainability and durability, exploring their implications and applications in the realm of concrete ports and harbours.

Keywords: Concrete, Durability, Corrosion, Design, Sustainability

The headings below examine the International Federation for Structural Concrete's (fib) MC2020 [1] through a number of key focus areas".

Sustainability

The UN's sustainability plan [2] should stimulate action up to 2030 in areas of critical importance for humanity and the planet. This has led fib to feature sustainability throughout MC2020's structural and durability provisions.

Sustainability, a concept integral to contemporary global initiatives, takes centre stage in MC2020. The United Nations' sustainability plan, shaping actions until 2030, has prompted a paradigm shift in the structural and durability provisions within MC2020. Notably, the code emphasizes critical aspects such as cement type and mix design for strength, durability, and rheology. The incorporation of slag and fly ash cements emerges as a significant strategy, offering dual benefits of reduced heat of hydration and lower chloride ingress. These advantages translate into enhanced durability, mitigating cracking and contributing to the longevity of concrete structures. Furthermore, the lower carbon dioxide emissions associated with these alternative cements align with the broader goals of environmental sustainability.

A compelling example of the practical application of sustainable concrete practices is exemplified by the Tauranga Harbour Link project [3]. Here, the use of high durability, self-compacting concrete (SCC) and durability modelling played a pivotal role in securing the winning bid for design and construction. The incorporation of a triple-blend binder, comprising High Early Cement, Class C fly ash, and natural geothermal microsilica, not only bolstered durability but also yielded a cost advantage. The reduction in the weight of cover concrete and subsequent effects on support structures resulted in a 20% cost saving compared to conventional concrete designs. This case study highlights the tangible economic and environmental benefits achievable through sustainable concrete practices.

Design Life

Design life, a critical consideration in concrete infrastructure, should be explored within the context of varying global conditions. While the Middle East, facing extreme chloride severity and uncertainty in construction quality, adopted short design lives of 30 years [4], regions with mature concrete production and construction practices extend infrastructure design lives up to 300 years [5]. Striking a balance between realistic expectations and achievable costs for the local market is paramount, as over-specification may lead to poor outcomes and legal ramifications. The importance of reliability-based design is underscored, particularly in contexts where fast-track construction may compromise long-term performance.

Reliability Based Design

MC2020 introduces a framework for determining target reliabilities [6], acknowledging the need for consensus among all project stakeholders. Reliability calculations, focused on end-of-life conditions, factor in corrosion-induced distress likelihoods for Serviceability Limit States (SLS). However, the determination of target reliability is also influenced by the cost of improving performance versus the estimated cost savings from Life Cycle Cost Analysis. This nuanced approach recognizes the variability in acceptable end-of-life conditions, dependent on the specific structure's robustness, accessibility, and repair costs.

Special attention is given to prestressed concrete in chloride exposure scenarios, where failure of prestressing cables due to corrosion poses a unique challenge requiring specific avoidance measures.

Exposure Assessment

Exposure assessment, a crucial aspect of concrete durability, challenges existing classification systems. While EN201 (Table 1) defines three broad exposure classes, fib proposes a more detailed classification, and the Concrete Institute of Australia (CIA) goes even further with six exposure classes. Concrete structures in external environments, such as ports and harbors, face a myriad of challenges, including airborne salts, beach conditions, marine immersion, spray, splash, and tidal effects. The intricacies of exposure assessment highlight the need for a comprehensive understanding of environmental conditions to inform durable concrete design.

	AS3600	EN201	CIA Z7/02 [7]	fib [8]	fib [1,9]
Airborne Salts					
Beach Med.	B2	XS1	XS1b (1.0)	(1.0-2.0)	XS1/2
Beach High			XS1c (2.0)		XS3a
Marine					
Immersed	B2	XS2	XS2	(2.0-4.0)	XS2
Spray	C1	XS3	XS3b (4.5)		XS3b
Splash	C2		XS3c (6.0)		
Tidal			XS3a (3.5)		

Table 1 Assessment of Exposures for Different Codes. Bracket figures are mean surface chloride as weight % cement and are used in chloride ingress modelling.

Z7/02 also incorporate special exposures, i.e.

a) ***Low Oxygen Corrosion*** - dissolving of steel without expansion e.g. cracks on frequently wetted floating decks.
b) ***Hollow Leg Corrosion*** – Transport of chlorides through the concrete giving internal corrosion
c) ***Long Wet Long Dry Cycles*** – e.g. dry docks with alternating to long wet long dry cycles.
d) ***Evaporative Concentration*** – Ponded sea water rises by capillary action. Evaporation concentrates the salts in the concrete.

Concrete – A Special Process

Concrete production, as identified by ISO9001 1987, encompasses various special processes that require meticulous planning and execution. Concrete mix design, reinforcement design and placement, design/construction interface, concrete transport, pouring and compaction, and curing and temperature control are all critical elements. An execution plan, as proposed by Marosszeky [10], serves as a guide to addressing potential issues and ensuring compliance with procedures.

Deemed to Satisfy (DtS) Requirements

Deemed to Satisfy (DtS) requirements in codes, based on historical performance observations, present challenges. The limitations of this approach include the potential for materials to change over time, the introduction of new materials with superior performance, and the applicability of observations from developed countries to those with limited infrastructure. This inherent rigidity in DtS requirements may hinder advancements in concrete technology and compromise the adoption of more sustainable and durable materials and practices.

Modelling Durability

Modelling durability emerges as a key enabler in realizing sustainability improvements. Chloride ingress modelling, detailed in international codes, has evolved from deterministic models to full probabilistic analysis (FPA). The common cause of reinforcement corrosion in marine structures is the ingress of chlorides, and accurate modelling is essential for predicting the lifespan of concrete structures. The shift to FPA is exemplified in a case from the Middle East, where a contractor's proposal based on discrete values was rejected in favor of the fib 34 [11] FPA method. This shift represents a critical advancement in ensuring the reliability and long-term performance of concrete structures.

Conclusion

In conclusion, the FIB Model Code 2020 provides a comprehensive framework that integrates sustainability and durability into the design, construction, and maintenance of concrete infrastructure. From cement selection to exposure assessment, and from design life considerations to reliability-based design, the code presents a holistic approach to address the challenges faced by concrete structures globally. The adoption of sustainable practices, innovative materials, and advanced modelling techniques showcased in MC2020 can pave the way for resilient and enduring infrastructure that meets the needs of both the present and future generations. As we continue to build the foundations of our societies, it is imperative to prioritize sustainability and durability in concrete infrastructure.

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Relevant UN SDGs 9, 11, 12, 13.

Social Safeguards, Gender Action and Port Planning

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Summary
Most port and harbour development projects in the Pacific have social safeguards requirements that need to be met, intended to protect, support and upskill the community. The objective of this paper is to provide insight into this obtained from outer island maritime projects, small work boat harbours and a new inter-island vessel, in Tuvalu. Requirements include challenging targets for female participation in consultation and the workforce, and capacity building in O&M, communicable diseases, gender sensitivity and equity, diversity and inclusion. Successes include engaging with youth groups, a Falekaupule questioning tradition, contributions from contractors and empowerment.

Keywords: social safeguards, upskilling, training, gender equity, Pacific, Tuvalu.

Introduction

Most port and harbour development or upgrade projects in the Pacific are funded by International Financing Institutions (IFIs) and each have various safeguarding requirements that need to be met by the recipient of the funding. These include social safeguarding requirements that limit impacts on the community but also those intended to support and upskill the community. This paper provides insight into the latter for outer island maritime projects in Tuvalu.

The Outer Island Maritime Infrastructure Project

Following a request for assistance from the Asian Development Bank (ADB) by the Government of Tuvalu (GOT) to rehabilitate its outer island maritime facilities (damaged by Tropical Cyclone Pam) and to improve the safety, efficiency, and sustainability of maritime transportation between the capital Funafuti and its outer islands, in 2015 the Outer Island Maritime Infrastructure Project (OIMIP) commenced [1]. Since 2016 to today, this has entailed the design and construction of small work boat harbours and boat ramps for Nukulaelae, Niutao and Nui (see Figure 1), along with transport master planning and institutional strengthening activities.

Figure 118 Small work boat harbour construction in Nui, December 2023

An early component of the OIMIP involved the examination of sea transport issues and options, and consultation with ship users and outer island communities (see Figure 2). This delivered a range of recommendations considered necessary to address stakeholder concerns, including a need to replace one of the nation's ageing inter-island vessels through the Strengthening Domestic Shipping Project (SDSP) [2].

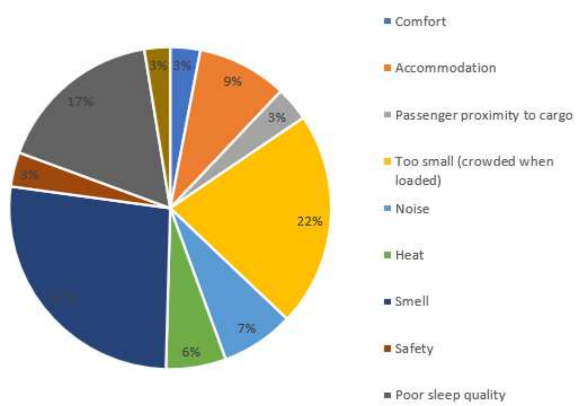

Figure 119 Consultation feedback on why the *Manu Falou* (the existing inter-island vessel) is not fit for purpose

OIMIP Social Safeguards Deliverables

Alongside delivering three small work boat harbour facilities in Nukulaelae, Niutao and Nui, and a new inter-island vessel, the OIMIP/SDSP are delivering the following:

- Women-friendly/persons with disability (PWD) designs (from handrails, ramps, and priority seating/designated areas for women with small children/PWD, to space for trading stalls).
- All community consultation has a target of at least 20 or 40% female participation (depending on the project), which is being met.
- Locals, including at least 10% women, are being employed by the contractors (and in some cases this is in trainable, semi-skilled roles such as drivers, machinery operators, administration etc.). This target includes at least one female student to be provided with financial assistance to attend the Tuvalu Maritime Training Institute.
- Women's participation in the workforce and non-traditional roles is being promoted. This

includes outreach events focused on encouraging women to work in the maritime industry.

- Cleared vegetation has been made available to the community for use in handicraft production and building.
- The capacity in the Ministry of Transport, Energy Communication and Innovation (MTECI) is to be strengthened regarding operations and maintenance (O&M), including (i) planning and executing ship maintenance, (ii) transport coordination, ship scheduling, record-keeping and budgeting, and (iii) the development of a gender sensitive recruitment policy for the Marine Division.
- Awareness training on communicable diseases (including STIs/HIV/AIDS), gender sensitivity (including gender-based violence, trafficking and the difference between gender equality and gender equity, see Figure 3), diversity and inclusion, and child protection has been provided to communities.
- Equal pay for equal work and zero tolerance for child labour and all forms of harassment and discrimination has been ensured.
- Grievance redress mechanisms are in place.
- First aid stations (multi-purpose rooms) are to be provided in the passenger terminals and on the ship.
- Ship crew are to report knowledge on passenger care issues, including specific challenges for women and girls (including harassment and signs of trafficking).
- Workshops have and are to be provided to the community on water safety, lifting and safe transfer, and basic harbour use and maintenance (with at least 10% of O&M work to be carried out by women).

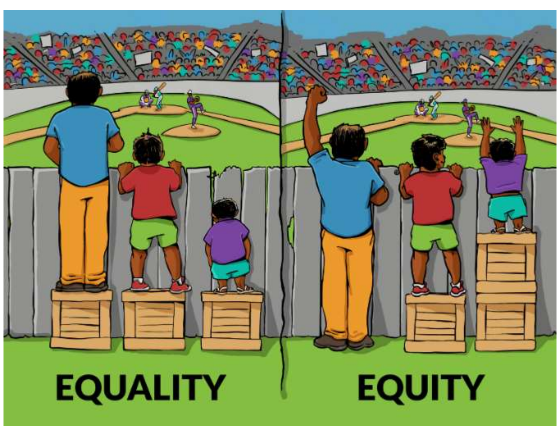

Figure 120 The difference between equality and equity

Delivery

Unsurprisingly, meeting such diverse requirements as part of harbour construction and ship building projects is challenging. It can, however, be done.

This paper will present the innovative approaches that can be and have been taken to deliver such requirements, including:

- Engaging with the Kaupule (the executive arm of the assembly of elders, literally *"grey hairs of the land"*) and women's groups to explain the importance of female participation in decision-making, and the link to funding.
- Monitoring the employment of locals by the contractors.
- Focused capacity building and an emphasis on maintenance.
- The involvement of local CSOs or nurses/ doctors to support awareness training on communicable diseases, gender awareness, and child protection (with permission).
- Agreed Codes of Conduct and community liaison officers (CLOs).
- Inclusions in contract documents.

Success stories

Successes include engaging with youth groups on gender equity (see Figure 4), a Falekaupule (assembly of elders) questioning a tradition where decisions can only be made by men over 50 years old, contractors contributing first aid stations, and the first female tug-boat pilot in the Pacific.

Figure 121 Youth group equity training in Nui, Jan 2024

References

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[2] Working Paper No 3, Grant No 0511 TUV: OIMIP Contract Tuvalu Outer Island Sea Transport, 20 August 2018.

Relevant UN SDGs

The four most relevant UN SDGs addressed by this work are 5, 8, 10, and 16.

Gold Coast Seaway Breakwater Stability Assessment

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Summary
Construction of the Gold Coast Seaway was completed in May 1986. Recent investigations have identified that parts of the structure were subject to movement and periodic stability assessments are required. Through a multiple lines of evidence approach, which include a condition assessment, survey assessments (Lidar & hydrographic) and geotechnical stability assessment, it is thought that the condition of the structure is primarily due to hydraulic instability. However, ongoing stability assessments are recommended.

Keywords: Gold Coast Waterways Authority, Gold Coast Seaway, Breakwater, Stability Assessment.

Introduction

Gold Coast Waterways Authority (GCWA) is responsible for the maintenance of the Gold Coast Seaway, located in southeast Queensland.

The construction of the Gold Coast Seaway (refer Figure 1) included the dredging of the Seaway, training walls and Wave Break Island. The Sand Bypass System was also constructed to bypass sand from the southern side of the Seaway to South Stradbroke Island.

The Gold Coast Seaway was constructed to stabilise the Nerang River entrance and to provide a safe navigation channel between the Broadwater and the Pacific Ocean. Wavebreak Island was created within the Broadwater to mitigate wave impact on the western foreshore of the Broadwater.

Figure 1 Gold Coast Seaway layout (Gold Coast Waterways Authority).

Design Aspects

The design drawings prepared by the Department of Harbours and Marine indicated that the Seaway channel was dredged to -6m AHD (refer Figure 2).

The Seaway between the training walls was designed to scour to approximately -10m AHD. As such, the toe berm had been designed as a 'Dutch' toe and some movement is expected in response to scour. Hydrodynamic action has resulted in scouring depths varying from -6 to -19m AHD.

GCWA monitor the stability of the Seaway entrance as part of routine asset condition assessments. This ongoing monitoring and assessment of the infrastructure surrounding the Seaway entrance was previously undertaken in 2011 (BMT), 2019, 2021 (GHD) and most recently in 2023 (RHDHV).

The 2023 assessment consisted of a condition assessment of the rock structures and geotechnical stability, and seabed scour.

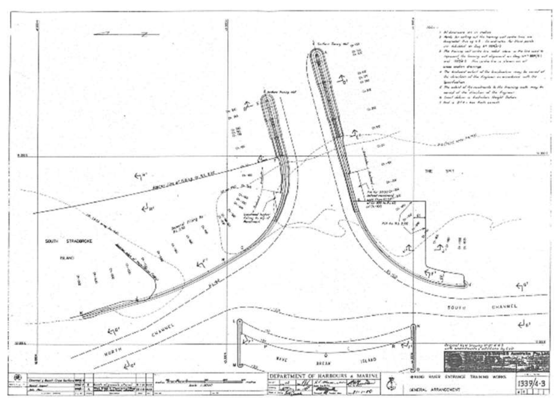

Figure 2 Seaway construction plan (Department Harbours and Marine, 1980).

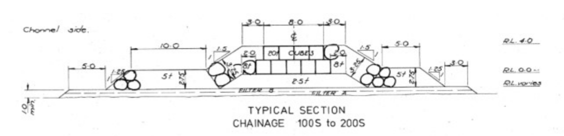

Figure 3 Typical section along the southern training wall (Department of Harbours and Marine, 1980).

Condition Assessment

The 2023 condition assessment of the rock structures was undertaken in accordance with the Wharf Structures Condition Assessment Manual (WSCAM) (Ports Australia, 2022). A level one assessment above water was undertaken on the north and south Seaway training wall and Wave Break Island training walls.

The condition assessment was undertaken at select chainages along each structure (e.g. 50m intervals on the Seaway training walls and 20m intervals on the Wave Break Island training walls. The condition of the armour units was assessed based on the rock condition rating scale in WSCAM and the armour rock mass was estimated based on dimensional measurements.

At most locations, the difference between the measured and design armour mass was less than 20%.

At a few locations, including the head of the Wave Break Island Training Walls and the Seaway South Training Wall, near the Seaway Tower, the difference in median mass was 30-46% less than design. The mid-section of the Seaway South Training Wall was noted to have a condition rating of 4/5 with armour displaced or heavily fractured.

This coincides with:

- transition from a design armour mass of 8t to 5t;
- rock armour with a median mass that is undersized by ~43% (median mass of 2.8t compared to design median mass of 5t); and,
- scour at the toe of the structure.

Previous assessments attributed movement of the armour to scour. However, analysis of bathymetric survey indicated that there was no deformation of the toe berm, which would be expected if scour was contributing to slumping of the armour. As such, the toe scour is not thought to be contributing to the armour displacement.

Survey Assessment

An assessment of scour within the Seaway and adjacent to Wavebreak Island was undertaken based on hydrographic survey.

Survey comparison from 1990 and 2015 indicated that two scour holes had developed in the Seaway. One against the southern training wall, near the Seaway Tower, and the other near the head of the northern training wall. Both scour holes have maintained a relatively consistent position since they first developed, although the depth has increased.

Figure 4 provides a comparison of survey from March 2012 and March 2023. Indicating further lowering of the Seaway channel over this period. This suggests that scour of the channel is continuing albeit at a slower rate than the 1990s.

The survey generally indicated a uniform toe berm with a width of 10m, except for the head of the northern training wall, where narrowing of the toe berm was observed with armour down to -18m AHD.

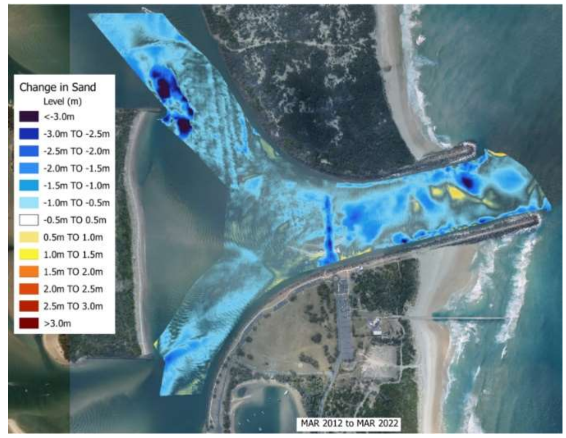

Figure 4 Isopach of the Seaway from 2012 to 2023.

Geotechnical Stability

The geotechnical stability of the rock structures was undertaken to assess potential instability of the structures. Localised instability, in the form of slip circles may occur where scour results over steepened slopes. Localised failures would be expected to manifest as uneven surface profiles of the lower portions of the revetments and/or settlement, which was not observed in the survey.

A critical stage may develop whereby oversteepening of the lower slope may lead to a deep-seated 'global' failure, which may impact the crest of the rock structures. However, this is likely to occur once the toe berm has significantly reshaped.

Previous slope stability assessments indicated shallow slip circle failure planes at a number of locations, with the slip circles interacting with the toe berm and a Factor of Safety (FoS) around one at a few locations, which is to be expected for a 'dutch' toe constructed above the design scour depth.

Conclusion and Recommendations

Overall, the design of the Seaway represents a robust design. The toe berm at the head of the northern training wall has reshaped in response to scour. At all other locations, minimal reshaping of the toe berm has been observed.

In the short to medium term ongoing monitoring is recommended to identify any emerging issues.

References

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[2] GHD (2021), GCWA Seaway Stability Review 2021 Study Report, prepared for Gold Coast Waterway Authority.

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Human Centric Design Approach in Enhancing Mooring Safety

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Summary
Mooring operations present significant safety challenges in the maritime industry. This paper advocates for the development of technology with a human centric approach to address these challenges. It explores the application of Human-Centric Design (HCD) principles in the development, implementation, and enhancement of a mooring safety technology. By drawing upon real-world experiences and collaborations with major ports globally, the paper highlights the transformative potential of HCD in addressing safety challenges and optimising efficiency in mooring operations and offers valuable insights for driving innovation and progress within the maritime sector.

Keywords: Safety, Mooring, Technology, Human Centric Design.

Introduction

Mooring is one of the most frequent and dangerous operations conducted onboard vessels. Over the past decade, the maritime industry has witnessed a significant number of mooring-related incidents, including fatalities. According to the UK P&I Club, mooring incidents are among the top seven types of insurance claims and the third most expensive per claim [3]. In an industry where safety of mooring is predominately reliant on seamanship and operator experience, various factors such as increasing size of vessels, constricted quay space, aging infrastructure, impacts of climate change, and the emergence of new mechanical mooring systems are expected to elevate the complexity and uncertainty surrounding mooring operations. While the integration of mooring safety technologies has a vital role to play in aiding ports to make informed decisions, it is essential that human factors are considered. In this paper, DHI's real world experience in applying Human Centric Design (HCD) principles to develop, implement, and continually improve a decision support tool for safe mooring will be discussed.

Human Centric Design in the Maritime Industry

HCD, as defined in ISO 9241-210:2010, is an approach to interactive systems that prioritises usability and utility by addressing the users' needs and requirements [1]. The benefits include enhanced effectiveness and efficiency, improved human well-being, user satisfaction, accessibility, and sustainability, while mitigating potential adverse impacts on human health, safety, and performance [1].

Although the philosophy of HCD remains relatively uncommon in the maritime sector, there has been a recent shift, with several guidelines and standards now incorporating HCD principles. For instance, the Oil Companies International Marine Forum (OCIMF) MEG 4 dedicates an entire section to human-centred mooring designs and human factors in mooring operations. OCIMF advocates for the integration of an HCD approach at every stage of a mooring operation or mooring design project, emphasising the need for continuous refinement and maturation [2]. This comprehensive process is broadly illustrated in Figure 122.

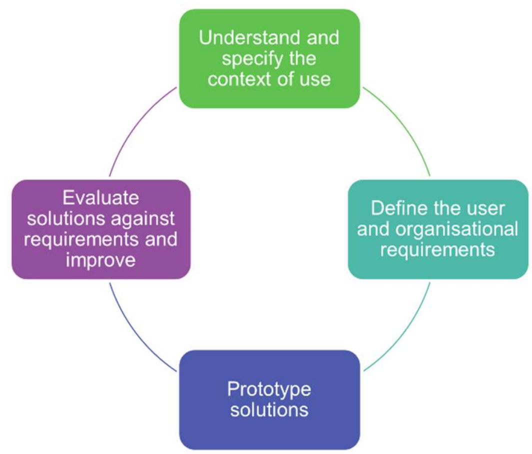

Figure 122 HCD process [2]

Recognising the challenges confronted by port operators and acknowledging the crucial connection between human factors and mooring operations, DHI embarked on developing a sustainable (aligned with UN SGDs 8 and 9) technological solution using an HCD approach. This endeavour involved (1) prototyping and developing a safe mooring technology, (2) partnering with ports to implement this technology and (3) utilising user feedback to continually improve the technology and process.

Developing a Safe Mooring Technology

To gain deeper insights into the users' needs and challenges related to mooring operations and to drive innovation, DHI forged extensive partnerships with leading ports such as the Port of Virgina, Port of Hamburg and Port of Brisbane. Leveraging our collective expertise, this international collaboration culminated in the development and rigorous testing of the world's pioneering physics-based maritime digital twin tool for mooring. This specialised web-based technology is capable of swiftly evaluating intricate mooring arrangements across a diverse spectrum of vessel types and metocean conditions.

A notable outcome of adopting an HCD approach was the integration of a standardised risk management framework into the tool. Upon completion of a mooring scenario, the tool generates standardised, intuitive mooring reports clearly showing safe wind thresholds and the corresponding maximum mooring line, fender, and bollard forces.

Implementing a Safe Mooring Technology

While senior port management readily acknowledges the benefits of this safe mooring technology, garnering acceptance and facilitating its implementation among day-to-day users often poses the most significant challenge. Without an HCD approach, the user may be reluctant to embrace change. A fundamental principle of HCD is to prioritise on the users' needs rather than forcing them to change their behaviour to adapt to the product. For DHI, this entails journeying with the port through the entire implementation process and beyond, ensuring the establishment of appropriate processes and empowering all users to leverage the tool effectively.

At Fremantle Ports, this commitment translated into hosting numerous training sessions with the same senior manager team and various user groups. These sessions aimed to foster user comprehension of the tool while enabling senior managers to gather feedback on existing barriers hindering the tool adoption. For the port, this has aided them identifying necessary changes to internal systems and processes and in defining each user's role. An inherent benefit of this HCD approach is its capacity to facilitate positive change and foster alignment across diverse user groups and senior management. Upon complete implementation, DHI will continue to support Fremantle Ports in making informed decisions regarding mooring operations. This signifies a substantial shift from mere service provision to establishing an operational partnership.

Evaluating and Improving our Solution

A pivotal outcome of the HCD process is the ongoing evaluation of the solution against the user requirements and relentless pursuit of improvement. Since its initial development, DHI has implemented several notable enhancements to its safe mooring technology.

One significant improvement to the tool involves the implementation of a traffic light system, featuring tiered, automated alerts that are filtered based on severity of risk and urgency to act. This innovation enables berthing teams to swiftly assess mooring risks ahead of severe weather, directing their attention to vessels deemed 'at-risk' while efficiently handling 'low risk' moorings. This approach effectively minimises user alert fatigue and has empowered the Port of Virginia and Fremantle Ports to consistently maximise berth utilisation even during adverse weather conditions. Other enhancements include the capability to assign individual line pretensions for complex mooring arrangements at the Port of Esperance and the automated population of vessel call information at Fremantle Ports. These advancements have streamlined day-to-day operations for these ports.

In addition to enhancing the safe mooring technology, DHI has applied an HCD approach to evaluate and refine the implementation process. For instance, a significant barrier in conducting training for port teams has been the varied work shifts, making it challenging for many users to attend training sessions during their off time. To address this challenge, DHI developed self-paced online training courses. These courses not only ensure comprehensive user training but also establish a robust certification process, ensuring proficiency among all users.

Conclusion

Amidst escalating uncertainty surrounding mooring operations and the critical importance of human factors in ensuring mooring safety, DHI has embraced an HCD approach in the development, implementation, and enhancement of its mooring safety technology. DHI's real-world experience showcases the effectiveness of this approach and provides a compelling case study for the transformative power of HCD in driving positive change and advancing safety and efficiency in maritime operations. As the maritime industry continues to evolve, embracing HCD principles will be essential in navigating future challenges and realising opportunities for continued progress and innovation.

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Vessel Impact on Bridge Structures in Australia

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Summary
Vessel Impact of bridge structures is an important topic for all bridges over significant waterways with navigational traffic. In the past, fender structures have been used to protect bridge piers from impact by vessels. The latest design methods consider significant vessel impact directly on the piers and pile caps with the substructure design allowing for capacity to withstand these loads. The loading regime in Australia is based on AS5100 with reference to the American code AASHTO. The abstract and presentation will cover the vessel impact design for the new bridges at Nowra and Nelligen on the NSW South Coast.

Keywords: Vessel Impact, Bridge, South Coast NSW

Introduction

Following the bridge collapse in Baltimore in March 2024, the importance of the consideration of vessel impact on bridges is described in this abstract with an emphasis of the design and calculations required to consider these loads in bridge design.
Vessel impact, for bridges in Australia, is defined in Australian Standard AS5100.2:2017. The impact force must be calculated based on operating vessels and vessels likely to operate in the next 100 years. The velocity for the impact is to be the larger of the maximum flood velocity and the maximum speed of the vessel under power. The velocity to be used in design must be approved by the relevant authority. If no guidance is given, then the impact force is to be determined in accordance with AASHTO LRFD Bridge Design Specification. As per the velocity calculated under the Australian bridge design code, the resulting minimum equivalent static impact force derived from AASHTO needs to be approved by the relevant authority.
It is noted that the AASHTO LRFD Bridge Design Specification requires differentiation between a ship collision and a barge collision force. The ship represents a ship with steel hull and Dead Weight Tonnage of 1,000 tonnes. A barge has a flexible hull, e.g. fibreglass, and would therefore absorb energy better and result in less force. Both of those approaches calculate a static equivalent load. Other methods allow a probabilistic approach that considers local constraints and the fleet operating at the location of the bridge.

Example 1: New Nowra Bridge

The New Nowra Bridge is a 10 span bridge over the Shoalhaven River. It was constructed using the incrementally launching method. The foundations comprise generally piers with 4 steel driven tubular piles and a concrete plug. The piles are 50-60m long and connect into a reinforced concrete pile cap.
Figure 1 shows the structure during construction. The new piers can be seen, which have the pile cap deep enough to cover high and low water levels. Potential vessel impact would primarily act on the pile cap, but impact on the piers themselves was also considered.
Based on maritime authority approvals, the design vessel for the New Nowra bridge was a 60t vessel traveling at 30knots.

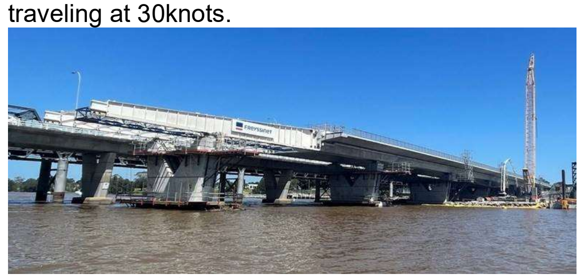

Figure 1 Photo of New Nowra Bridge during construction

To address the vessel impact design actions, the design provides fixity between piers 1 to 8 and the superstructure which are located in the navigational channel. With this configuration, the vessel impact loading is resisted partly by the impacted pier foundation and partly by the other pier foundations via the distribution provided by the superstructure. A representative bending moment diagram for sideways vessel collision is shown in Figure 2. The vessel impact produces a maximum bending moment at the pile closest to the impact point, while the other piles attract less action.

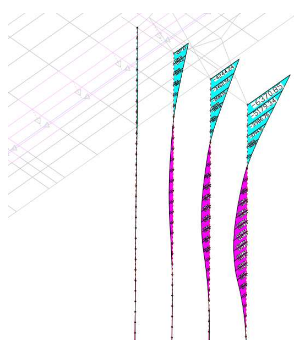

Figure 2 Typical bending moment diagram – longitudinal (sideways impact) direction

For the head on collision, the geotechnical model provides the spring stiffness' for the soil which accounts for pile group effects. This accounts for the leading pile soil springs to be stiffer than the trailing pile soil springs due to pile group effects. Therefore, the leading pile receives a higher transverse resistance than the trailing piles behind the leading moving with the pile group block. This results in higher moments in the top of the leading pile compared to the remaining piles.

The bending diagram shown in Figure 3 shows the above described pile group behaviour due to head-on collision and the required length for the reinforced concrete infill in the piles.

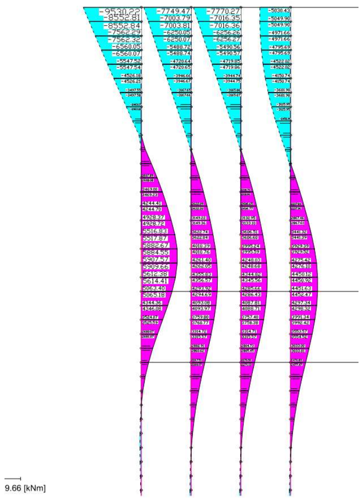

Figure 3 Typical bending moment diagram – transverse direction

The horizontal loadings on the fixed bearings at the piers were determined from the same substructure design analysis model, and significant horizontal forces due to vessel impact had to be transferred between piers and superstructure. Bearings had to be specifically designed to transfer these extremely large horizontal forces.

The launching operation requires temporary bearings to allow for sliding of the superstructure over them. The design utilises the application of the same spherical bearings set for temporary and permanent function. Transformation to permanent bearing involved jacking of the bridge to remove the sliding equipment and activation of fixed arrangement was required. Amongst a couple of options investigated for horizontal fixity between superstructure and substructure, it was concluded that the best outcome for the project program and safety during construction was to provide spherical fixed bearings, by ultimate means of welding the bearing to cast-in plates to the girder soffit.

The innovative idea of using the fixity of the bearing to redistribute the vessel impact loading has contributed to the optimisation of the design of the bridge substructure and foundations.

Example 2: New Nelligen Bridge

The New Nelligen Bridge comprises also a 10 span structure with a reversed-curved superstructure. The foundations 4 bored concrete piles fixed into a reinforced concrete pile cap. Figure 4 shows the new and existing structure. The existing structure is due to be demolished.

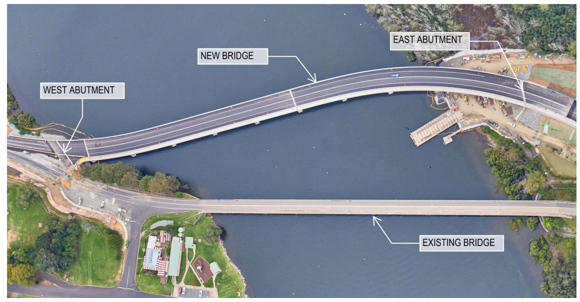

Figure 4 Plan of New Nowra Bridge

Nelligen Bridge is required to resist a vessel impact in the ultimate limit state. This includes an impact on any pier in the waterway and at any point on any span of the deck for the marine section, which consists of 7 piers (Piers 3 to 9).

The design approach adopted for Nelligen Bridge is the simplified approach, which effectively results in an Annual Frequency of Collapse of zero, and so will be more conservative than the probabilistic approach.

The ultimate equivalent static vessel impact force was determined in accordance with the AASHTO LRFD Bridge Design Specification. A load factor of 1.00 for Ship Collision Load was used in the ULS load combination for collision of vessel.

Based on the approval by the maritime authority the design vessel for Nelligen was a 18t vessel travelling at 20knots.

The vessel impact effects have been determined using the finite element design software package InfoCAD. This full bridge model enables redistribution of forces between adjacent piers through the deck and bearing system under vessel impact. The lateral support to the piles provided by the ground has been modelled as bedding springs with limiting lateral soil pressure (i.e. elasto-plastic behavior).

Conclusive Summary

Vessel impact considerations for bridges over motorways in Australia are based on the Australian Standard 5100:2017 which refers to AASHTO LRFD Bridge Design Specification for a more detailed approach. The AASHTO specification was used for the bridges at Nowra and Nelligen and resulted in a robust design to accommodate the risk of vessels impacting the substructures of bridges.

Relevant UN SDGs

9, 11.

Enhancing capacity of domestic small container terminal through yard re-layout

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Summary
This is a case study of the Samarinda Terminal where capacity was enhanced at the domestic terminal to meet demand. There was limited land to extend the wharf. Capacity, optimizations and productivity improvements were instead realized by adding an empty container yard at relatively low construction costs and investment in empty stacker equipment. The terminal characteristically handles 60% full and 40% empty containers, mostly 20 feet. Relocating the empty containers handling activity to a dedicated empty yard reduced bottlenecks at the full container yard. The result of the project is the increase of productivity and capacity of the Samarinda terminal with a BOR (Berthing Ratio) still under 60%.

Keywords: Productivity, Re-layout, Capacity

Introduction

The volume of activities at Domestic Ports outside Java is 100% inbound from Java, with Java being the producer port and ports outside Java being the consumer ports. Most of the goods and raw materials are transported using 20 feet containers. However, 80% of the containers returning to Java are empty.

With the economic demand growth in the Kalimantan region, there is a high demand for inbound container volume. This has the potential to cause congestion due to high demand and limited capacity.

Small Domestic Ports in Indonesia mostly at river area, cannot easily expand their infrastructure and superstructure due to several influencing factors, such as limited land. Limited land and high investment costs are obstacles for domestic ports in developing their capacity.

This study identifies that limited land can hinder a port's ability to build additional berths or add new dock cranes, as well as the presence of high investment costs. With budget limitation, Small domestic ports may face significant constraints.

Limited land and high investment costs are obstacles for domestic ports in developing their capacity. In the storage yard area, containers may be mixed and stacked, both full and empty, resulting in a lot of shifting that has no value for the terminal

The purpose of this study is to reducing the workload of RTG (Rubber Tired Gantry Crane) in the container yard, shifting, increase the flow of container supply from the yard to the wharf and wharf capacity without high investment. Innovations need to be found to achieve efficiency and productivity improvements that will lead to increased capacity at the port.

Method

This research method compares yard layouts between mixed and separated configurations and their impact on productivity improvement.The productivity of QCC (Quay Container Crane) at the wharf can be improved by increasing the speed of container supply from the container yard by reducing the workload of RTG (Rubber Tired Gantry Crane) in the yard.

This can be achieved by relocating empty containers to a new yard designed specifically for empty containers, thereby saving on investment costs. The handling of empty containers can be done using a side loader, which is cheaper compared to the cost of an RTG (Rubber Tired Gantry Crane.

Re-layout of the yard is carried out by moving the container stripping and stuffing activities outside the port area in cooperation with third parties and converting the area into a yard for empty containers.

Instead, separating the locations for full and empty containers and using appropriate equipment for each can optimize operations, thus enhancing productivity and capacity.

With this method If there is an increase in demand and potential congestion, it does not necessarily require high investment for building new wharf or container yards and equipment yards specifically for full containers.

Result

Year	Call	Load/Unload (Teus)	Volume Design	Yard Capacity	BCH (Gross)	BCH (Nett)	Opr Time	Port Stay	BOR	YOR
2015	577	232.581	220.000	216.810	15,9	20,6	13,3	17,7	63%	107%
2016	542	226.965	220.000	574.163	23,8	30,5	12,4	15,6	48%	40%
2017	491	238,819	220.000	459.331	24,6	31,2	14,0	17,2	48%	50%

Table 1. Impact Re-layout To Productivity

The re-layout by converting 2.6 hectares of the open yard for stripping and stuffing into an empty storage

Yard, as mentioned table 1., not only increases the total storage yard capacity but also enhances the productivity of BCH (Box Crane Hour) on QCC (Quay Container Crane) by 30% from 2016 to 2017. The BOR (Berth Occupancy Rate) decreased from 63% to 48%. Additionally, the YOR (Yard Occupation Rate) decreased, allowing capacity to grow beyond the design capacity.

The re-layout can significantly impact productivity by using specialized equipment for handling empty containers. The operational handling and transport of the empty yard to and from the dock use twinlift handling equipment (Twinlift spreader, Double box Empty side loader, and Trailer combo) as mentioned in Figure 2. This results in increased supply to the ship and enhances the productivity of QCC (Quay Container Crane).

Figure 2. Twinlift Handling Equipment for Empty Container

Existing Yard (Land area 5,1 Ha)						Additional Relayout (Land area 2,7 Ha)						
Blok	Slot	Row	Ground Slot	Tiers	Capacity (TEU's)	Blok	Slot	Row	Ground Slot	Tiers	Capacity (TEU's)	Total Capacity
D	33	6,0	198	5	990	A	33	9,4	311	8	2.488	4,950
E	33	6,0	198	5	990	B	31	8,0	248	8	1.984	6,328
F	33	6,0	198	5	990	C	29	8,0	232	8	1.856	
G	33	6,0	198	5	990							
H	33	6,0	198	5	990							
			990		**4,950**				**791**		**6.328**	**11.278**

Table.2 Additional Capacity

The re-layout, which converts the stripping and stuffing open yard into an empty container yard, increases the terminal's container capacity to 6,328 ground slots from the previous 4,950 ground slot capacity.

Discussion

Considering 80% of Loading Activities Involve Empty Containers and 100% of Unloading from Ships Involves Full Containers It is necessary to consider implementing double cycling to further enhance productivity at (Quay Container Crane)

Conclusion

The productivity of (Quay Container Crane) increases, leading to reduced port stay for vessels, increased volume, and a decrease in BOR (Berthing Ratio). Productivity improvements can be achieved with the addition of infrastructure at a low investment cost by developing an empty container yard and using empty handling equipment.

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WG225 Seismic Design Guidelines for Port Structures

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Summary
This abstract presents an update on the status of the development of WG225 “Seismic Design Guidelines for the Port Structures”.

Keywords: WG225, earthquake, seismic design, Port Structures,

Abstract
The existing PIANC Seismic Design Guidelines for Port Structure WG34-2001, (PIANC 2001 Report) reflect lessons learned from the 1995 Kobe, earthquake disaster and were “the state of the art” report at that time. The PIANC 2001 Report brought performance-based design to much of the marine structures community and was a critical document in aiding the development of many later codes.

However, new codes and standards reports have been published over the last 23+ years including:
the Japanese standards (Technical Standards and Commentaries for Port and Harbor Facilities in Japan, 2007 & 2018) and
the American standards (ASCE Seismic Design of Piers and Wharves 61-2014),
which have improved the guidelines for seismic design of port structures. PIANC has initiated the Working Group 225 (WG225) to provide an up-to-date of the seismic design guideline document.

The WG225 is reviewing the latest technical information and publications related to seismic design of port structures including codes and standards, literatures, and case studies to reflect current best design practices. The focus of WG225 has been on technical information published after the current PIANC 2001 Report, including lessons learned from events in Indonesia (2004), Haiti (2010), Chile (2010), Japan (2011, 2024), New Zealand (2016), and Turkiye (2023).

WG225 members are representative of countries throughout the world and include members of other committees and code writing organizations, such as the American Society of Civil Engineers (ASCE), the Overseas Coastal Area Development Institute of Japan (OCDI), and the European standards (Eurocodes). This has allowed the committee to develop a range of methods and structural types which reflect best practices in various regions worldwide.

While the focus on performance-based design methods remains the intent of the document, the previous guidance is being updated to reflect the most recent developments and techniques. WG225 also compared different regional approaches and various codes and guidelines.

Guidance is provided for the evaluation of seismic ground motions, selection of performance objectives including demand events and damage states, as well as discussion on appropriate detailing to ensure ductile performance of marine structures.

Similar to the other PIANC documents, the new PIANC WG225 document is being developed as a guideline. intended to aid marine infrastructure stakeholders (facility owners / operators, designers / practitioners, regulators, scientists / academia, etc.) both in locations which do or do not currently have their own marine structure design standard.

The document reflects the importance of selection of design standards and provides recommendations where appropriate for typical design parameters, while not prohibiting or counteracting any other existing design standards. The document will include guidance for pile supported piers and wharves, sheet-pile and combi-wall bulkheads, gravity block walls, and caissons.

How does this guideline contribute to the advancement of the industry and profession?

The PIANC WG225 will provide a practical guidance on best practice approaches to design criteria, damage performance for marine structures, and detailing recommendations appropriate for use in the different regions (i.e., areas with low, medium or high exposure to seismic activities) worldwide.

Does the guideline implement new and innovative techniques, materials, technologies, and delivery methods?

The PIANC WG225 will endeavor to combine and reflect the current best practices used worldwide, including innovative techniques that will be novel in some regions as well as long-established yet practical methods which may have been neglected in some regions. The intent is to cover a wide range of materials, approaches, and techniques in order to cover the breadth and depth of current seismic design practice worldwide.

What was the most challenging aspect of the guideline and how it is being handled to ensure success?

The most challenging aspect for the WG225 team has been melding the various approaches used worldwide to reflect a consistent concept of capturing expected performance and demand while not restricting any one region's technical approaches or construction methods. While the underlying physics doesn't change, the approach by region may significantly change, especially in regard to economics of performance, available materials, and factoring of loads and capacities. The team has spent significant effort in ensuring that the final document reflects the best approaches while respecting the countries or regions specific practices.

Who is the target audience for this guideline?
Marine infrastructure facility owners / operators, designers / practitioners, regulators, scientists / academia

Enhancing Tsunami-Borne Debris Velocity Estimation for Improved Risk Assessment

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Summary
This paper highlights accurately estimating debris velocity during tsunamis to enhance risk assessment for coastal infrastructure. It focuses on an equation to estimate debris velocity based on the structure-debris pickup distance. It delves into the dynamics of tsunami-borne debris movement using a theoretical model and evaluates the model's performance using case studies. The New Zealand harbourfronts are chosen strategically within tsunami inundation zones and with available tsunami data. The study reveals varied velocities influenced by container size, highlighting the pivotal role of mass and distance from the debris source in assessing structural impact during tsunamis.

Keywords: tsunami, shipping container, debris velocity, debris mass

Introduction

In tsunami-prone areas, the collision of tsunami-borne debris with structures presents a significant hazard, often resulting in substantial damage to inland infrastructure. Previous studies [3,5,6,7] highlight the importance of accurate force quantification in tsunami-prone areas. Harbourfront areas, characterised by the storage and movement of shipping containers, contribute to increasing the risk of tsunami-borne debris impacting nearby key structures. The rising frequency of tsunamis affecting Pacific nations [2] highlights the importance of understanding the risks associated with debris impact, particularly near harbours.

Various methodologies, like impulse-momentum, work-energy, and contact-stiffness approaches, are used for estimating debris impact forces on structures. These methods consider parameters such as mass, velocity, stopping time, stopping distance, or effective contact stiffness [1]. However, some empirical equations derived from these methods often assume debris movement at flow velocity, leading to overestimation of forces, and thus impacting risk assessments.

Recent studies by Shafiei et al. [7], who is the first author of this paper, have highlighted disparities in comprehending the factors affecting debris contact duration and velocity before colliding with structures. To tackle these issues, Shafiei et al. introduced the impulse-momentum method for estimating force, supplemented by direct impact acceleration measurements, reducing uncertainties related to determining parameters like contact duration and pre-impact velocity.

This paper presents a portion of Shafiei et al.'s research, focusing on formulating a debris velocity equation between defined pickup and structure locations. Through a case study application, it offers practical estimations of debris velocity, enhancing risk assessments beyond simplistic assumptions of debris velocity equal to the tsunami flow velocity.

Theoretical Debris Velocity

Figure 123 illustrates the theoretical concept of debris velocity. It shows how debris, initially stationary, accelerates in response to an incoming tsunami bore. Heavier debris takes longer to reach the bore velocity compared to lighter debris, highlighting the varying impact potential based on the debris mass.

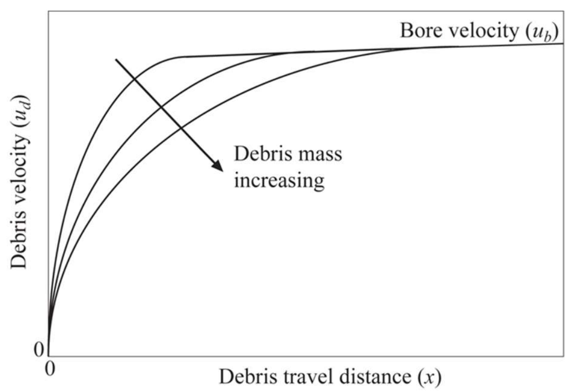

Figure 123 Schematic diagram of the theoretical concept of debris velocity, indicating that the heavier the debris, the longer it takes to reach bore velocity. Note the scale is arbitrary.

The differential equation describing the debris velocity theory illustrated in Figure 123, along with its associated initial conditions, can be expressed as Equation 1 and Equation 2:

$$m_d \ddot{x} = 0.5 C_d \rho_w (u_b - \dot{x})^2 A_d \quad (1)$$

$$\begin{cases} \dot{x}(0) = 0 \\ x(0) = 0 \end{cases} \quad (2)$$

where m_d = debris mass; ρ_w = water density; A_d = projected area of the debris to the incoming bore; C_d = shape coefficient for the debris; x= distance; $\dot{x}$ (dx/dt) = debris velocity and $\ddot{x}$ (d^2x/dt^2) = debris acceleration.
The debris velocity increases gradually until it collides with a structure. Depending on the debris

mass, sometimes its velocity reaches the flow velocity over a considerable travel distance. As the debris is entrained by the flow, it accelerates, thereby entraining water. To simplify the velocity calculations, we assumed no additional mass from entrained water, which may slightly overestimate the debris velocity.

Equation 1 can be rewritten in terms of the debris velocity u_d:

$$m_d \frac{du_d}{dt} = 0.5 C_d \rho_w \left(u_b - u_d(t)\right)^2 A_d \quad (3)$$

Integrating Equation 3 for the debris velocity gives:

$$u_d(t) = u_b - \left(\frac{C_d \rho_w A_d}{2 m_d} t - \frac{1}{u_b}\right)^{-1} \quad (4)$$

where t = debris travel time. Equation 4 consists of two terms within the bracket: the first term denotes the velocity of the debris, while the second term represents the velocity of the tsunami flow. Integrating Equation 4 with respect to time provides an approximation of the distance travelled by the debris (x) to attain the flow velocity.

$$x(t) = u_b t - \frac{2 m_d}{C_d \rho_w A_d} ln\left(\frac{C_d \rho_w A_d u_b}{2 m_d} t + 1\right) \quad (5)$$

Once the distance of travel is known, Equation 5 can be solved to determine the time (t) required for the debris to traverse that distance. Subsequently, the debris velocity can be estimated by utilising Equation 4.

Case Study Investigation

Two harbour sites in New Zealand were chosen as examples, characterised by the presence of numerous residential and commercial structures situated at varying distances from the harbourfront.

The selection of the two case study site locations was purposeful, chosen specifically because they are situated within tsunami inundation zones and have readily available tsunami data. The tsunami data were obtained from the "Review of Tsunami Hazard in New Zealand" by Power et al. [4].

Discussion and Conclusion

The tsunami flow velocity was estimated based on the tsunami inundation depth, utilising a Froude Number of 1.0. A range of shipping container sizes, from 8FT to 40FT, was examined. The dimensions and mass of the empty containers were sourced from the container datasheet. Additionally, variations in container mass were explored by considering both half- and full-container masses, drawing on practical experience. This approach aimed to assess how debris velocity varies with differing masses for a given tsunami flow velocity.

Additionally, structures were designated at varying distances from the debris pick-up location, ranging from 100m to 1000m. Using Equations 3 to 5, debris velocity was estimated for different container masses and structure locations relative to the pick-up point.

Upon initial analysis, the following conclusions were drawn from the study:

- None of the examined containers achieved the tsunami flow velocity within 500 m of the pick-up location.
- Smaller empty containers could reach the tsunami flow velocity but only at a distance of 1000m from the pick-up location.
- Larger half- and full-containers, alongside structures positioned within 1000m from the pick-up location, generally reached 30-60% of the tsunami flow velocity.

Overall, the study highlights the following key points:

- Debris velocities varied significantly depending on container size, with smaller containers exhibiting different behaviour compared to larger ones.
- Understanding debris velocities is crucial for assessing the impact on structures located at varying distances from the pick-up location.

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Understanding the dynamics of a large and complex ebb-tidal delta to support a greenfield port feasibility assessment

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Summary

The Manukau Harbour has been identified as a potential greenfield port location to replace the cargo operation of the Ports of Auckland. The Manukau Harbour is New Zealand's second largest estuary covering 344 km^2 and with a spring tidal prism of around 918M m^3. At the entrance to the harbour is a large ebb-tidal delta known as the *Manukau Bar*. The Manukau Bar is a very large geomorphological feature containing approximately 1,250M m^3 of sand that is also notable for its dynamic nature with changes in the main channel position noted in many previous studies and evident in previous navigation charts. The Manukau Bar was the scene of New Zealand's worst maritime accident with the HMS Orpheus being wrecked after striking a shallow bar in 1863 resulting in 189 deaths. As part of the establishment of a port within Manukau Harbour, a navigation channel would be required to be dredged through the Manukau Bar. This paper reports on a series of field, remote sensing and numerical investigations undertaken to understand the processes currently occurring on the Manukau Bar, and to assist in predicting the likely consequence of opening and maintaining a navigation channel.

Keywords: Ebb-tide delta, Manukau Harbour, Field data, Numerical Modelling, Dredging.

Introduction

This paper provides an overview of the geomorphological characteristics of the Manukau Bar, it's historic and recent changes, modelling undertaken to describe the hydrodynamic, wave and sediment transport processes and the likely implications of opening and maintaining a navigation channel. This paper may be read in conjunction with [1] which discusses the technical considerations of dredging and maintaining a channel in such an environment.

Ebb-tide delta processes

The Manukau ebb-tidal delta or Manukau Bar is located at the mouth of the Manuka Harbour (Figure 1) and is a very large geomorphological feature containing approximately 1,250M m^3 of sand [2]. New bathymetric data collected as part of this study provides the most comprehensive survey since 1989 and, combined with satellite image analysis, confirms the migration of the main channel to the north, followed by breeching to the south, as noted in previous studies [3] and conforming to the conceptual model of ebb-tidal delta breaching and outer delta breaching [4]. A model of this ~30 year cycle was developed and can be matched to historic surveys dating back to the 1830s (Figure 2).

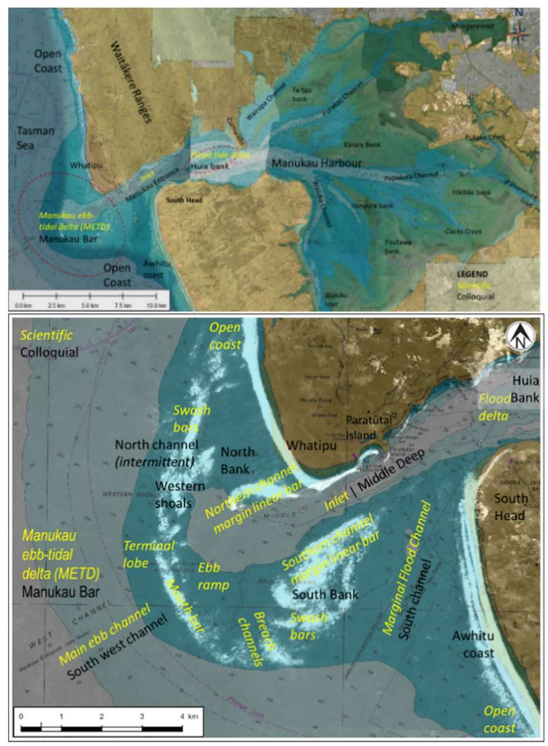

Figure 124 Key features of the Manukau Harbour (top) and Manukau Bar (lower)

Hydrodynamics and sediment transport

Wave, current and water level data was collected to calibrate a suite of coupled hydrodynamic and sediment transport models. These were used to describe the processes operating on the Manukau Bar under a range of environmental conditions and then to predict changes following the opening of a navigation channel [1].

Key findings were that sediment transport on the Manukau Bar is highly complex with very large volumes being recirculated out through the main channel during ebb tidal flow, then onshore across the shallow bars under wave-driven flows and back into the main channel (Figure 3). Total (gross) volumes being transported on the bar were an order of magnitude higher than on the open coast.

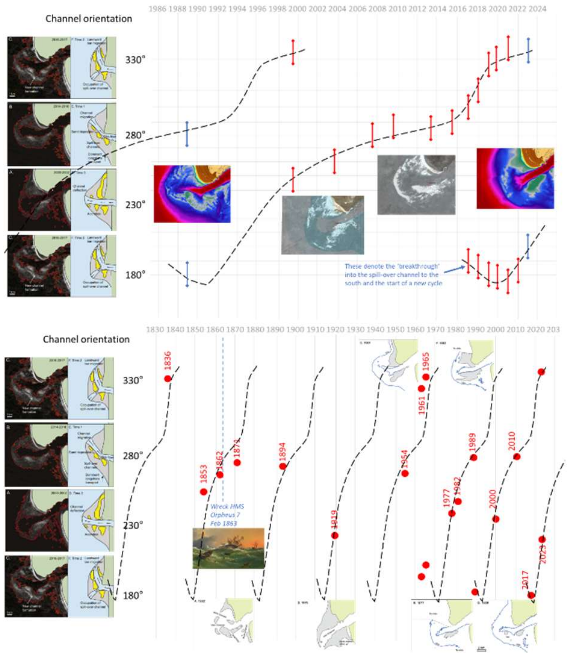

Figure 2 Conceptual model of channel configuration during the past 35 years (top) and 200 years (lower)

The addition of a navigation channel allows the tide to more efficiently enter Manukau Harbour, slightly increasing tidal prism. Flow velocities were increased within the channel and slightly decreased outside. Sediment transport tends to be increased over the bar with greater scour occurring within the middle parts of the dredged channel and material being deposited further offshore as a more seaward bar develops and at the landward end of the dredged channel as a shoal.

Geomorphological considerations of maintaining a navigation channel

If the channel was left for a prolonged period, the shoals forming within the channel would likely develop until it eventually returns to a pre-dredged form. This is not compatible with a shipping channel and so material that accumulates above the design depth would need to be removed by dredging. This volume has been assessed to be in the order of some 5 to 8 M m^3/year.

The placement of capital and maintenance dredge spoil will affect the geomorphology of the bar and adjacent beach systems. The calculated dredge volumes are substantially larger than the calculated longshore transport rates on adjacent beaches so if the material were all placed downdrift it may affect existing coastal processes on adjacent beaches and, over time, shrink the bar system. A reduction in the ebb-tidal delta volume may have adverse effects on adjacent coastlines and/or the flood-tidal delta as sand is 'sourced' from elsewhere to bring the system back to equilibrium. Placement of spoil would need to be designed to maintain the existing sediment transport circulation patterns on the bar.

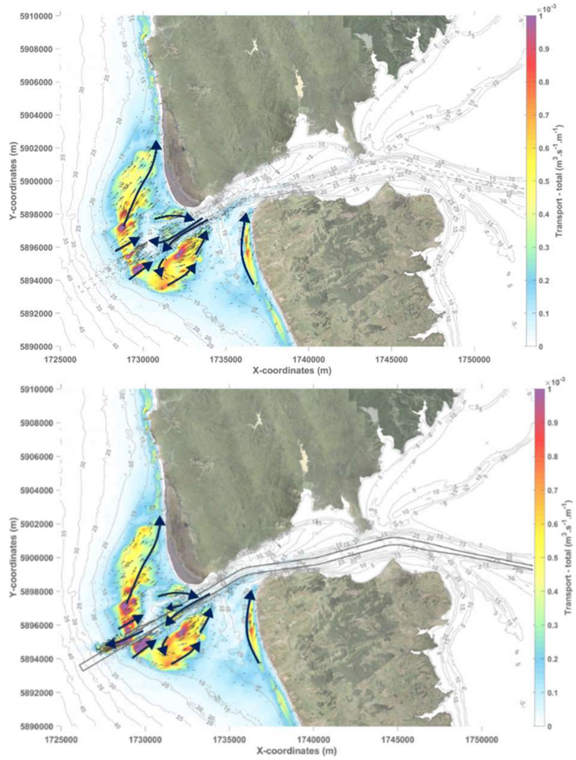

Figure 3 Sediment transport regimes during high wave conditions on the existing Manukau Bar (top) and with a dredged navigation channel (lower)

During certain stages of the channel and bar evolution, large volumes of sediment (several M m^3) are forced by waves and currents across the proposed channel alignment. However, these changes are likely dependent on sufficient material accumulating on the southern banks to interrupt the strong tidal flows and force the channel to the north. By selective (and adaptive) placement of the maintenance dredge spoil, the accumulation of sediment can be likely be managed and this process controlled.

Acknowledgements

This study was commissioned and funded by Te Manatū Waka | The NZ Ministry of Transport.

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Wharf Surveys (WSCAM) Using Photogrammetry Digital Twin Models

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Summary
The use of Photogrammetry 3D models for the inspection of wharf and related marine structures are increasingly being utilized to provide a snapshot of the structures condition and allow accurate inspection and WSCAM assessments. The paper discusses the use and advantages of these “digital twin” models in the important asset management of these highly exposed structures.

Keywords: Asset Management, Condition Assessment, Photogrammetry, Wharf Structures, WSCAM.

Background - WSCAM

Wharf Structures Condition Assessment Manual [1] (WSCAM) surveys are intended to provide a consistent approach for condition assessment of a variety of port structures. They typically include both “baseline” and “periodic” visual surveys, which are used to create and update an asset inventory. More detailed investigations are then performed on specific areas of concern. This then enables maintenance work to be budgeted accurately and carried out within the appropriate timeframes.

Photogrammetry

Carrying out a detailed visual inspection in person can be slow, and the area inspected is frequently limited (for example by access considerations and the need to minimize disruption to port operations). An alternative approach is to “capture” thousands of high-resolution images with precise location information, and to use these to build a detailed 3D “photogrammetry” model of the wharf (sometimes referred to as a “digital twin”, “precision reality twin” or “virtual replica”). The visual inspection is then carried out on the model rather than directly on the structure. The capture may be carried out via drones, or boat-mounted or hand-held cameras. Application of drones to asset inspection has been recently reviewed [2]. Here we provide examples of how photogrammetry (including drone capture) can make WSCAM visual inspections safer, faster, and more effective.

Models for WSCAM purposes

To be able to accurately carry out a visual assessment of a structure, the resolution of the 3D models must be high. Precise location of defects in 3D-space is also required. This is more challenging, but still possible, when GPS is not accessible (e.g. below deck).

Software used to view the 3D digital twins enables measurements to be taken, and areas of interest such as defects to be “annotated”. An annotated model can include fields for WSCAM requirements (refer to Figures 1 and 2 for typical examples).
Models can be integrated with existing asset management databases and GIS systems and allow the condition of an individual element to be followed over time.

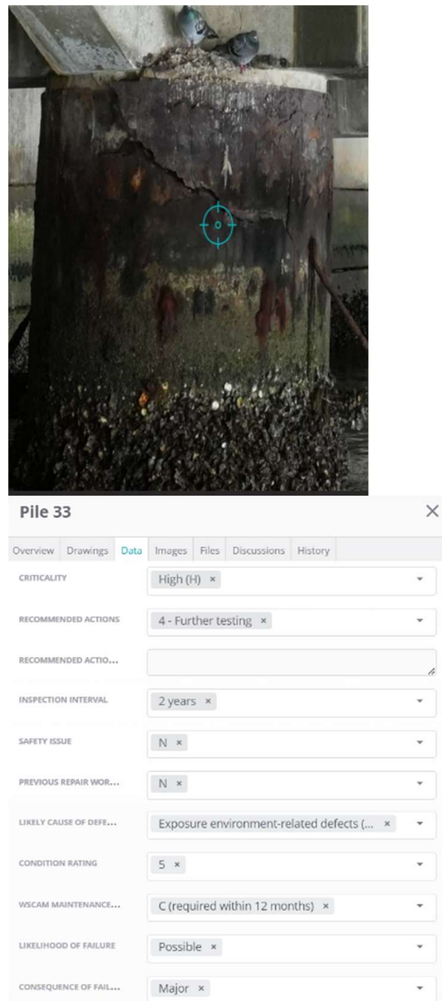

Figure 125 Example of an image from a digital twin model, showing a damaged steel-encased concrete pile, and part of the WSCAM-based annotation for that pile. The model can be “navigated” in 3D, and images and annotations precisely located.

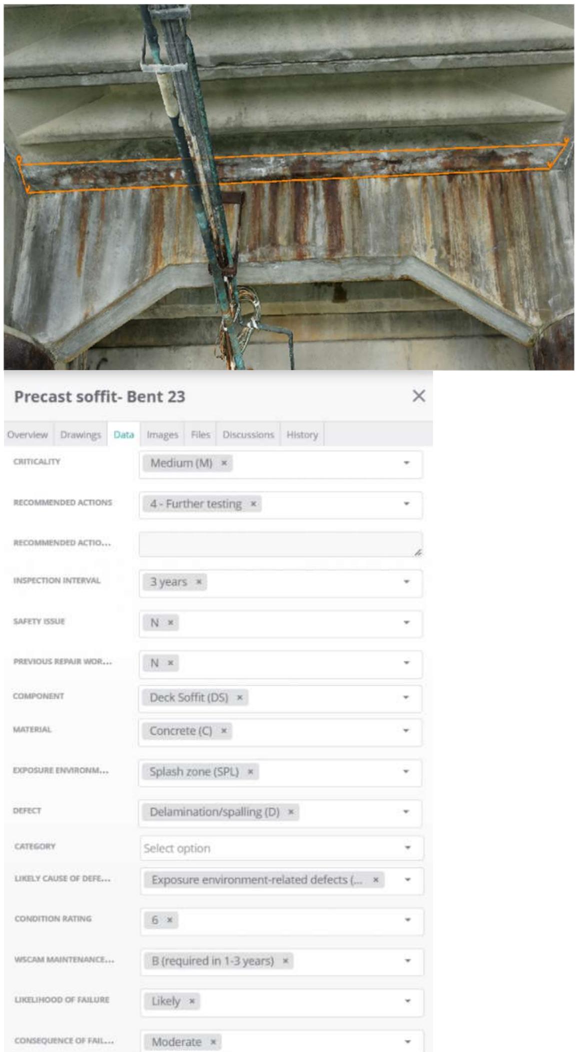

Figure 2: Example of an image from a model that was captured under a wharf, and WSCAM annotation for this defect.

Advantages of this approach

Access to some wharf structures (or parts of structures) can be a difficult aspect of condition assessment. For example, inspecting the entire underside of a wharf from a boat is slow and disruptive to shipping operations. Many wharves are only accessible during narrow tidal and shipping windows. Using a digital twin means that disruption can be reduced, because capturing the information needed to build the model is far faster than carrying out a full visual inspection. In addition, working in boats and other hazardous operations are minimised using the photogrammetry models.

Being able to inspect far more of a structure provides more complete condition information, enabling better programming of maintenance works and more detailed inspections, reducing overall costs. On-site detail testing (for example chloride penetration depths or electrochemical measurements) can be carefully planned and targeted, rather than test locations being determined once the inspection crew arrive on site.

Using a digital twin for WSCAM surveys enables all the information required for each individual element that is assessed to be consolidated and tied to the exact location on the structure. Lists of defects are easily assembled and quantities can be readily estimated. Typically, the models and data can be securely shared with whomever the asset owner wishes to share it with.

Beyond WSCAM

Being able to view and inspect a structure without having to physically visit it has many other advantages for asset management as discussed below.

As-built drawings and legacy drawing sets can be confusing, inaccurate or even lost. A digital twin provides accurate location and scale information as well as visual condition. The photogrammetry models can be utilized for point cloud information to accurately create BIM or structure drawings.

The 3D models can be shared with maintenance staff or external consultants as required, removing their access if no longer required.

Tender site visits can be done utilizing the model on-line. Potential contractors can be given access to the model (temporarily) so they can plan access and maintenance works more effectively. They can be provided with accurate estimates of defect types, locations, and quantities, leading to greater accuracy in pricing and reduced risks.

Quality control during repair works can be captured by digital photos stored in the models, or sections of the structure re-captured for comparison of condition at various points in time.

In summary, the benefits of 3D photogrammetry models in asset inspection and maintenance are numerous.

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Relevant UN SDGs (*https://sdgs.un.org/goals*)
11, 12, 9, 3.

Operational Forecasting of Container Stacking Risk

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Summary
Seaport OPX Yard Safe Suite is an innovative tool, designed to mitigate risks in container yards due to extreme weather. It uses high-resolution wind forecasts and machine learning to predict potential container toppling or sliding up to 7 days ahead. The tool also considers 3D block sheltering effects and local sheltering between containers. It calculates wind forces on each container and checks their force balance to identify critical containers that need to be moved. A recent development to the Suite allows for outputting area-based rules for down-stacking containers, optimising yard movements before wind events. This results in more efficient container management and reduced disruption during inclement weather.

Keywords: Port Operations, Container Yards, Wind, Operational Systems.

Introduction

Container yards and terminals worldwide are facing many challenges. The global surge in shipping, expected to grow even further, is exerting immense pressure on yard operators to increase throughput. Consequently, yards are expanding and increasing capacity to accommodate this growth, and these increases in shipping are not without problems. Trade imbalances [1] have also led to a rise in the number of empty containers stored in many Australian ports, creating additional logistical challenges and the creation of incentive schemes to increase the export of empty containers [2], to help reduce this congestion.

Simultaneously the frequency of extreme weather events is on the rise globally. This, coupled with the increase in empty containers, significantly increases the risk to container yards. The threat is twofold; container toppling and container movement. Container toppling not only poses a severe safety risk to personnel, but also often results in substantial damage to the containers and the cargo. Container movement, on the other hand, can wreak havoc in automated container yards, where there is a risk of automated straddle carriers colliding with, and further displacing the containers, or even getting damaged themselves.

These issues can lead to significant trade disruptions and extensive shipping delays, impacting the global supply chain. Therefore, it is crucial to address these challenges head-on, and seek innovative solutions to mitigate these risks.

Yard Safe

Seaport OPX Yard Safe Suite is an automated, physics-based decision support tool, developed to minimise container moves and mitigate the risk of containers sliding and toppling during wind events in terminals and yards.

The Suite utilises high-resolution wind forecasts, generated via the Weather Research and Forecasting (WRF) model [3]. This model, combined with a machine learning algorithm, optimises the forecasts' performance, predicting wind speeds over the entire yard up to 7 days ahead. The wind model is based on local topography. These wind forecasts are integrated into the Safe Stack Tool, along with data extracts of container positions, weights, and types, from the Terminal Operating System (TOS). This data is combined to calculate all containers at risk, every five minutes. This enables the tool to calculate potential container movement or toppling risks across the yard during the next 48 hours.

At-risk containers are identified and communicated to yard operators in real-time, enabling pre-emptive action such as moving or down-stacking containers.

Since its introduction at APM Terminals MedPort Tangier, there have been zero toppled containers, and feedback from the operator is that "the terminal now only needs to move about 20 containers for each wind warning, down from 800." [4]

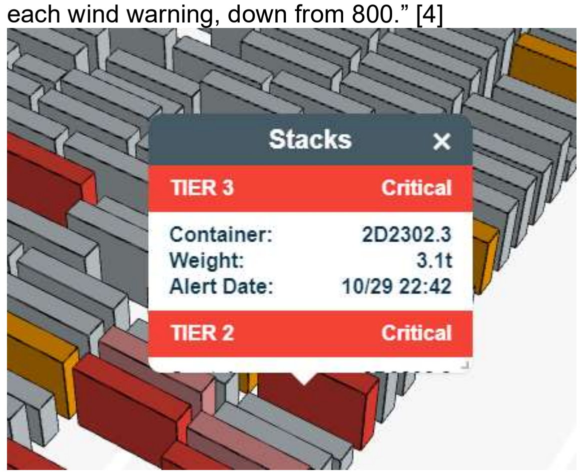

Figure 1 The Safe Stack Tool interface showing a container as critical.

Wind Forces

The tool incorporates 3D block sheltering effects between adjacent blocks, determining local windspeed experienced by each container in the yard. This includes both amplification and reduction effects in the windspeed, horizontally, and vertically across different blocks.

Sheltering or amplification varies based on yard layout, stack height in each block, and wind direction. These sheltering coefficients are computed for each yard using computational fluid dynamics (CFD). The tool also accounts for local sheltering between adjacent containers, e.g. 'shadow' effects where containers are fully or partially sheltered by other adjacent containers.

Container Forces

The tool calculates wind forces on each container and container stack across the entire yard, based on the input wind speeds. It also calculates restoring forces from the containers' type and reported weight, against both toppling and sliding. The weight is the primary restoring component, to avoid both sliding and toppling failures. This is why empty containers are especially vulnerable. A Force Balance Check is performed for each container to ensure that the restoring force for both sliding and toppling failures is greater than the wind forces experienced. If the wind forces in either of these two failure modes exceed the set limit including a safety factor, the container is marked with a critical alert. This alert is clearly visualised to operators, indicating that the container needs to be relocated.

Safe Stack Height

A recent improvement to the Suite allows ports to manage yard operations proactively, more than 48 hours ahead; addressing the dynamic nature of container yards where containers are constantly moved, added, or removed. This development takes a different approach, generating area-based rules for down-stacking specific yard areas, rather than individual containers. This is particularly effective in semi- or fully automated yards, where down- stacking can be integrated into the ongoing automated housekeeping program. The tool, based on the same block sheltering effects and engine as the Safe Stack Tool, calculates maximum safe stack heights in yard areas based on the 7-day wind forecasts, default yard layouts, and container weight. It identifies yard areas where the maximum safe stack height is less than the current maximum, allowing these areas to be marked for down-stacking in the Terminal Operating System (TOS). Thanks to the tool's accurate forecasts and physics- based approach, the total number of required moves before a wind event can be significantly reduced. It targets only the at-risk areas and tiers of the container yard, reducing their height. This results in fewer containers to move in the last 48 hours before the wind event, when the Safe Stack Tool is run on the current yard, as most of the at-risk containers will have already been moved.

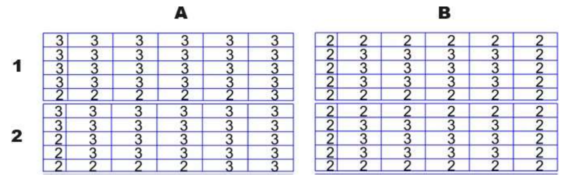

Figure 2 Graphical Example of the Safe Stack Height Tool output. Showing varying max stack heights across the blocks.

This physics-based automated decision support tool optimises the maximum number of safe tiers across a container yard, helping to streamline yard movements before wind events. It enables yards to efficiently move containers several days prior to the arrival of a wind event, as part of their normal "housekeeping" moves, thereby greatly reducing the number of moves required just before the arrival of dangerous winds.

Conclusion

The integration of advanced technology into port operations has proven to be a game-changer. The development of a physics-based decision support tool has revolutionised the way container yards manage their operations ahead of wind events, greatly reducing the required moves and allowing operators to focus on areas of the yard at risk. The newest development in the Yard Safe Suite generates area-based rules for down-stacking specific yard areas. The tool allows for proactive management of yard operations more than 48 hours in advance. The ability accurately to forecast and target only the at-risk areas and tiers of the container yard ensures efficient use of resources and time. As we move forward, such innovative solutions will continue to play a pivotal role in enhancing the efficiency, safety, and resilience of port operations worldwide.

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UN SGD 8 and 9.

OmniLift™ Littoral Heavy Lift System Design

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Summary
Global port infrastructure is inadequate to meet the simultaneous demands across shipping, offshore energy (wind, hydrocarbon, and hydrogen), maritime defence, and marine vessel new build and maintenance for both the commercial and private sectors. Space within existing ports and capital for investment are limited resources. Successful life cycle operation of offshore energy generation facilities requires optimizing capital expenditures and real estate within ports by designing infrastructure projects capable of supporting maritime economic activity across many marine economic sectors over decades of operation. The OmniLift™ System is designed to support life cycle operation of all of these vital marine industries. This paper presents the schematic design of OmniLift Systems for concrete or steel floating wind foundations as well as other heavy lift applications.

Keywords: offshore wind, ports, infrastructure, energy

Introduction

Global energy production is changing to address the effects of carbon emissions on the climate. Every country with coastlines bordering major bodies of water is in some stage of planning or actively replacing fossil fuel generation with marine-based wind power generation and hydrogen production. Simultaneously decommissioning and recycling legacy marine hydrocarbon energy production systems requires a littoral heavy lift system capable of efficiently launching and retrieving large structures.

This systemic change in energy production is driving the need for investment in port infrastructure to enable deployment of offshore wind energy production infrastructure and provide support for future operations and maintenance of these assets. Currently, this transition is focused on shallow-water fixed-base structures supported on monopiles and jacket structures. In 5 to 10 years this market will expand to include offshore floating wind generation. Eventually, thousands of these devices will be operating along coastlines globally, generating the gigawatts of electricity needed to power modern industrial economies.

All of this development will occur from repurposed port facilities, many of which are currently engaged in legacy energy production and maritime trade. Efficient planning of multi-use port facilities is essential to securing the success of this economic transition. Most importantly, well-designed port infrastructure projects will support the entire life cycle of offshore energy production and provide regional economic benefits and employment over many decades.

New types of heavy lift equipment that can support a variety of maritime industries are required. These systems must support industrialized production and maintenance of steel and concrete floating wind foundations, commercial and military vessel maintenance and decommissioning activities. They must use available space efficiently and avoid negatively impacting ongoing port operations and vessel traffic.

Figure 1 Life cycle solutions are required to support high volume projects.

Floating Wind Foundation Types

Floating wind foundations are constructed from either steel or concrete material. Steel floating wind foundations are larger in footprint, 90 to 105m square. The weight of these devices ranges from a low of 6,000 tons to 10,000 tons or more.

Concrete floating wind foundations are popular for countries where steel production and fabrication capacity are limited. These foundations come in many shapes and are smaller in footprint, 60 to 80m square. The weight of these foundations ranges from 18,000 tons to 28,000 tons.

OmniLift™ Systems for Steel Foundations

OmniLift™ Systems for steel foundations feature larger platform dimensions and lower lift station capacities. Platform dimensions range from 90 to 105m square. Lift station capacities from 500 tons to 800 tons are typical, depending on foundation geometry.

The OmniLift™ system is unique in that it is the only littoral heavy lift system designed to lift and lower fully integrated floating foundations including; tower, nacelle and blades. This capability greatly reduces operational risks associated with integrating the generation equipment on a floating platform that is constantly in motion. More importantly the tide and weather window for integration is expanded as the foundation remains stable on the platform during the assembly process. As many as 5% of installed floating wind generation foundations will require major repairs annually, this means 3 to 4 units per Megawatt of offshore generation capability. Performing major repairs on the generation assembly at sea is a high risk undertaking that can only be managed in optimal weather conditions. Major repairs to a foundation at sea are not feasible. Towing these assemblies back to the implementation facility is safe and effective. Damaged generation equipment including blades and nacelle can be exchanged with replacement components allowing the device to be quickly returned to service.

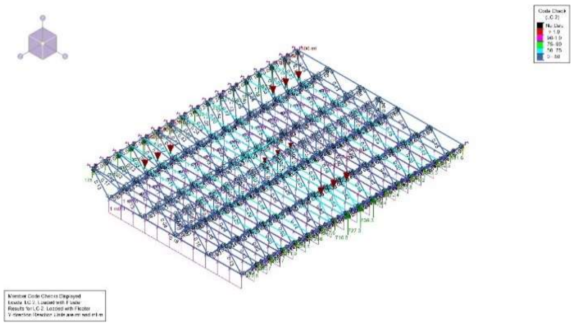

Figure 2 FEA Model of OmniLift™ with fully integrated foundation.

OmniLift™ Systems for Concrete Foundations

OmniLift™ Systems for concrete foundations have smaller platform dimensions and higher lift station capacities. Platform dimensions range from 60 to 80m square. Some concrete foundations are rectangular in plan and utilize cylindrical concrete ballast tanks for buoyancy, the platform is matched to the foundation footprint. Lift station capacities from 1,200 tons to 1,500 tons are typical, depending on foundation geometry.

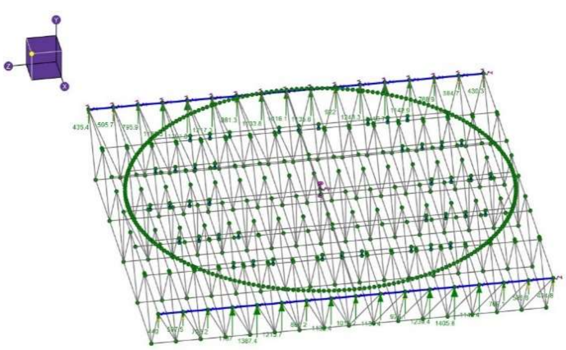

Figure 3 FEA Model of OmniLift™ with 28,000 ton Concrete Floating Wind Foundation.

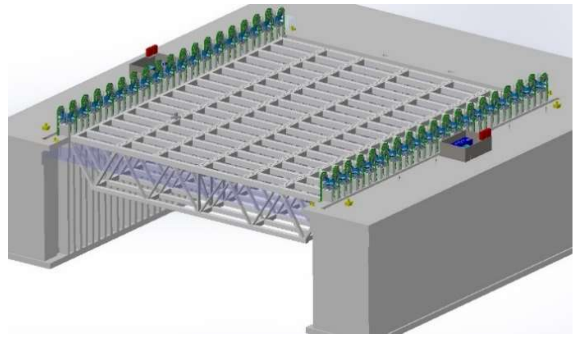

Figure 3 Model of OmniLift™ for launching and retrieving concrete floating wind foundations.

Integration of Existing Technologies

OmniLift™ Systems are a combination of existing proven technologies. These systems combine long span steel trusses with hydraulic chain jacks to produce a lifting system with capacities far beyond what was previously considered possible. Long span steel trusses are a proven structural design that has been in continuous use in onshore and offshore applications for well over a century. The hydraulic chain jack was first developed in the 1960's for marine heavy lift applications. These devices have proven to be reliable, there has never been a failure of chain jack during operation.

The OmniLift™ concept is derived from long span truss lift bridges. The system can be thought of as a series of truss bridge lift spans connected to reliable and powerful hydraulic lifting mechanisms.

OmniLift™ systems utilize modern feedback motion control valves. This technology is widely used to precisely control heavy industrial manufacturing equipment. The OmniLift system chain jack operation is synchronized to within 1mm of precision, the tolerance limit of the linear transducer on each lift station.

The combination of these technologies produces an intrinsically safe lifting mechanism with immense capacity and high reliability. Chain Jack Shiplift systems built in the 1970's are still in operation today, none of these systems have ever failed during lifting operations.

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Relevant UN SDGs (*https://sdgs.un.org/goals*)

7, 8, 9, 12, 13, 14

Surge Movement Criteria Related to Container (Un)Loading Efficiency: Data Analyses and Simulations

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Summary
The operational efficiency of container handling at the quay can be negatively impacted by excessive motions of the moored vessel. It is therefore important to establish a threshold for allowable motions for (un)loading of moored container vessels related to efficiency. Constraints for loading and unloading of container ships are mostly related to surge motions. Data from laboratory experiments and field measurements were used to calibrate a numerical simulation model. The simulation model was used to conduct many simulations under controlled conditions to establish a relationship between significant surge amplitude and (un)loading throughput.

Keywords: Container ships, allowable movements, moored ships, simulation, experiments, measurements.

Introduction
The PIANC MarCom Working Group (WG) 212 [4] was formed in 2019 with the objective to review and update the vessel movement criteria in the WG24 (all vessels) [2] and WG115 (container ships) [3] reports. The shipping industry has undergone significant changes in the last decades. Especially the size of container ships has increased significantly.

The WG 212 report [4] provides a complete overview of the data sources, analyses and criteria for all vessels. A summary of the data sources and analysis methods was also presented at the 35th PIANC World Congress [6]. Most information was available for container ships. The motion criteria for (un)loading of moored container ships were updated using additional numerical simulations, experimental data, and field measurements.

This paper focuses on container ships. A summary of the data analysis as described in the WG 212 report [4], Appendix C.1 is provided here. Criteria for 95%, 90% and 85% (un)loading efficiency were determined. In addition, an extreme motion criterion for surge is provided to account for single movements, e.g. caused by a passing ship event.

Container Loading
Ship-to-shore (STS) gantry cranes use a spreader to lift or lower containers. These movements for (un)loading are in the transverse direction, which allows the crane operator to account for sway motions. However, the spreader is longitudinally fixed. Therefore, corrections for surge motions are not possible, which makes surge the constraining movement for (un)loading of containers.

Flaps on the four corners of the spreader can be deployed to ease the placement of containers on deck. However, this is not possible below deck, where containers are placed within narrow cell guides. The entry guides to the cell guides have small tolerances of approximately +/- 120 mm in longitudinal and +/- 110 mm in the transverse direction.

When the vessel motions are small, the STS crane operator aligns the spreader with the entry guide and lowers it into the cell guide. However, when motions are larger, the STS crane operator holds the container or spreader in position above the target entry guide and often needs to wait for the entry guide to return to the target position to be able to lower the spreader or container into the guides. This delay causes a reduction in (un)loading efficiency. Typically, STS cranes operate at 25 to 40 moves per hour. The (un)loading efficiency is determined by the ratio of moves per hour to undisrupted moves per hour.

Data Sources
The WG had access to a wide array of data sources consisting of:

- Feeback from terminal operators;
- Experimental container handling operations performed in idealised oscillations;
- Field-recorded data of vessel movements and container handling rates;

The experimental data and field-recorded data were used to calibrate a computer simulation model of container loading with prescribed irregular oscillations. These results were also used to derive the surge motion criteria.

Loading rates based on experimental results
Slinn [5] conducted experiments of container placement using an experimental set-up with a container crane and a target set-up that oscillated in surge and sway in a controlled manner. He subsequently developed a set of probabilistic equations for the number of attempts needed to place a container in a predetermined position. Slinn found that the average number of unsuccessful attempts, before successfully placing a container in

a moving cell is proportional to the velocity of the target.

Field Data of Loading Rates and Surge

Measurements of container loading rates and surge motions of approximately 150 vessel calls conducted during two measurement campaigns (one in 2000 and the other in 2008) were used in the analysis and shown in Figure 1.

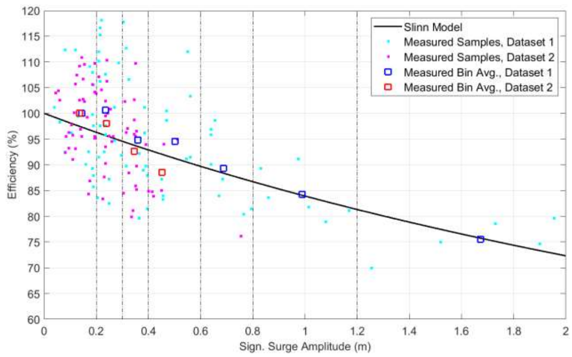

Figure 126: Container loading efficiency versus vessel surge according to the experimental model of Slinn (1979) [5] (solid line) and the measured data from the anonymous port. The squares indicate binned averages of the measured data with the bin edges shown as dash-dotted lines.

A general downtrend in production is visible for increasing surge motions. Three segments can be identified in this trend:

- For small surge movements, the loading efficiency remains constant as the target is mostly within the tolerances of the entry guides.
- Subsequently there is a downtrend in loading efficiency.
- For large movements the downward trend of the (un)loading efficiency becomes less pronounced, as the operator is still able to load or unload a container within one surge motion oscillation.

Computer Simulation of Container Loading

A numerical model that simulates the placement of containers subject to position and velocity tolerances for a time series of surge motions following a Pierson-Moskowitz spectrum [1] was applied in a deterministic way to further analyse loading efficiency rates. The time to place the container was approximately 3 s and an undisrupted loading rate of 30 moves per hour was assumed.

The displacement and velocity tolerances were calibrated against the experimental data from Slinn as well as the field measurements:

- Surge displacement tolerance ± 0.12 m
- Surge velocity tolerance ± 0.10 m/s

The model results are shown in Figure 127 with the field measurements and experimental model from Slinn. Results of sensitivity runs for loading rates of 25 and 40 moves per hour showed that the efficiency percentage is impacted more for a higher nominal loading rate. However, the results near 95-100% efficiency are not significantly influenced.

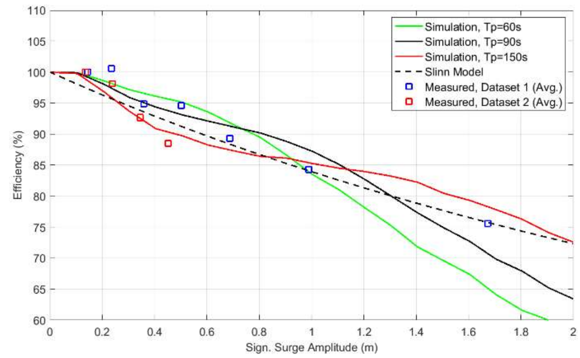

Figure 127: Container loading efficiency as a function of significant surge amplitude according to the Numerical Simulations for Different Peak Motion Periods (Solid Lines), the Experimental Model of Slinn (Dashed Line, for an Undisrupted Loading Rate of 30 Moves per Hour), the Measured Field Data (Squares, Representing Surge Bin-Averaged Measured Data)

Conclusions

The (un)loading efficiency of containers concerning surge motion criteria was analysed in detail. Field measurements and experimental results were used to calibrate a deterministic numerical model to simulate container loading in a controlled environment with many simulations to account for uncertainties in the time series of surge motions. The surge motion criteria are based on the results for 60 s and 90 s periods as the natural surge period for most container ships is between 50 s and 100 s.

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Total Cost of Ownership Analysis of Steel Fibre Reinforcement Concrete Rigid Pavement and Concrete Beams for Container Terminal

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Summary
Container terminals are vital to global trade, necessitating durable infrastructure for heavy container. This study presents a thorough Total Cost of Ownership (TCO) analysis for steel fibre reinforced concrete (SFRC) rigid pavement and concrete beams in container terminal infrastructure. Soil settlement considerations and reparations post-50mm settlement are evaluated. Additionally, it explores differences between soil scenarios, one without improvement and one with soil cement column reinforcement. Economic modelling is rigorously employed to integrate initial construction, repair, and downtime costs. This research aims to inform decision-makers, engineers, and planners on pavement system selection, considering geotechnical and economic factors for long-term sustainability in container terminal development.

Keywords: CONTAINER PAVEMENT / STEEL FIBRES / SOIL CEMENT COLUMN / SETTLEMENT ANALYSIS / TOTAL COST

Introduction

The container terminal infrastructure is vital for global trade, often utilizing concrete pavement, paving blocks, and concrete beams to support containers. However, maintenance needs are higher for blocks and beams due to increased settlement rates. This study examines the Total Cost of Ownership (TCO) of container terminal construction, covering initial expenses, repair costs from settlement, and revenue losses due to downtime. Assessing a five-stage stacking container yard, structural analysis evaluates pavement and beam performance over varying soil support conditions characterized by k-values of 0.01 N/mm³ and 0.045 N/mm³. Specifically, the investigation assesses soil settlement in two scenarios: one involving thick soft clay and the other incorporating the same clay with soil cement columns to enhance bearing capacity. The frequency of required repairs for storage areas, based on a criterion of 50mm soil settlement, is examined. Economic analysis includes construction and maintenance costs.

Geotechnical Information

The paper focuses on reclamation, common in new port terminal construction, using Bangkok's typical soil [1] as a representative for clay-based compositions. Sand-based reclamation lands are not addressed in this study.

SFRC Pavement and Concrete Beam Design

In designing the pavement for the container storage area, which comprises five stages of stacking, the load transfer mechanism through corner castings, measuring 178mm x 162mm and bearing a load of 224kN per corner, is crucial [2].

For the Steel Fibre Reinforced Concrete (SFRC) pavement, strategic placement of the corner casting at centre of 2.84x2.76m panel, reinforced with dowel is employed to optimize construction and maintenance costs. Utilizing Bekaert's in-house software and adhering to soil-specific recommendations from CUR-111 [3], the slab design is executed employing yield-line theory.

In the design of concrete beams, beams are designed with 1.40m width and 9.082m length to support the container corner castings. Structural analysis treats the beam as sitting on spring supports. Design protocols outlined in ACI-318 [4].

Soil Settlement Analysis

The study employed a three-dimensional numerical parametric analysis using PLAXIS 3D 2023 to assess the impact of container loading on soft soil foundations.

Finite element mesh was utilized for settlement analysis, with roller support on the four vertical sides and hinge support at the bottom. Water flow boundaries were open on all sides and closed at the bottom. Soil-cement columns, 600mm in diameter and spaced at 2-meter intervals with a depth of 14m, were simulated using embedded beams, considering friction and end bearing for each column within the respective soil layers.

The Hardening Soil model with Small strain stiffness (HSS) consider [5], [6] was adopted for analysis. The sequence involved generating initial stress and pore water pressure conditions, constructing the slab, beam, and soil-cement columns, applying surcharge under undrained conditions, and conducting a 10-year consolidation analysis to simulate long-term settlement behaviour, accounting for time-dependent effects.

Construction, Reparation and Downtime Cost Analysis

The construction and reparation costs, as well as downtime analysis, were conducted based on a 100,000m² project, focusing solely on the container stacking area. Unit costs were derived from Ministry of Commerce data for 2023 average prices, supplemented by information from the Office of the Basic Education Commission, and further validated through contractor interviews.

For the concrete pavement, thicknesses of 300mm and 225mm were utilized, reinforced with steel fibres, catering to different soil conditions (k-values of 0.01 N/mm³ and 0.045 N/mm³). Settlement analysis revealed 83 mm. settlement, necessitating one repairs at intervals 10 years. Reparations utilized higher-grade concrete to minimize downtime, factoring in the loss of storage revenue during the three-day repair period per panel. The NPV of costs amounted to 176,222,659 THB, considering an average MLR interest rate of 6.8893% in 2023.

Concrete beams, 800mm thick with 1.12% reinforcement, were analysed for similar soil conditions, with 162 mm. settlement indicating the need for three repairs over a 10-year period. Repairs were conducted within the container yard to minimize handling costs and accident risks. Downtime costs accounted for the loss of revenue during five-day repairs per set of six beams. NPV costs for concrete beams were determined based on the same interest rate, resulting in 267,474,071 THB. Further details are presented in Tables 1 and 2.

Table 17 10-years TCO of 100,000 m2 SFRC Pavement (k-value 0.045N/mm3)

Items	**Quantity**	**Value (THB)**
Construction		
- Concrete	22,500 m3	60,975,000
- Steel fibre	675,000 kg	50,625,000
- Formwork	16,075 m2	5,143,906
- Others	1 EA	29,106,403
Total		145,850,309
Maintenance (1 time)		
- Concrete	8,325 m3	24,544,597
- Steel fibre	249,750 kg	18,731,250
- Others	1 EA	20,442,490
Total		63,718,337
Downtime cost		
- Container-days loss	283,200	8,496,000
NPV of 10-years TCO		188,229,197

Table 2 10-years TCO of 100,000 m2 Precast Concrete Beam (k-value 0.045N/mm3)

Items	**Quantity**	**Value (THB)**
Construction		
- Concrete	16,555 m3	43,863,650
- Steel	1,450,605 kg	56,756,780
- Formwork	21,433 m2	4,425,890
- Asphalt	80,292 m2	18,708,050
- Transportation	39,731 Ton	19,865,604
- Others	1 EA	46,012,681
Total		189,632,655
Maintenance (3 times)		
- Precast handling	158,924 Ton	2,325,000
- Asphalt	321,168 m2	56,124,150
- Others	1 EA	34,646,954
Total		93,096,103
Downtime cost		
- Container-days loss	813,750	24,412,500
NPV of 10-years TCO		267,474,071

Conclusion

The study reveals that SFRC pavement offers cost advantages over precast concrete beams for container terminal applications. SFRC pavements entail lower initial investment costs, whereas precast concrete beams, although initially cheaper per repair, require more frequent maintenance due to significant soil settlement.

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Relevant UN SDGs

9, 11 and 12

Digital by Default: A digital engineering initiative for delivery of marine infrastructure

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Summary

The marine sector is generally less mature in its adoption of Digital Engineering (DE) for construction project delivery compared with the land transport sector. As a result, less opportunity exists to leverage models developed at design stage for improved coordination and more informed planning of construction delivery. In response, McConnell Dowell has developed *Digital by Default*, a contractor-led initiative which defines a baseline approach to digital engineering across all projects in the absence of customer DE requirements. *Digital by Default* guides the design supply chain to produce information-rich models, and their subsequent use by construction teams for improved project delivery.

Keywords: Digital Engineering, Building Information Modelling, Common Data Environment, Digital Project Delivery, Virtual Design and Construction.

Introduction

Across most infrastructure sectors, designers have moved from Computer Aided Drafting (CAD) to the more sophisticated BIM (Building Information Modelling) approach in which 'intelligent' models are created to virtually represent physical assets. A key benefit of many BIM authoring applications is that drawing production is automated from the model to some extent, meaning changes can be implemented efficiently across numerous drawings simply by updating the model. The constituent virtual components of these models also typically contain a set of information useful to the procurement, construction, and operation of the physical counterparts.

Despite the opportunity presented by this technology, project information delivery in the marine sector continues to be predominantly based on the periodic exchange of drawings and written documents such as specifications. While models are commonly developed in the design phase of projects and often aid early inter-discipline coordination, their ultimate purpose in most cases is simply to generate conventional drawings. A significant barrier to effective collaboration between design and construction teams therefore persists.

In contrast, many of the agencies responsible for the delivery and operation of land transport infrastructure across Australia have addressed this situation by specifying the development of highly structured data which is exchanged and managed on web-based Common Data Environments (CDE). This approach is informed by ISO 19650, the preeminent international BIM standard, which provides a framework for defining information requirements and production and exchange protocols. Agencies like Transport for New South Wales and the Victorian Infrastructure Delivery Authority require the ongoing development and exchange of data-rich models to support improved decision making through all phases of the asset lifecycle.

We are yet to see wide-scale adoption of this approach in the marine sector where, in contrast to land infrastructure, marine and coastal infrastructure has significantly more private sector developments delivered for a diverse array of commercial enterprises. To realise more value from BIM on projects in sectors that are less digitally mature and lack the regimented client-led delivery framework, McConnell Dowell has developed *Digital by Default;* a contractor led initiative which defines a baseline approach to Digital Engineering across all projects.

Concept

Internal data shows that a significant share of the issues that can impact project profitability stem from the design phase. In the first stage, *Digital by Default* is therefore principally aimed at providing early and ongoing visibility for all stakeholders to the development of design. Through this initiative, project teams are better-equipped to identify issues at a stage of delivery where they can be 'designed-out', minimising impacts to program and cost and ensuring high quality outcomes.

Importantly, *Digital by Default* is not solely focused on risk management, it also enables project teams to identify opportunities at a stage where they can be thoroughly explored and validated. Rather than wait for stage gate drawing submissions, projects have continuous access to up-to-date, high quality, and data-rich 3d information through an intuitive web-based CDE, enabling a more proactive and collaborative approach to design management.

Implementation

The implementation of *Digital by Default* is guided by a suite of documents. McConnell Dowell has amended its standard design consultant agreements to ensure its digital requirements are contractually defined for supply chain appointments. It has also developed an ISO 19650-compliant DE management framework within the business' management system. The DE management framework requires the use of standard specification documents to provide clarity for project supply chains, as well as detailed technical guides to support implementation.

Design models are either hosted or regularly registered to a web-based CDE owned by McConnell Dowell. The CDE provides model federation, clash detection, change detection, automated quantity take-off, and issue management and reporting functionality.

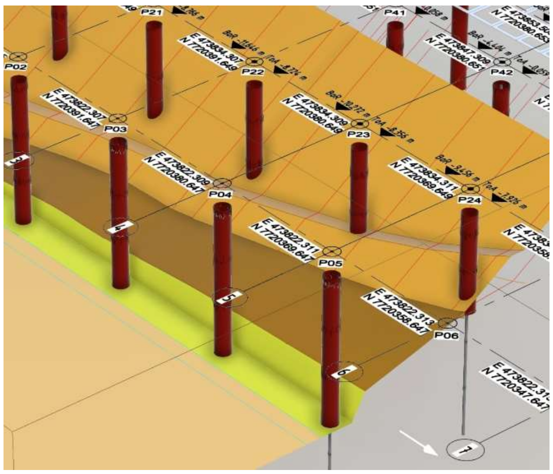

Figure 128. A work-in-progress wharf design model review. This federated model includes civil and structural design scope and is updated weekly on the project Common Data Environment. Seamless access to the developing federated model enables the construction team to identify and communicate constructability issues early in the design program before drawings are issued. (Source: McConnell Dowell).

Digital by Default represents a significant shift from traditional design and information management approaches and training and support are therefore a fundamental component to the success of the initiative. The McConnell Dowell DE team engages with both internal stakeholders and design partners to develop awareness of the concept and procedures and provides focused technical training to projects on the use of the CDE and model-based workflows.

Benefits

Digital by Default provides McConnell Dowell and its stakeholders with the ability to interrogate a project's design early and continuously, enabling identification of issues at a stage where they can be effectively mitigated. Supply of quality models according to a specified level of development, embedded information, structure, and granularity also enables McConnell Dowell to manage the coordination and planning of construction more efficiently and effectively using data centric approaches. Examples include automated and rule-based design checking and clash detection, and the integration of models with the construction program to simulate and assess the proposed sequence and methodology (4d planning).

The CDE also provides automated change identification and associated quantity take-off, enabling identification and assessment of design quantity growth. While there are obvious commercial benefits to this approach, McConnell Dowell also leverages this functionality to continuously assess the impact of design decisions on embodied carbon through the pairing of element quantities with carbon factors.

Figure 129. Automated model change detection for a jetty headstock assembly. The Common Data environment is used to detect changes between work-in-progress design model versions by identifying elements that have been added, removed, or modified. Automation of this task creates capacity for delivery personnel to investigate creative opportunities to mitigate design quantity growth. (Source: McConnell Dowell).

As issues are logged within models on the CDE with supporting information linked or attached, stakeholders also benefit from improved context when reviewing and responding to issues. A live issue register also eliminates the need to manually compile and update spreadsheets with information from disparate project systems, freeing up delivery personnel to focus on higher-value work.

Relevant UN SDGs (*https://sdgs.un.org/goals*)
9, 12, 13.

Concept of operations for Western Australia's next container port

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Summary
Westport is the Government of Western Australia's planning program to relocate container trade from the Port of Fremantle to Kwinana, the State's premier industrial precinct. The project includes planning for a new container port, upgrades to the metropolitan road and rail freight network and new inland intermodal logistic facilities. This paper provides an overview of the potential concept of operations for the container terminals and on-dock rail terminal, including industry proven solutions and those that are emerging and undergoing feasibility studies. Assuming a port landlord model, the final terminal arrangement, mode of operation and technology solutions are generally the responsibility of the appointed terminal operator(s).

Keywords: Kwinana, port operations, container terminal, rail terminal, automation

Introduction

Westport is the Government of Western Australia's long-term vision to plan and build a future container port with an integrated road and rail freight network, linked to inland intermodal logistic facilities. The objective is to deliver a resilient and optimised supply chain that is a flagship for sustainability and that unlocks opportunities for the Western Australia economy. At present, Westport is in its early planning phase with a preferred supply chain solution recently identified in the Westport Supply Chain Integrated Design (SCID) Project. The proposed port location is between the end of Barter Road and the end of Mason Road within the Kwinana Industrial Area. The Masterplan of the preferred port arrangement is shown in Figure 130, consisting of two container terminals and a single on-dock rail terminal.

Figure 130 Masterplan of preferred port arrangement

Container terminal operations

While the port is planned on a greenfield site (reclaimed land) several factors dictated the preferred layout, including spatial constraints, environmental considerations, stakeholder impacts, port operability, operational flexibility, landside connectivity and cost.

The process of evaluating and selecting the preferred port arrangement required consideration of different modes of operation. One of Westport's key goals is to produce better trade outcomes by developing an efficient, reliable, resilient, scalable and flexible supply chain [1]. To meet this goal, the port design uses a proven mode of operation, while providing resilience to support different container trade profiles, and flexibility to allow implementation of alternative solutions that may emerge at the time of Westport delivery. The SCID Project designed and modelled the following modes of operation for the container terminals:

Automated stacking cranes (ASCs)
Automated straddle carriers (AutoStrads)
Automated rubber tyred gantry cranes (ARTGs)

Based on analysis carried out during the SCID Project, the difference in cost between the modes of operations were not significant over the Westport planning horizon as shown in Figure 131. All equipment included in the cost estimate are assumed to be electric powered.

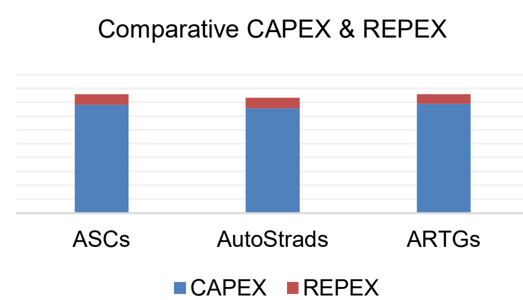

Figure 131 Comparative capital expenditure (CAPEX) and replacement expenditure (REPEX) for tested modes of operation in real present value terms (illustrative only)

Consequently, ASCs were selected as the preferred mode of operation for the container terminals, based on further considerations including:

Proven mode of operation in high performing container terminals.

- Operations are highly automated, which improves the health and safety of workers and operational efficiency.
- High container stacking density which allows storage demand to be met in smaller footprints. Can support the ‘high’ container trade forecast and presents opportunities for on-dock empty container storage or on-dock warehousing if container trade follows a ‘low’ profile.

On-dock rail terminal operations

The Port of Fremantle has a rail modal share of ~20%, one of the highest in Australia, and Westport is looking to increase this as a driver to improve the movement of containers across the supply chain. To achieve this level of performance, the on-dock rail terminal has been designed with semi-automated cantilevered rail mounted gantry cranes (CRMGs), spanning over eight (8) working sidings. For the purpose of design and costing in the SCID Project, it was assumed the on-dock rail terminal will be operated independently from the stevedores.

Other on-dock rail terminal configurations were also considered during the SCID Project, including dedicated rail terminals for each of the two container terminals. While there may be benefits to adopting this model, the number of assumptions and simplifications required at this early planning phase of the project made it difficult to develop a robust quantitative analysis to clearly demonstrate advantages over a single on-dock rail terminal. Therefore, throughout the port layout development process, a conscious decision was made to space-proof for the option to have two rail terminals, if future studies show this as the preferred solution.

Port concept of operations

The container handling concept of operations at the port is outlined below:

- Semi-automated dual trolley ship-to-shore cranes (STSs) transfer containers between the ship and container terminal;
- Automated guided vehicles (AGVs) for horizontal transfer between the STS and container terminal stacks;
- ASCs operating container terminal stacks arranged perpendicular to the berth line;
- Terminal tractor trailers (TTs) for horizontal transfer between the container terminal stacks and on-dock rail terminal;
- Terminal tractors park the trailers under the CRMGs perpendicular to the rail sidings at the on-dock rail terminal;
- Semi-automated CRMGs transfer containers between the trailers and train wagons at the on-dock rail terminal.

For the purpose of modelling and costing in the SCID Project, TTs were assumed to be automated, without segregating manual operations. While current best practice in container terminals fully segregate manual and automated operations, proof of concept projects are currently being explored, which involve the mixing of manual road trucks and automated TTs (ATTs). By the time the Westport is constructed, it is assumed automation concepts such as this will have developed for full commercial deployment at container terminals .

Other automated horizontal transfer solutions were considered between the (ASC) container terminal stacks and on-dock rail terminal, including:

- Dedicated stacks at one end of the container terminal for rail bound containers, with a corridor not accessible by manual road trucks. This solution was not preferred as it requires certainty with the container modal split and a segregated corridor would be inflexible to changes in volumes and container modal split.
- Allocating some or all the waterside container exchange area to allow the transfer of containers to the on-dock rail terminal via a dedicated corridor. This solution was not preferred as the corridor would be long, requiring higher than typical horizontal transfer equipment. Additionally, depending on the rail modal share, there would be a significant imbalance in waterside and landside ASC utilisation, such that additional ASC blocks may be required to meet the waterside demand.

Conclusions

Developing the concept of operations for a port requires careful planning and consideration to ensure the solution is suitable and meets the objectives of the port. This can be challenging even for greenfield ports which are planned over a decade before construction, as clear solutions are not often evident at the time, due to uncertainty in the development of new and emerging technologies over time, which may lead to phasing out of those that are less desirable.

In Australia where a port landlord model is commonly adopted, the final terminal arrangement, mode of operation and technology solutions are generally the responsibility of the appointed terminal operator(s). As the port landlord, in the early planning phase of the project, it is generally desirable to retain as much flexibility as possible to allow the development and implementation of an optimal solution at the time of construction.

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Relevant UN SDGs

11, 9, 8

Ports and Shipping Enabling the Clean Energy Transition Through Common User Infrastructure

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Summary
With the global shift towards green energy and fuels, the focus needs to shift towards the transportation of these commodities between producers and consumers. Common use infrastructure has an important role to play in the future development of the green energy sector maximising the potential throughput of ports.

Keywords: Common User Infrastructure, Clean Energy, Port Master Planning

Introduction

With the global shift towards green energy and fuels, more focus needs to be directed towards the transportation of these commodities between producers and consumers. Whether that be by means of overland transmission lines, subsea power cables, or trans-oceanic shipping of green fuels such as hydrogen and ammonia.

From a traditional port perspective, the key role of the port in enabling the clean energy transition is the import and/or export of green fuels, goods required for clean energy projects, or oversize/overmass (OSOM) project related cargo via a dedicated module offloading facility (MOF) as outlined in Figure 132 [1].

However, the energy transition presents opportunities for ports to encourage growth in related sectors surrounding the port. Ports can enable this by building common user facilities by berth side and also importantly on the landside.

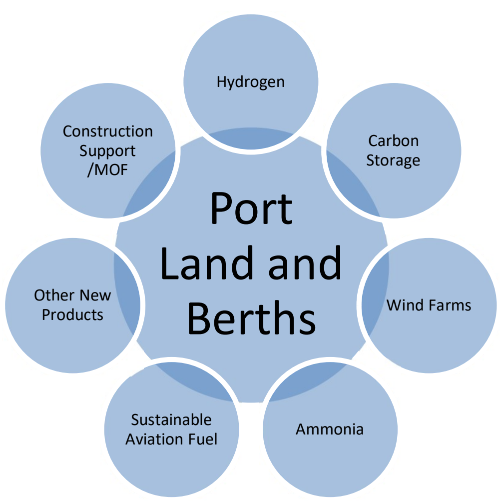

Figure 132: Potential clean energy related commodities transiting via a port

Port based infrastructure projects have typically been proponent led and funded, which can lead to disjointed and segregated port layouts in some instances, due to land leases for example, or duplication of the same infrastructure but owned and operated independently by entities in competition to one another.

This operational model has been typical of liquefied natural gas (LNG) export facilities, where each operator will have their own dedicated MOF, export wharf, processing facilities, and liquefaction plant as shown in Figure 133 in Gladstone, Queensland. The South Trees Island LNG facilities in the Port of Gladstone contains three separate operators in an estimated area of 850 ha.

Figure 133: Gladstone Port South Trees LNG precinct where there are three separate LNG liquefaction and export facilities for each operator [2]

Common User Infrastructure

In recent years Worley has been involved in numerous port master planning studies investigating the viability of the port to produce, store, and/or export green energy products, such as green hydrogen and ammonia, and handle the associated large ships without impacting existing port operations through the concept of shared common user infrastructure.

Shared, common user infrastructure requires the port owner/operator to invest the capital into the infrastructure, such as the tanks, processing plant, pipelines, power transmission network, wharves etc., such that a proponent can tender to utilise that common user infrastructure to produce, sell, and export green product. This reduces the risk for the new green energy proponents who do not have to raise significant capital. However, it does require the port to owner/operator to invest in this infrastructure at their risk.

This operating model is becoming more common for single commodity ports that are looking to diversify their cargo portfolio so they can secure their future or maintain their social license. However, this diversification of commodities, or mode of operations, can cause complex issues around ownership, and operation of infrastructure which needs to be properly planned or risks clashing with existing operations and/or future development.

An example of a multicommodity berth is shown in Figure 134 which is a grain export berth at Port Kembla, NSW. This berth has been modified to allow for bulk liquid operations during the grain harvest offseason. Without this modification, the berth would have zero utilisation for half the year [3].

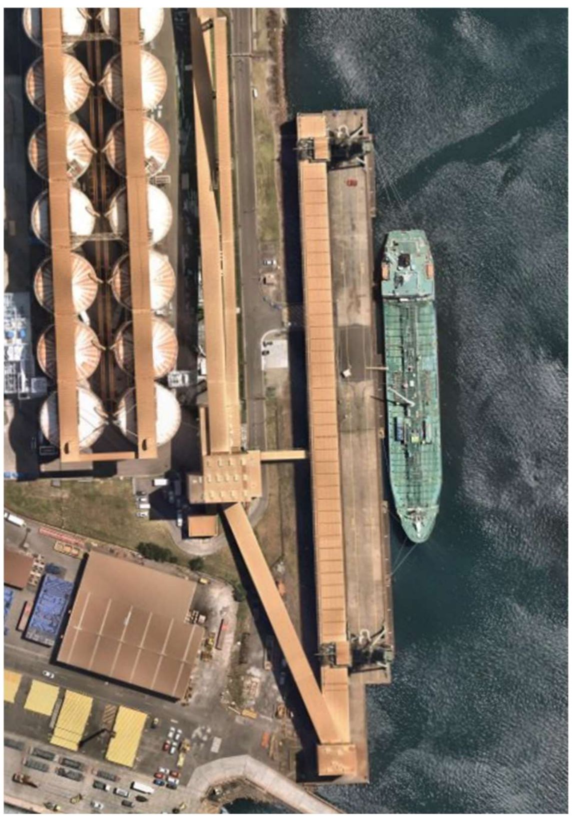

Figure 134: Port Kembla Berth 104 – primarily grain berth but can also handle bulk liquid cargo in the grain off season via flexible hoses [4]

Considerations

However, this is only one part of the puzzle when it comes to enabling the clean green energy transition.

The green fuels that are going to enable the energy transition are considered to be hazardous. The fuel quantities that will need to be handled by ports (for example hydrogen and ammonia) will be orders of magnitude larger than present day volumes. The associated production, storage, and loading areas will therefore be subject to exclusion zones. These exclusion zones could have significant potential to disrupt existing, or future, port operations from occurring nearby and thus sterilising areas within the port. Therefore, a thorough masterplan is crucial for ports looking to enable the clean energy economy.

Conclusion

Common user infrastructure can allow ports to consolidate their infrastructure based on commodity type to avoid duplication. However, the main aspect that needs to be considered for all common user or green energy transition based projects is a comprehensive safety and risk analysis to ensure that potential show stoppers are identified early and treated appropriately. This can only efficiently be done with a thorough port masterplan layout looking at both the existing and future trade opportunities of the region and port.

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Relevant UN SDGs (*https://sdgs.un.org/goals*)
7, 14

Evaluating the Risk of Battery Energy Storage Systems at Port Facilities

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Summary
Growing interest in Battery Energy Storage Systems (BESS) incorporating lithium-ion batteries (LIBs) presents unique challenges to port facilities. Hazards associated with BESS are not well established, and existing ports may not be designed to mitigate thermal runaway fires and deflagration events. Ongoing development of battery technology further creates an everchanging terrain of hazards. Through fire safety studies and risk assessments, future port designs can be better equipped to face the challenges ahead.

Keywords: Battery Energy Storage Systems (BESS), Electric Vehicles (EV), Risk Assessment, Thermal Runaway, Fire Safety.

Introduction
The global surge in Battery Energy Storage Systems (BESS) and Electric Vehicles (EVs) worldwide is expected to lead to a significant increase in quantity and frequency of throughput at port facilities. Lithium-ion batteries (LIB), the current leading technology for these applications present unique challenges to handling, transport, and storage, stemming from the batteries being susceptible to a phenomenon called thermal runaway. The batteries' ability to self-generate explosive and fire prone atmospheres presents a risk to port infrastructure, life safety of personnel and port operations.

Despite the benefits provided by BESS and EVs in assisting the world achieve Net Zero decarbonisation targets, the uncontrolled self-heating state of a battery during thermal runaway can produce significant volumes of combustible gas, creating atmospheres susceptible to both fire and explosion [2]. Coupled with the battery's ability generate its own ignition source, this presents as a hazard to handlers and operators alike.

Thermal runaway can arise from various forms of battery abuse, including physical damage, manufacturing defects, exposure to high temperatures, overcharging and discharging or poor Battery Management Systems (BMS) [2][3]. During transport and handling, battery cells are susceptible to the physical aspects of abuse such as impact or exposure to uncontrolled temperatures. They are also unlikely to have an active BMS to monitor and manage cell abnormal conditions. Cell damage can be exacerbated during unloading, encouraging the progression to thermal runaway when stored at ports.

Batteries contained in BESS are Class 9 Dangerous Goods (DGs). Technical guidance for handling of such is documented in *AS 4681 – The storage and handling of Class 9 (miscellaneous) dangerous good and articles* [1]. And while the standard covers the handling and storage of lithium-ion batteries, the standards last update took place in March 2001, so procedures are inadequate when considering the development of large-scale battery applications in recent years. Particularly from a separation and segregation standpoint if a fire or explosion were to occur.

While EVs are a Class 9 DG, the moment they are unloaded from the vessel, this classification is removed, and vehicles are no longer required to be handled as such. Potentially leaving a gap in the handling of these batteries relative to the risks.

Methods and Techniques
AS 4681 specifically identifies the need for Fire Safety Studies (FSS) to be undertaken in accordance with the Hazardous Industry Planning Advisory 2 (HIPAP2) guidelines.

The study starts with the identification of fire and explosion hazards on a site, taking into consideration the manifest of DG's stored and the sites planned operations. Once completed, key fire hazard scenarios are assessed in detail to determine whether the proposed fire safety systems for the facility, including measures for fire brigade intervention is adequate for the hazards. Where gaps are identified, additional design recommendations are established. The process is iterative until the desired outcome is achieved.

Discussion
For a big battery facility or one that handles a significant volume of batteries such as a port, the primary goal is to develop a design that is suitable to prevent the propagation of fire between BESS enclosures as well as surrounding infrastructure. This can be achieved through the incorporation of features including increased separation distances, passive fire construction, active fire suppression systems and fire brigade intervention. The complexity and extent of fire safety measures for a site will largely be dependent on catastrophic level fire testing data for a given BESS. This data can then be used as the input parameter to radiative

heat flux models to determine the risk of fire propagation.

Matters such as toxic gas emissions and overpressure events arising from thermal runaway are also explored as part of the study to ensure hazards are suitably addressed through design. Namely to protect property and preserve life safety of personnel at the facility.

Blast over-pressure levels are initially examined from unconfined explosions and deflagration events that can arise from ignition of evolved flammable gases.

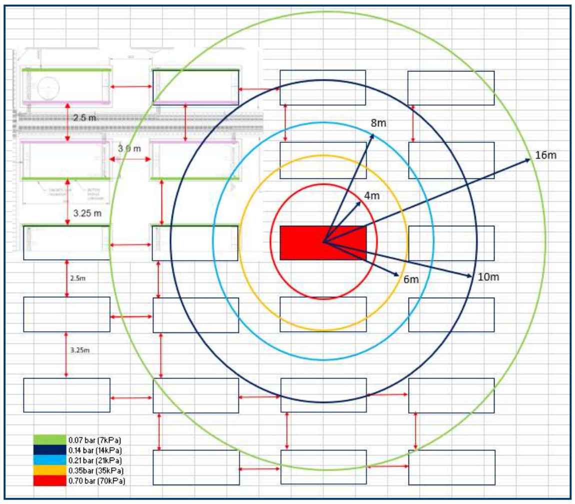

Figure 1. Preliminary unconfined BESS overpressure modelling (GHD, 2023). 20’ sea-container sized BESS with ignition occurring at 50% hydrogen levels in the container space. 15% chance of fatality in open at 6m (0.35bar).

These preliminary overpressures provide an order of magnitude perspective on possible consequences and the need for further refined analysis via Computation Fluid Dynamics (CFD) modelling. This type of modelling examines mitigations provided by BESS container design such as wall thickness, pressure relief mechanisms and ventilation as well as providing guidance on suitable overpressure separation and segregation distances.

The level of information provided in Safety Data Sheets (SDS) and other OEM specifications does not provide sufficient fire or overpressure consequence details for port handling and storage operations and emergency response management. A port fire safety study that considers the frequency and quantities of BESS/EVs and their storage and handling in the port will provide the technical resources for decisions around safe port operations and suitable emergency response management.

Conclusion

The increased uptake of LIB BESS worldwide presents a unique hazard to port facilities as throughput of these systems increase over time. Understanding the potential hazards posed by a thermal runaway event through undertaking of fire safety studies and risk assessments allow for future port designs to manage and reduce exposures to infrastructure, personnel life safety and port operations.

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Relevant UN SDGs

7, 9

Port Strategy in Navigating the Hydrogen Economy

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Summary
The hydrogen economy presents a transformative opportunity for ports, positioning them as key players in the clean energy trade, infrastructure development, and decarbonisation effort. However, this transition demands strategic planning and robust decision-making tools to overcome challenges. This study explores strategies for ports to capitalise on these opportunities while navigating complexities like regulatory uncertainties and infrastructure investments. Our findings emphasise the importance of port development planning tools and decision support to create long-term roadmaps that prioritise sustainability and ensure hydrogen infrastructure design is safe, reliable, flexible and constructable. Furthermore, this study highlights the importance of decision support tools that can empower ports by simulating market scenarios and mitigating risks. By implementing strategic planning and leveraging decision support tools, ports can navigate effectively and become key drivers of a sustainable maritime future.

Keywords: Port, Hydrogen Economy, Hydrogen Supply Chain, Strategy, Sustainability

Introduction
World economies embark on their journey towards a hydrogen-fuelled future. Leveraging their strategic location, existing infrastructure, logistical expertise, and social influence, ports are poised to play a pivotal role. They can act as central hubs for the global hydrogen supply chain, seamlessly connecting producers and consumers across borders. They can also be catalysts for a cleaner maritime industry built on hydrogen. While research on port adaptation to the hydrogen economy remains limited, existing studies suggest multifaceted roles for ports [1,2]. These include trade facilitation, infrastructure provision, regional decarbonisation, logistics support, job creation and fostering social acceptance within hinterland communities. This study aims to build upon lessons learned from port management and energy industries, gathering potential strategies for ports to manage the hydrogen supply chain successfully.

Method
This study leverages a comprehensive literature review conducted across the Web of Science, Scopus, and Google Scholar database. By focusing on port strategy, hydrogen, and the energy economy, the review aims to identify potential strategies for ports to participate effectively in the hydrogen economy. This study directly addresses the questions: "What are the potential strategies for ports to play their roles and functions in the hydrogen economy?" By exploring this topic, the paper contributes to the achievement of several UN Sustainable Development Goals (SDGs), specifically SDG7, SDG8, SDG9, and SDG11.

Result and Discussion
While the hydrogen economy offers a transformative path for ports, assuming new roles as trade hubs, infrastructure providers, and decarbonisation enablers presents significant challenges [1,2]. These challenges include:

1. Regulatory uncertainty: Unclear regulatory landscape, policy inconsistencies, and complex licensing procedures create hurdles for port development [3]
2. Financial Considerations: High infrastructure costs coupled with uncertain market demand for hydrogen complicate investment decisions [2]
3. Environmental Impact: The construction of hydrogen infrastructure raises environmental concerns [4]
4. Social Acceptance: Negative public perception can hinder ports from obtaining a Social License to Operate (SLTO)
5. Technical and Operational Complexity: Uncertainty in hydrogen demand and the hazardous nature of the fuels necessitate careful infrastructure planning, comprehensive operational procedures, and robust maintenance protocols.

To navigate the hydrogen economy, ports necessitate strategies in four key areas:

1. Economic Sustainability: Ports play a critical role in facilitating trade, and ensuring their long-term commercial success is essential. The hydrogen economy presents a strategic opportunity for them to achieve economic sustainability. To capitalise on this, ports need to predict future hydrogen demand and take it into account in their adaptive planning processes.
2. Technology and Operation: Green hydrogen infrastructure encompasses production (renewable sources), pipeline, storage facilities, and consumption points across various sectors (industry, transportation, urban areas, and ports) – the latter including refuelling stations and adapted equipment) [5].
   Due to the inherently hazardous nature of hydrogen, comprehensive risk assessments are crucial. These assessments identify potential hazards and risk control measures such as safety zone design and proper infrastructure

placement [6]. Sunarko et al. [7] emphasise the importance of prioritising safety, reliability, flexibility and constructability in hydrogen infrastructure design. These factors are essential for ports to successfully manage the hydrogen supply chain in the long term.

3. Decarbonisation: The concept of sustainable port cities reimagines ports as central players in regional energy transition, fostering new business opportunities as they become enablers for decarbonisation, with hydrogen as a solution. Ports can capitalise on this by transforming into renewable energy hubs, leveraging hydrogen for internal decarbonisation, green shipping, and land transport decarbonisation. Furthermore, ports, particularly those within industrial areas, can act as keystones for coupling diverse sectors like maritime, oil and gas, tourism, power plants, electricity grid operators, and offshore wind [8]. By functioning as multifuel hubs handling various renewable energy sources, ports can contribute to broader regional decarbonisation beyond their operations.
4. Collaboration/Partnership: Ports, as a community manager, holds a vital role in developing the hydrogen economy. Their success hinges on ensuring stakeholders' alignment [2]. This necessitates engagement with a diverse group, including government representatives, policymakers, industries, researchers, contractors, and other ports within the regional area. Effective communication, particularly regarding the social acceptance of hydrogen activities, is crucial. Building public trust and addressing concerns is essential for scaling up the hydrogen economy and encouraging the adoption of hydrogen technologies.

Port planning and decision support tools (DST) that can cover the four key areas are critical for navigating the hydrogen economy. The port master plan provides a long-term framework for strategic decision-making, infrastructure development, and financial planning. It facilitates stakeholder engagement, risk management, and adaptation to a dynamic landscape. Additionally, decision support tools analyse complex data and account for uncertainties to mitigate risks and enable real-time decisions considering cost, infrastructure and existing port limitations. Port master plans and DSTs work together to position ports as key players in the hydrogen economy.

Conclusion and Future Research

The hydrogen economy presents a transformative opportunity for ports, offering them new roles as trade hubs, infrastructure providers, and decarbonisation enablers. However, navigating this transition requires overcoming significant challenges: regulatory uncertainties, funding limitations, environmental concerns, social acceptance, and managing the technical complexities of hydrogen infrastructure. Despite these hurdles, ports can capitalise on these opportunities through the development of economic sustainability strategies (demand forecasting, exploring diverse funding options and implementing green marketing strategies), technical and operational strategies (safety, reliability, flexibility and constructability in hydrogen infrastructure design), decarbonisation strategies (internal decarbonisation and green shipping), and collaboration/partnership strategies.

This research identifies key strategies for ports navigating the opportunities and challenges of the hydrogen economy. However, effective decision-making in this dynamic landscape requires robust support. Future research may explore the development of the DSTs. This tool can significantly benefit ports by performing scenario planning, risk assessment and mitigation, and investment optimisation. The phased approach from port master planning, combined with the capabilities of DSTs, empowers ports to become key players in a sustainable hydrogen economy.

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Sand as a Resource, best practices to conduct responsible dredging projects

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Summary
For hundreds of years, dredging activities have shaped the interface between land and water to support a variety of human activities including navigation, coastal protection, flood risk management, as well as residential, tourist, commercial, agricultural and industrial activities. The use of dredging to achieve these purposes has always been guided by an understanding of the costs and benefits. The increasing tension between human development and planetary resilience urges us to rethink the way we work and live. The dredging sector is no exception. It uses sand as a building block to create infrastructure projects for social and economic development.

Keywords: dredging, best practice, beneficial use, sand resources

Introduction

For hundreds of years, dredging activities have shaped the interface between land and water to support a variety of human activities including navigation, coastal protection, flood risk management, as well as residential, tourist, commercial, agricultural and industrial activities. The use of dredging to achieve these purposes has always been guided by an understanding of the costs and benefits. The increasing tension between human development and planetary resilience urges us to rethink the way we work and live. The dredging sector is no exception. It uses sand as a building block to create infrastructure projects for social and economic development. At the same time, the increasing quantities extracted and its impacts on environment and society raise concerns. According to the UN Environmental Programme (UNEP), 50 billion m^3 sand is mined annually. Of this amount however, only a small percentage (2-4%) is dredged by dredging companies. As a sector, the dredging industry has extensive expertise in the sustainable extraction of sand. For this reason, its goal is to share its experience and findings with a broader audience to advise other industries and stakeholders in sustainable practices. For taking these concerns to heart is the shared responsibility of dredging contractors, project designers, project owners and authorities.

Discussion

The path towards sustainable use of sand is set out in ten recommendations formulated by UNEP[1]. IADC builds on this from the perspective of the dredging industry and directly refers to UNEP'S recommendation number 7, "Establish best practices and national standards, and a coherent international framework". Keeping pace on this path requires the combined efforts of authorities, project owners, stakeholders, project designers and industry. When all actors contribute within their field of competence and responsibility, opportunities can be seized to significantly reduce negative impacts on environment and society and to increase positive contributions. This paper responds to UNEP's call to contribute with best practices and presents a wide range of initiatives the dredging industry has taken to counteract concerns and impacts related to sand extraction and reclamation. These contributions include initiatives on both project and operational levels.

Performing and adhering to an Environmental and Social Impact Assessment are key to finding consensus about conditions and requirements for sand extraction. Impactful mitigation and nature-inspired design start with monitoring and understanding the physical and ecological processes involved. In our vision, dredging in or near sensitive sites with high natural or cultural value is only feasible with extensive monitoring, adherence to strict limits and adequate supervision. But we also conclude that beneficial use of dredged sediment from capital and maintenance dredging projects is an alternative to sand extraction. Another important aspect is that stakeholder engagement addresses concerns and unlocks potentials. Also adaptive management counters risks and uncertainties associated with dredging projects. And appropriate procurement processes are able to prioritise project objectives. In the paper we also describe that large marine infrastructure projects entail opportunities to involve the local socio-economic community. And that incentives for investment in innovation, safety culture and impact mitigation measures encourage improved practices. And finally, transparency about activities, with publicly available monitoring data and warning triggers, helps to maintain focus on impacts and to obtain project acceptance.

Conclusion

The dredging industry is committed to help build a better future and continues to contribute to the understanding of the ecosystems by exchanging information and know-how with knowledge institutions and scientific communities, by encouraging research and participating in joint research programmes. It also invest in innovations that increase sustainability and biodiversity, reduce accidents and impacts, and improve operational excellence. We need to anticipate and adapt practices to new and upcoming standards and regulations, such as the European Sustainability Reporting Standards (ESRS) and Corporate Social Responsibility Directive (CSRD) and Green Taxonomy and engage in dialogue with a wide group of stakeholders to ensure that the public's concerns are addressed and projects benefit the entire society. The dredging industry has an important part to play in seizing opportunities. Operating globally, dredging contractors are working within a wide variety of physical, environmental, social, and legal conditions. Their first-hand experience can serve as a guide to formulating recommendations for responsible use of sand resources.

This all led to a paper which presents best practices for optimal use of scarce sand resources, on both project and operational levels. Every stage of a project presents opportunities to increase the sustainability of sand extraction.

References

Relevant UN SDGs (*https://sdgs.un.org/goals*)
9,12,13,14

MEDLOG Empty Container Park Development

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Summary
Following an open Expression of Interest process, NSW Ports signed an agreement for lease with MEDLOG Australia for the long term lease of parcels of land in Port Botany NSW. The lease required NSW Ports to undertake the development of an empty container terminal which included relocating 8 operating hydrocarbon pipelines to connect two parcels of land making up the empty container terminal. Minor operator works such as cameras, notice boards and building fit outs were left with the tenant.
This paper outlines the challenges and tribulations that the project team went through throughout the development of the new terminal.

Keywords: Empty Container Park, Hydrocarbon Pipelines, Port Botany NSW

Expression of Interest
NSW Ports pursued an Expression of Interest process for an additional empty container terminal on a parcel of land where the lease was expiring. The expiring lease was held by Origin Energy and the site had been in use as an LPG storage and distribution facility for close to 40 years.

At the conclusion of the EOI process a new tenant (MEDLOG) was selected. The additional empty container capacity aligned with the long term objectives of NSW Ports.

Figure 135 Project site prior to redevelopment

Introduction
The project included the decommissioning of the LPG storage facility as well as design and development of the new Empty Container Park (ECP) undertaken by NSW Ports in Port Botany NSW.

Decommissioning of site
Before any site development could commence it was essential that the LPG terminal was adequately decommissioned and demolished. Origin Energy was responsible for this task and NSW Ports oversaw the activities and making sure the works were completed in accordance with the expiring lease agreement.

Design Development
NSW Ports engaged consulting engineering companies to assist with the design development of the proposed ECP and subsequently for the full detailed design and documentation of the proposed works associated with the ECP.

Due to some site specific scope of work inclusions, NSW Ports chose to engage a consulting engineering company for the general civil and buildings design and another for design specifically associate with relocation of existing operational hydrocarbon pipelines.

The relocation of the hydrocarbon pipelines required innovative solutions to be developed in order to keep the pipelines operational while constructing a culvert below these pipelines.

Throughout the design development the new tenant was engaged in providing operational and functional inputs to maximise the functionality of the new ECP design. At the completion of the concept design development, the tenant was provided with a complete design package for review and comment.

Construction Procurement
Two construction tenders were issued to selected contractors based on the detailed design. One tender for the pipeline relocation works and one for the civil and buildings works of the ECP.

Following extensive procurement processes contracts were awarded for the pipeline relocation works and the civil works.

Site Development
In order to capture the site redevelopment, NSW Ports deployed timelapse cameras on the site. This provided benefits to reviewing site progress, records of site works and full visibility of weather conditions on the site.

Bulk earthworks associated with the pavement structures for the site involved dynamic compaction of subgrade materials in close proximity to the operational hydrocarbon pipelines. To make sure these operational pipelines were not exposed to excessive vibration, a network of vibration monitoring equipment were deployed on the site for the full duration of the pavement works.

Through engagement with the pipeline owners a schedule of outages was established for the hydrocarbon pipelines and all works were planned around this outage schedule. The initial task for the pipeline works was to establish a temporary works structure capable of supporting the pipelines in a temporary state while a permanent culvert was constructed below the suspended pipelines.

Figure 136 Temporary works structure for pipelines

Figure 137 Permanent Culvert Completed

Once the culvert construction was complete, each pipeline could in sequence be relocated into the new culvert This required extensive consultation, planning and engineering to satisfy the requirements of each of the three owners of these pipelines.

The civil works for the ECP entailed extensive pavement works, installation of stormwater systems, services, lighting and the construction of an Administration Building and a Workshop for container repair services.

Sustainability

An integral part of the design and construction of the new ECP was inclusion of sustainability principles into materials selection and works practices.

For the pavement structure, the basecourse materials chosen were a mix design by Boral containing 2% Lime and 5% Fly Ash in lieu of cement to achieve the required strength of this material.

Throughout the works, use of low carbon concrete was selected where a minimum 50% reduction on carbon footprint was achieved through the use of Boral ENVISIA ® concrete mix design.

The design for the Administration Building and Workshop included PV Panels and battery storage as well as rainwater harvesting for use across the site.

Site Commissioning

The project was completed in stages in the second half of 2023. All pipelines were recommissioned as soon as they were relocated. MEDLOG started operations on the site in September 2023.

Conclusions

The development of the ECP faced a lot of challenges. The timing of the project coincided with some of the heaviest and prolonged rainfall events in recent history for Sydney, and very an extremely busy construction industry across NSW with high demands on labour and supplies etc.

Relocating hydrocarbon pipelines introduced complex stakeholders requirements. Adopting an integrated approach to the delivery of the development enabled NSW Ports to successfully deliver this project within budget and on time.

Sydney Autostrad Botany Rail Extension (SABRE)

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Summary
As an island nation, Australia relies on ports as a gateway to supporting our economic needs. Essential goods arrive via shipping containers into Port Botany in Sydney to be distributed via road or rail, while many of Australia’s exports arrive by rail.

Project SABRE was a four-year $190m investment to introduce automated rail operations to increase the 'on-dock' rail container handling capacity at Patrick Terminals - Sydney AutoStrad.

SABRE, a joint project between NSW Ports and Patrick Terminals, is a world-first fully automated on-dock rail terminal integrated with an automated straddle-operated container terminal and has won the award for Innovation Project of the Year with Infrastructure Partnerships Australia. The project focused on increasing the number of available rail windows and reducing train handling times by installing four 600m long rail sidings, a loco shifter and three automated rail mounted gantry cranes.

Keywords: Sustainable port operations, World firstl, Decongestion, Automation, Port Botany NSW.

Introduction
Project SABRE (Sydney AutoStrad Botany Rail Expansion) is a joint initiative between NSW Ports and Patrick Terminals which uses a world-first fully automated on-dock rail terminal integrated with an automated straddle-operated (AutoStrad) container terminal at Port Botany.

The primary objective of the $190 million project was to significantly increase capacity and efficiency, while safely handling containers arriving at and departing from Patrick’s Sydney AutoStrad Terminal by rail.

Boosting the terminal’s capacity and efficiency makes rail a far more attractive proposition for shippers of both imports and exports who rely on the timely movement of their goods through the supply chain to and from the port.

Previous Rail Siding Operation
Prior to the completion of the SABRE project the rail terminal at Patrick Terminals consisted of dual sidings capable of accommodating a 550 m train consist. Trains would be propelled in to the rail sidings from the Botany Yard which required locomotives to complete a run around in the Botany Yard.

Once a consist was placed in the Patrick rail yard, reach stackers would be utilised to offload and load each consist. Offloaded export containers would be placed into a temporary stack in the rail yard. An import container would be picked up from the temporary rail yard stack and placed onto the rail consist.

Containers were then handled a second time being transferred between the rail and shipping yards by road trucks.

Figure 138 Previous Rail Terminal Operations

Each rail container was handled a minimum of five times due to the inefficient internal road loop between the container yard and the rail yard.

Project Features
The SABRE project commenced in 2019 and was completed in April 2024 and consisted of the following key features:

- Four rail sidings each able to service a 600 m long train consist;
- Three Automated Rail Mounted Gantry Cranes (ARMG);
- Locomotive shifter; and
- Train scanning portal on incoming rail line.

Increased rail handling capability within the Patrick Terminal from 200k TEU to 500k TEU with an ultimate capacity of 1.0M TEU through addition of a further three ARMG’s. This would ultimately result in a reduction of approx. 900 truck movements per day.

Current Rail Yard Operations
Following the completion of the SABRE Project, the rail yard is now fully automated and has the

capability to receive and service up to three 600m long train consists at the same time.

Figure 139 Current Rail Terminal Operations

The introduction of the loco shifter allows for trains arriving at the Patrick rail facility to be loco leading eliminating the need for the loco run around in the Botany Yard with the consist proceeding directly to the Patrick Rail Yard. This saves time and expense for rail operators.

As the consist enters the Patrick Terminal, it is scanned at the rail OCR portals and the scanned file is compared with the train operators submitted loading plan.

Once the train consist is placed within the rail terminal, the loco is disconnected and moves onto the loco traverser and is then transferred to a vacant track so it can run around to the front of the consist.

The rail terminal gates are closed at each end before the ARMG's commence their automated operations to strip and load the train consist.

All containers coming from and going to the rail terminal are handled directly inside the AutoStrad Container Yard without the need for manual operations or further handling. Once an export container is inside the AutoStrad yard it is available for ship loading.

Project Benefits

The new rail terminal has boosted the terminal's capacity and efficiency making rail a far more attractive proposition for shippers of both imports and exports who rely on the timely movement of their goods through the supply chain to and from the port. It means more containers can be loaded and unloaded at the same time, more rail services and windows are available with 33% faster train turnaround times.

From grain farmers in the Riverina to a supermarket in Dubbo or a family in living in Sydney's Inner West, each and every one of us interacts with the supply chain every day. Project SABRE has significantly improved the efficiency and capability of this supply chain by enabling more containers to be moved by rail in a single movement to and from the port at Port Botany. This means faster transport times for goods to and from the port, reduced transport costs through the supply chain and fewer emissions.

Innovation

Project SABRE sought to significantly increase capacity and efficiency while safely handling containers arriving and departing Patrick Terminals by rail using a fully automated end-to-end solution to move containers from rail to the quay line, and vice versa.

Patrick Sydney AutoRail Terminal is the world's first fully automated container rail terminal that integrates existing automated straddle-operated container operations and systems with the new automated rail terminal currently using three ARMG cranes (with capability to add an additional three cranes in future).

SABRE utilises several technological and innovative solutions, that are at the forefront of port automation globally, to deliver efficiencies and improve safety. Inbound trains are scanned with sensors and cameras before lockout systems exclude personnel from entering the rail terminal during operations.

With specialised commissioning engineers unable to travel to Australia during COVID travel restrictions, the ARMG cranes were commissioned using innovative digital-twin technology and remote testing.

Conclusion

The project achieved an excellent outcome for rail operators, Patrick Terminals and NSW Ports, while setting a new benchmark for on dock rail terminal operations globally.

Faced with significant challenges throughout the delivery of the project, the collaboration of all project stakeholders resulted in minimisation of project delays and delivery cost.

Testament to the innovative approach taken to deliver the project, Project SABRE has paved the way for other port and intermodal operators with similar projects now being planned at Port Botany's other stevedore terminals.

Relevant UN SDGs (*https://sdgs.un.org/goals*)
9, 11 and 12

Carnarvon Dredging and Babbage Island Spit Stabilisation – Site Works

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Summary
Maritime Constructions (MC) is currently executing a long-term dredging contract for the Department of Transport in Western Australia to maintain the State's coastal facilities. Under this contract, the company was called upon to execute an additional project for the dredging of a number of Carnarvon's entrance channels and stabilisation of the spit on Babbage Island. The project involved extensive dredging works and capturing dredge spoil for boosting coastal defences and improving resilience of the marine asset from severe weather events. This project brought about many challenges and called for a collaborative approach from the client, technical consultants and Maritime Constructions to ensure the best outcome for the community, which was to re-establish a navigable connection between the heart of Carnarvon and the ocean.

Keywords: dredging, reclamation, aboriginal engagement

Introduction

The project being presented is part of a wider, multifaceted, program of works known as the Carnarvon Fascine Entryway and Boat Harbour Pen Project, announced by the WA state government in 2020, to deliver improved ocean access for boat owners in Carnarvon.
This program of works follows the deterioration of the fascine entrance channel and resulting in larger vessels essentially becoming 'land-locked' inside of the Fascine waters along the Carnarvon township.

Figure 1: Carnarvon boat fishers during the "Free the Fascine" rally in February 2020: source The MidWest

The Carnarvon project is the largest package in this program to-date, and included dredging, capturing and placement of dredge spoil, dune stabilisation and revegetation.

During dredge operations MC crew discovered historic jetty piles from the 19th century within the dredging footprint. To continue dredging and not to delay the program, MC mobilised a team of divers to safely remove a total of x24 timber piles (0.4m dia), under observation of a marine archaeologist from the WA museum who ensured the piles were removed and stored in accordance with the legislation.

Dredging Works

37,000m^3 were removed from the Teggs channel between July and September 2023. This period saw the most favourable weather conditions of the year for dredging the ocean side of the channel. Pumping distance was generally 1,500m, and the selection of the cutter suction dredge 'Ironheart' was able to achieve this without the need for a booster station and with minimal downtime.

Figure 2: Dredge vessel, Ironheart, dredging Teggs Channel. Source: Maritime Constructions.

Following from Teggs, between October and December, 101,000m^3 were dredged from the Fascine and a new Entrance Channel constructed.
In early 2024, an additional 16,000m^3 was removed for maintenance of the Boat Harbour entrance channel, which marked the end of dredging works on the project.

Spit Stabilisation with New Dune

All seabed material extracted from the dredging works was hydraulically pumped via HDPE pipeline as a slurry to an outfall point on the Babbage Island

Spit. The slurry was directed through a network of temporary earthen bunds before the return water was released into the ocean. The increased travel distance allowed the water to slow and maximised material drop-out for reclamation onto the spit. Retention of sand material was very high, shown to be approximately equal to the in-situ volume removed from the channel(s).

Material was harvested and controlled by a number of earthmoving machines stationed on the spit. Operators constructed the dune shape concurrent with their reclamation duties.

Through a strategic partnership between MC and civil contractor, Garli, the spit works were undertaken by an entirely aboriginal workforce, most of whom are local to the Carnarvon area. This resulted in approximately 23% of the person-hours for the project being aboriginal employment.

Figure 3: Stabilisation of reclaimed material Source: Maritime Constructions.

Stabilisation and Vegetation

MC, along with local contractor Gascoyne Landscaping, installed a series of drift-fences and matts using locally sourced bushing material. The installations immediately started to capture wind-blown sand and will serve to temporarily stabilise the dune until the dune can be seeded and revegetation takes hold.

Revegetation work was completed in March 2024 to coincide with the ideal seeding time, with cooler weather and rains.

Technical Challenges

As the Fascine was no longer navigable, dredging in the shallow waters of the Fascine had its challenges, primarily, the difficulties of repositioning anchors at low tide. The anchors were moved using an anchor handling vessel, and movements required strategic planning around the tide and the variable progress rate of the dredge. With constant monitoring and forecasting, the anchor vessel did not run aground while attempting to move anchors, and the dredge progressed uninterrupted.

With limited geotechnical information MC managed the disposal of varying dredged material in different stages. The disposal pipe outfall point was moved regularly to allow equal disposal of material making working the material manageable. Additionally, the design called for an undulating surface mimicking a natural dune shape. Site engineers, using a GPS rover, provided constant survey support setting out the target dune toe and peak levels at out-of-phase undulations along the length of the dune. This constant feedback allowed operators to shape the dune to within specification immediately at the point of disposal from the dredge.

Figure 4: Progress of dune construction. Source: Maritime Constructions.

Conclusion

The project execution was a success as MC completed a package of works that the community was unable to undertake themselves without the support of State Government and an experienced contractor.

The project was completed despite the challenges faced by both contractor and principal, and within the funding allocation made available by the State.

The beneficial reuse of the dredge spoil is a prime example of *working with nature;* in an industry that is typically considered as one which negatively impacts on the environment.

Relevant United Nations Sustainability Development Goals: 10, 14

References

Carnarvon boat fishers during the "Free the Fascine" rally in February 2020: source The MidWest

Coupling sustainability and technology in port equipment

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Summary
Konecranes, a global leader in material handling solutions, stands at the forefront of integrating sustainability into its business strategy. Committed to the UN Global Compact since 2010, the company aligns its operations and strategy with 9 out of 17 key UN SDGs. The company's push for low-carbon, energy-efficient solutions is exemplified by its Ecolifting™ and Path to Automation approach and a commitment to provide a full electric port equipment portfolio by 2026. Digitalization further bolsters its predictive maintenance capabilities, ensuring efficiency and cybersecurity in line with ISO 27001 and IEC 62443 standards, showcasing Konecranes' commitment to eco-efficiency and operational excellence.

Keywords: Sustainability, Port Equipment Technology, Decarbonization, Automation, Digitalization

Introduction
The global imperative demands balancing the supply chain of essential materials and goods with resource conservation and emissions control. As an industry leader in lifting equipment services with the most extensive patent collection, Konecranes advances this objective through its decarbonization, Ecolifting™, Path to Port Automation, and digitalization initiatives. The company provides a comprehensive and advanced portfolio of container handling technologies that enhance safety, sustainability, and productivity. By applying global insights to local needs, Konecranes enhances operational efficiency while minimizing lifetime ownership costs. This paper highlights the company's commitment to unify technology advancements optimizing operational efficiency with environmental stewardship.

Sustainability at the core of business strategy
As a United Nations Global Compact participant since 2010, Konecranes is committed to the ten principles of the UN Global Compact. In 2023, Konecranes received a Gold rating from EcoVadis, a notable sustainability assessor, ranking in the top 4% of all evaluated firms and within the top 1% in its industry for the third consecutive year. In their latest published Annual Sustainability Report, Konecranes states that their sustainability approach and targets are aligned with the following UN Sustainable Development Goals (SDGs): 7, 9, 12, 13, among others.[1] Konecranes' Zero4, a five-year ecosystem program, aims to tackle two major challenges: the climate change impact of material flows and the declining productivity of industrial companies in developed countries.[2] Konecranes products and services support the customers' operations with innovative solutions that enhance productivity, lower emissions, and drive business forward.[3]

Designed for Environment
Konecranes uses Design for Environment (DfE) as a design approach in product development to reduce the overall environmental impact of a product where the impacts are considered across its life cycle. The Environmental Product Declaration (EPD), that Konecranes provides for its port equipment, describes the environmental aspects of our products. The EPD is a standardized way of quantifying a product's environmental impact through a summary of the relevant eco-efficient features which has been reviewed by an independent third- party service provider.[4] These EPDs are currently available for all main products: RTG (Rubber Tired Gantry crane, Rail Mounted Gantry (RMG) crane, Automated RMG (ARMG), Lift truck, Ship To Shore crane (STS), Mobile Harbor Crane (MHC), Automated Guided Vehicle (AGV) and Straddle Carrier (SC).

Ecolifting™
The Konecranes Ecolifting™ approach is a systematic movement towards lower CO_2 per container move.[5] As an Original Equipment Manufacturer (OEM), Konecranes is actively pushing forward new solutions focusing on providing safe, uninterrupted, and secure material handling with advanced low-carbon and energy-efficient technology that enables customers to transition to a decarbonized future. Konecranes introduces innovative technology to enhance sustainable practices in the port industry to ensure that low-carbon solutions and selected technologies are attractive to its clients. The first major step in this direction was the introduction of the Konecranes Gottwald all-electric AGV over ten years ago. Substituting existing technology with lower-emission alternatives is a big opportunity for all parties involved.

Electrification necessitates a paradigm shift
Konecranes has steadily expanded its offering of electric and hybrid products, with the last remaining diesel-fueled only product lines within the lift truck business to be made available electrically by 2026.[1] Targeting to deliver safe and secure material handling solutions and enable a decarbonized, circular world. The shift to electric equipment is an ongoing process driven by a step-

by-step approach and necessitating a paradigm shift, which presents challenges within the port sector that can be hesitant to adopt new practices. Upgrading infrastructure to enable full electric operation, including accommodating charging stations is necessary, along with possible modifications to planning and yard operations to adapt to the requirements of the new equipment. Additionally, the initial acquisition costs for electric machines are typically higher than those for traditional machines such as manual operated RTGs that run with diesel gensets. It's common industry knowledge that RTGs are the most used container handling equipment in the world accountable for over 55% of container operations. Konecranes has been pioneering with different battery technologies since '90s and Ecolifting facilitates this shift in manageable steps for the port industry with the availability of battery-powered heavy mobile equipment.[6] Furthermore, Konecranes maximizes lifecycle value and eliminates waste with circular solutions throughout the value chain, such as retrofitting and modernizing of existing equipment. Over the past decade, technological improvements have increased berth and crane performance benchmarks by 15% and 14%, respectively, with yard performance benchmark up 9%.[7]

Technological leadership in automation

Over the course of the last 20 years, Konecranes has systematically become the leading port automation supplier for both brownfield and greenfield port developments. The Konecranes Gottwald AGV debuted in 1993 at ECT Port Rotterdam. Today Konecranes boasts an operational fleet of over 960 Konecranes Gottwald AGVs in some of the world's largest terminals. Many of them have been in service for over 20 years.[8] One of the emerging new concepts, Automated High-Bay Container Storage, addresses the constraints of space by utilizing both Path to Port automation and Ecolifting approaches for sustainable container handling.[3] The Automated High-Bay Container Storage (AHBCS) is a storage system for containers designed for use in logistics centers, distribution centers and similar facilities that need to handle significant quantities of containers on a reduced footprint.

Digitalization

Another aspect of technology advancements improving port operations is the increased utilization of digital technologies. Digitalization improves predictive maintenance by harnessing the industrial internet to connect data, machines and people to provide the right service at the right time, being a key enabler for circular economy. Big data analysis allows the development of new predictive services which help in enabling uninterrupted operations and therefore improve the efficiency of terminals. Preventive and predictive maintenance through Lifecycle Care, enabled by sensors and data analysis, minimizes the cost of downtime.[9] Konecranes port equipment creates value for crane operators by providing applications that increase safety, usability and efficiency. Fleet analysis gives customers a unified overview of how all of their equipment is performing. Konecranes emphasizes the security of its software and connected services by incorporating fundamental cybersecurity safeguards and adhering to relevant regulations. The organization commits to protecting customer data and following established best practices, such as ISO 27001 and IEC 62443.[1] The adherence to security standards encompasses both the company's product and service portfolio offered to customers and its internal information security governance.

Discussion and Conclusion

Coupling sustainability and technology is a wider effort within the entire supply chain, governmental regulations, and commercially technological advancements that extends the realm of a traditional OEM. Konecranes has demonstrated a profound dedication to integrating sustainability into its operations and the solutions it provides to the industry to contribute to reducing environmental impacts in the port equipment sector. With a strong focus on innovation, Konecranes leads port automation with electric AGVs and the AHBCS system as well as automated gantry cranes enhancing operational efficiency. Capitalizing on digitalization for predictive maintenance and emphasizing cybersecurity standards, the company exemplifies its commitment to eco-efficiency and setting industry benchmarks for sustainable practices.

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A Digitalised Port Safety Rule Scheduling Framework Using a Digital Port Twin

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Summary
A Port's Harbor Master Directions (or equivalent) document continue to form the principal means for defining the safe port scheduling rules managing the day-to-day movements of vessels within most Ports.

However, as port operations become increasingly congested and complex, complicated scheduling scenarios and dynamic metocean weather events increase the potential for the frequent manual interpretation and evaluation of the port safety rules defined in these documents to be incorrectly applied.

A digitalised port safety rule framework has therefore been developed that enables all port rules, variables and scheduling logic contained in these documents to be automatically evaluated in a logically robust and auditable digital forecast twin scheduling environment.

Keywords: Digitilisation, Port Twin, Port Safety Rules, Scheduling.

Introduction

Harbor Master Directions set out the series of safety rules, thresholds, logic and prioritisation that define relationships between a range of vessel and environmental variables and the resulting thresholds or conditions in which vessel movements in the port can be completed or should be prioritised.

In these documents, the port safety rule-variables, -thresholds, and -logic are defined in various tables and descriptive, text-based logical statements. The frequent manual interpretation and evaluation of these often complex port safety rules and scheduling logic contained in these formats has the potential to introduce mistakes in their execution in dynamic weather and operational port scheduling environments.

The development of the NCOS Online Port Rules Module enables all port rules, variables and scheduling logic contained in Harbor Master Directions to be digitalised to ensure all rules pertaining to the safe scheduling of all vessel movements and scenarios is evaluated in a logically robust and auditable digital forecast twin scheduling environment. Extensive functionality is provided to enable the delegated Harbor Master user to flexibly update, remove, define and evaluate new port rules as required to accommodate changes to the vessel fleet and the type of environmental and scheduling scenarios evolving in the port.

Port Rules

The concept of using port rules to manage safety in congested waterways has been around for centuries. The British Royal Navy can be credited with some of the first attempts in the 1700's to formalise in writing, practical rules for managing safety of shipping in congested waterways:

'*All ships on the larboard tack are to bear up for those on the starboard tack when passing on opposite tacks'* [1]

Arguably, and with only some exceptions focussed around under keel clearance management, ports today still largely rely on similar text-based, descriptive statements of their port rule safety logic which are manually interpreted, evaluated and applied in the port's day to day scheduling operations.

As the size and complexity of modern port operations has continued to grow, the number of rules required to manage the safety of port operations has significantly grown such that contemporary Harbour Master Directions comprise large documents with increasingly complex, compound and precise port rule logic defining rules covering a wide range of port rule safety variables such as:

- Wind speeds
- Tidal current streams
- Daylight-nighttime transit restrictions
- Under keel clearance
- Bridge air draft restrictions
- One-way channel passing restrictions
- Transit separation distances
- Tug and bollard pull requirements.

An example of a typical contemporary port rule with complex, compound port rule logic for applying safe two-way passing channel restrictions to scheduling of vessels in the Port of Brisbane is provided below:

'5.5.3 One mile to seaward of the Entrance Channel to Outer Bar Reach

Ships with an aggregate LOA less than 370 metres may pass provided:
• neither ship has a draft 12 metres or more
• neither ship has a beam greater than 33 metres.' [2]

The prevalence of precise, numeric port rule logic to manage shipping safety in modern day ports lends themselves to digitalisation and automated evaluation.

Generic Port Rule Software Class
The digitalisation of port rules and their logic requires the identification of the common components of all ports rules so that they can be defined in a generic software class object. Defining port rules in a generic software class object enables the programmatic interaction with the generic properties and methods of all port rule class instances to be performed in a digital twin scheduling environment.

With very few exceptions, at a fundamental level, port rules can be defined as containing the following common components:

1. Vessel Definition
   A logical statement identifying the vessel definition that evaluates to TRUE/FALSE.
2. Port Rule Variable & Value
   The variable and its value that is to be applied as a scheduling constraint or operational requirement.
3. Spatial Definition
   The location within the port where the rule applies. i.e., channel reach, berth, anchorage waypoints.

With reference to the Port of Brisbane two-way passing channel restriction rule defined previously, the rule can be visualised in this generic framework as demonstrated in Figure 1.0 and subsequently defined in the following generic port rule class properties:

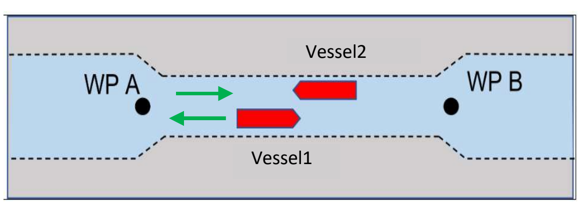

Figure 1.0 Visualisation of a two-way passing channel restriction rule using the Vessel Definition, Port Rule Variable and Value and Spatial Definition generic port rule component framework.

1. Vessel Definition
   $SUM(LOA1, LOA2) < 370m\ AND(\ MAX(DRAFT1, DRAFT2) < 12m\ AND\ MAX(BEAM1, BEAM2) < 33m\ )$
2. Port Rule Variable and Value
   $RULE[PASSING] = TRUE$ (2)
3. Spatial Definition
   $WAYPOINTA =$ ['Entrance Channel']
   $WAYPOINTB =$ ['Outer Bar Reach']

Evaluation of Port Rules in Digital Port Twin Scheduling Environment
A digital port twin provides a detailed and accurate representation of the relevant port infrastructure, vessels and physical environment of a port including port channel assets, berths, swing basins, scheduled vessel movements and importantly forecasts of the physical environment, including variables such as water levels, currents, waves, and winds.

Through the application of the generic port rule software class, all port safety rules can be defined for all locations in the port and for all vessel scenarios. The resulting port rule 'set', containing all port rule safety rules and logic, can then be programmatically evaluated through the integration with the required input data sources in the digital port twin as displayed conceptually in Figure 2.0.

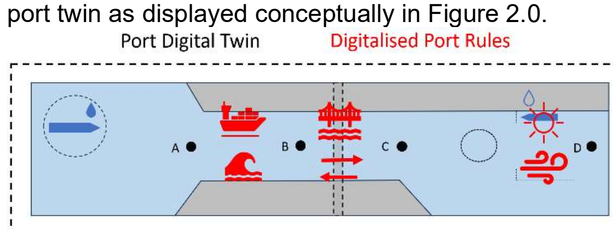

Figure 2.0 Conceptual integration of digitalised port rule set and digital port twin

Conclusion
The size and complexity of modern port operations has continued to grow while the approaches to defining and applying port safety rules have remained largely unchanged.

The ability to automatically evaluate all port safety rules through the programmatic integration of ports port rule safety logic with a digital port twin is considered to enable a fundamental change in the way the safety and efficiency of port scheduling operations are undertaken in the future.

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Relevant UN SDG's 8, 9, 14

Strengthen Critical Maritime Transport in Remote Pacific Country

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Summary
In Tuvalu, inter-island transport relies on two cargo ships, one of which is unsafe and nearing end of life. Additionally, harbours are in poor condition or non-existent in some of the outer islands. Given how crucial shipping services are to the community, RHDHV is involved in supporting the Government in delivering two projects. The Manu Folau Replacement Project involves a new, safer, and more energy-efficient ship which incorporates emission minimisation technology and advanced safety features, and upgrade of fenders at Funafuti berths. The Outer Island Maritime Infrastructure Project ensures safe and efficient operations by creating a workboat harbour, a navigation channel, a wharf, and raising the foreshore with excavated material to provide coastal protection.

Keywords: Pacific Islands, Climate Change, Decarbonisation, Maritime Transport

Introduction
Tuvalu is a geographically isolated country in the southwest Pacific Ocean, over 1,100 km away from its closest neighbour, Fiji. About 60% of the population resides in the capital, Funafuti, with the rest scattered across eight outer islands [1]. Funafuti hosts the country's only serviceable runway, fuel infrastructure, and international seaport, all of which are in a poor condition.

Domestic shipping is the only means of transport between islands, which is provided by two passenger and cargo ships (Table 1), which are crucial for the nation to access goods, cultural events, medical clinics, and education. In a typical year, they will perform a combined 70-74 voyages. One of the ships, Manu Folau, is nearing 20 years old. The increased maintenance required has disrupted the shipping services, overloaded the other ship, and caused some safety concerns.

Table 18: Outer Island Passenger and Cargo Data

Vessel	*Manu Folau*		*Nivaga III*	
Type	**Passengers**	**Cargo (m^3)**	**Passengers**	**Cargo (m^3)**
2016	3,593	595	11,294	2,103
2017	5,453	910	7,750	1,185
2018	3,544	1,879	10,843	1,373
2019[a]	3,051	1,623	10,480	2,211

[a] 2019 figures are based on data extrapolated from incomplete records.

The distances between islands varies from 64-247 NM, which requires ships that can safely operate in open ocean conditions. Passengers and cargo are transported by small workboats between the ship and shore, and it is strenuous and risky in rough seas due to a narrow passage on the fringing reef.

70% of the passengers have been dissatisfied with the existing service, citing it as poorly maintained, unsafe, undersized, and lacking modern facilities. Its workboat is also cited as unsafe, not fit for purpose, and having poor loading and transfer efficiency [2].

$48.7 million has been committed for the Outer Island Maritime Infrastructure Project to construct boat harbors, and $30 million to replace the aging interisland vessel with a more reliable, resilient, and carbon-efficient one. Both projects align with Tuvalu's National Strategy for Sustainable Development (Te Kete), 2021–2030 IV [2].

Manu Folau Replacement Project
Three outputs are required in this project:
1. Replace existing passenger and cargo ship.
2. Rehabilitate port auxiliary infrastructure (fenders).
3. Strengthen operation and maintenance capacity.

To achieve Output 1, a new ship, the MV Manu Sina, will replace the Manu Folau, which is under construction in Japan, adhering to strict internationally mandated energy efficiency design requirements. The design incorporates emission minimisation technology to lower the carbon footprint. It is designed to cope with predicted open sea conditions and increased storminess, with anti-rolling devices to increase passenger comfort, and improved safety equipment, e.g., better cranes and workboats.

Output 2 involves improving fendering standards at Funafuti berths to decrease damage risk. The new fenders panel will allow for sea level rise and provide better support while offloading cargo, reducing potential hull damage.

For output 3, an Energy Efficiency Design Index (EEDI) Phase 3 Standard engine, which could potentially exceed IMO standards [3], will be used to increase the ship's lifespan, simplify maintenance, and increase travel distances between refuelling. This results in less need for bunkerage at multiple locations. The replacement vessel will use distillate diesel, a low sulphur fuel type with lower emissions. Due to the current lack of infrastructure and the specialised bunkering requirements of alternative fuels, which are major obstacles for the Pacific region in general, this vessel was selected in part given its ability to retrofit an alternative fuel source in the future.

Outer Island Maritime Infrastructure Project

This project aims to ensure safe and efficient operations by the provision of a small workboat harbour, navigation channel, and a new wharf.

Wave and current conditions play an important role in the redistribution of sediments along Nui's shoreline. Numerical models, including a wave penetration model and a cyclone model were used to optimise the layout for the Nui Workboat Harbour. Based on the results, the wharf is designed to be connected to the shoreline by a suspended accessway from the beach crest. This design approach offers several benefits in contrast to the previous design that does not take these models into account, including reduced impact on coastal processes closer to the shore, less maritime structure, lower construction time and price, and better wave operational conditions at the wharf head.

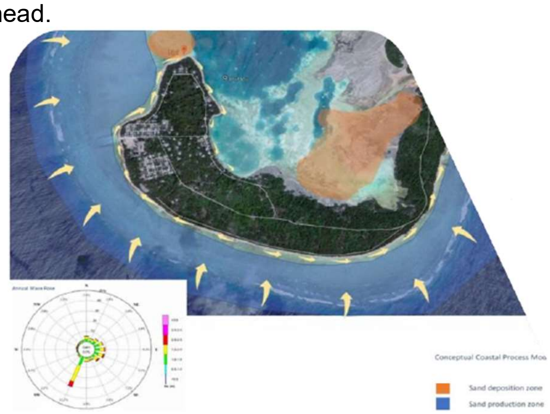

Figure 140 Conceptual coastal process model for Nui's Southern Coast (Source: in house).

Figure 141 New excavated channel in Nui (Source: in house).

Due to the toughness of the reef, the dredging was carried out by 50-ton excavators using a hydraulic rock breaker. Navigational aids were installed to provide safe operation at night.

8,000 m^3 of dredged material was re-used as backfill for the wharf designed as blockwork structure to withstand cyclones estimated from computational analysis and sea level rise expected in the next 50 years. Around 4,500 m^3 of dredged material was used to raise the foreshore to provide improved coastal protection. Stormwater drains have been incorporated to drain the village in case of flooding during extreme cyclone events. The rest of the dredged material was used to fill rock bags to limit scouring of the wharf structure and coastal erosion of the shoreline.

Figure 142 The blockwork structure of the wharf head and rock bag filled with dredged material next to accessway (Source: in house).

A new building used by the community was relocated and elevated to protect against coastal flooding and built to international standards for cyclone resistance.

Discussion and Conclusion

Making marine transportation in Tuvalu more efficient and safer supports the economic development of the country and helps reduce migration to islands which currently face the challenges of overcrowding, pollution, and the spread of disease. Involvement in both projects provided a unique opportunity to understand how much the outer island communities depend on resilient and clean domestic shipping.

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Relevant UN SDGs (*https://sdgs.un.org/goals*)

8, 9, 11, 13,

Establishing priorities for Australia's Coastal Research Infrastructure

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Summary
Climate change is rapidly altering our coastlines, exacerbating habitat loss caused by human activity. Yet, Australia lacks a national, cohesive approach to monitor, understand, predict, and adapt to these changes. In response, we propose the Coastal Research Infrastructure (CoastRI) Initiative. To ensure CoastRI aligns with community needs and creates social benefits, we have conducted nationwide consultations with ocean observation stakeholders. Identified key themes include the need for increased data collection on coastal processes, conditions, and human use and wellbeing. Stakeholders also highlighted the importance of high-resolution, near real-time data and data summaries to improve forecasting and enable informed decision-making.

Keywords: coastal observations, modelling, infrastructure, risk assessment, management.

Introduction
Over 50% of Australians live within 7 km of the coast, along with billions of dollars of infrastructure. Our cities, industries, recreation, and culture are closely entwined with this environment [1]. Climate change is altering our coastlines at unprecedented rates, with sea level rise, coastal erosion, inundation, and weather changes compounding the habitat loss already experienced due to human activity [1]. These changes also impact the built environment, natural resource systems, and Australia's infrastructure planning. Yet, Australia currently lacks a national cohesive approach to monitor, understand, predict, and adapt to coastal change. To increase preparedness, improve decision-making, and support sustainable use, we need more data to understand the implications of these changes on our coastal areas [1].

In response, a consortium of National Collaborative Research Infrastructure Strategy (NCRIS) capabilities is working to establish a national-scale Coastal Research Infrastructure (CoastRI) Initiative to meet the current and future needs of Australian researchers, industry, and government. Planned activities align with three major categories: observing coastal processes, cross-sector modelling and prediction, and data identification, management, and integration. Given the scope and breath of issues facing our coastal systems, this initiative is only feasible through synthesis and coordination among NCRIS capabilities and close collaboration with other related agencies such as Geosciences Australia and the Bureau of Meteorology. This integrated effort will represent a step-change in Australia's approach to operating and connecting essential research infrastructure in coastal regions, enhancing the services provided to stakeholders and end-users. Additionally, CoastRI will provide integrated national-scale environmental and coastal climate capabilities that are not currently available.

The establishment of CoastRI will occur in two-stages. Stage 1 involves a consultation process to determine stakeholder and end-user needs, impact pathways, indigenous co-design program partners, governance, synthesis, and co-investment opportunities. Stage 2 will implement a fully informed CoastRI initiative to maximise impact. This paper presents our preliminary consultation results to understand priorities for coastal research infrastructure, data, and information.

Methods
The priority-setting process solicited possible user needs and priorities through an online survey, workshops, and virtual meetings with members of the Australian research, industry, and stakeholder communities involved in the entire coastal observation value chain. Participants were invited to these activities via email, drawing from relevant NCRIS facility mailing lists, government agencies, and professional networks.

Results and Discussion
The online survey received responses from 221 participants, with the highest participation from research organizations (36.9%), followed by State governments (25.3%), and Commonwealth governments (16.5%) (Figure 1). Notably, respondents hailed from all states and territories, ensuring broad representation across target communities and sectors. State governments, crucial for CoastRI's development and success, were well-represented with 61 individuals participating. Survey respondents predominantly worked in research (45.2%), resource management (17.2%), and mitigation/adaptation (8.1%) sectors.

Themes of interest encompassed a range of closely ranked selections. Key priorities included coastal habitat condition, sea-level rise and inundation, water quality, coastal erosion, and habitat restoration, all of which were highlighted as critical areas of focus. While other categories were selected by less than 40% of respondents, none fell below 20%, reflecting the significant data needs in coastal systems. Coastline change and inundation emerged as consistently top-ranked issues, indicating a pressing need for data to better understand these issues. Additionally, concerns related to habitat loss, marine and estuarine water quality (e.g., pollutants, nutrients, harmful algal blooms), and human use were identified as high-need areas. Some of these issues occur at national scale, while others will likely have more regional and local focus or need, necessitating careful planning and integration with existing state or local government programs. Comments related to other priority areas included: 1) understanding marine heatwaves and climate change impacts on island communities and cultural knowledge/heritage, 2) better predictions of future wind and wave states, 3) improved tidal and sea-level observations, and 4) addressing the lack of baseline data in coastal and remote regions such as northern Australia.

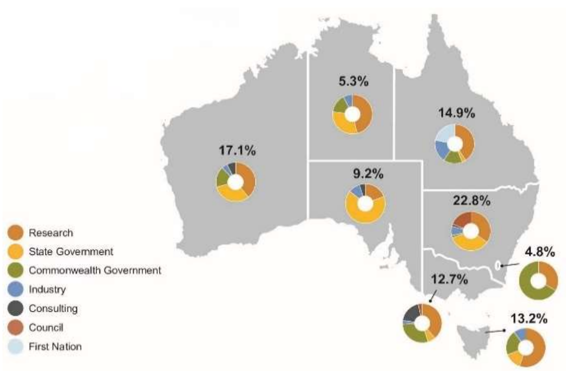

Figure 143:Sectors and geograpical distribution of survey respondents.

Respondents identified a wide range of data and information needs, including bathymetry (60.6%) waves/currents (58.4%), sea-level data (57.0%), habitat cover/health (55.7%), and water quality (54.3%), all integral to the identified priority areas of coastline change, inundation, and habitat condition. An important element of an effective CoastRI will be ensuring that data and information are delivered in a readily usable format. The majority of respondents requested data summaries such as compiled maps or graphics (60.7%), raw data (57.5%), and data dashboards (54.3%). This reflects the need for interpretation, communication, and user-friendly presentation of research findings to inform policy, management, and community use. There were also numerous requests for near real-time data, model outputs, and modelling/analysis tools, underscoring the need for additional observing capabilities, data synthesis, and modelling to support end-users across Australia.

Additionally, between October and December 2023, meetings took place with representatives from various organizations, and several departmental agencies at both state and territory levels, along with local councils. These discussions aligned with the needs and priorities identified in the survey. Further priority areas were identified, such as understanding the implications of coastal and climate change on human health and well-being, and fostering partnerships with First Nations communities.

Summary

Key themes and emerging needs from the consultation phase for consideration in CoastRI include:

- Data on coastal processes and changes (erosion, inundation, habitat loss, tides, land motion).
- Data on coastal condition (biodiversity).
- Data on human use and wellbeing.
- Data on water quality and water levels in estuaries.
- Centralised and easy to use data.
- Data summaries and dashboards to support non-experts.
- High-resolution, near real-time data streams for forecasting and prediction.
- Modelling platforms and outputs.

This work has highlighted CoastRI's requirements and priorities to meet the current and future needs of Australian researchers, industry stakeholders, and government bodies. It will serve as a guide for the development of a National CoastRI Initiative and the prioritisation of activities to meet community needs and create societal benefits. Progress is already being made on many of these activities. A key focus will be to facilitate coordination, data sharing, and leveraging opportunities and research strengths nationwide to develop a coordinated National Infrastructure in the coastal zone. Significant investment and co-investment will be required to address knowledge gaps, with appropriate governance ensuring the sustainable fulfillment of the Nation's observing and data needs. The next phase of the initiative will involve refining the scope and scale of the initiative based on the consultation activities.

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Relevant UN SDGs

9,11,13,14

Cross-border collaborative innovations for business and environmentally sustainable ports

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Summary
Ports, as crucial hubs bridging between waterborne and road transport, are the critical nodes of global logistics and supply chain and play an essential role in global social and economic prosperity. Digitalization and decarbonization have already been shaping the port future, which however is still scientifically and technically challenging due to inherited complexities and uncertainties existing in port operational environments. This paper exemplifies a cross-border innovative collaboration and employs a holistic approach to addressing the industry's challenges and need for port electrification, digitalization and automation towards business and environmentally sustainable ports of future.

Keywords: sustainable port, collaborative innovation, digitalization, decarbonization, federated intelligence

Introduction

Climate change is a global problem faced by our generation! Both EU and China have launched a number of initiatives, such as EU's Twin Transition and Green Deal [3], and China's "30-60" Carbon Peaking and Carbon Neutrality goals [5], targeting to reduce emissions and speed up the digital and green transformation. All societies and industries must play their parts in addressing the global challenge. As the critical nodes of the global logistics network, seaports are crucial for the global trade, thus play an important role in reducing the emissions from the global trade. Given that the global trade is projected to grow by up to 250% by 2050, the need for efficiency improvement & emissions reduction is urgent.

Port decarbonization, digitalization and automation have been steadily permeating through the entire cluster. Huge amount of business and technical data is generated globally at every second. Smart and green technologies and innovations are continuously gaining momentum in the cluster, and major digital transformation enablers, such as AI, Big Data, IoT and Cloud/Edge Computing, are already shaping the future of ports and their operations. On the other hand, due to the inherent complexity and collaborative nature, the port operations require close collaboration and data sharing across the entire port operations and logistics chain. However, only limited amounts of data and information are practically shared among involved stakeholders due to the functional silos existing in global logistics networks and actual operational practices, which adds unnecessary complexities and uncertainties to the already highly complex and uncertain operating environments. Lack of holistic considerations and collaborations has been the major cause for the inefficiencies of global port operations. Digital transformation can be an enabler, but the level of readiness varies largely at different ports. Furthermore, due to the inherent complexities and uncertainties, the adoption of smart and green technologies in ports and their operations practices remain slow although steady. The potential and benefits of digitalization and decarbonization to ports and port operations remain largely untapped.

The paper presents a most recent cross-border collaboration between Finland and China to develop innovative solutions to the decarbonization and digitalization and operation optimization of ports and wider logistics chain.

Methodology

To holistically address the challenges and need for port decarbonization, digitalization and operational optimization, a case-driven approach is adopted, not only to develop novel methods, algorithms, frameworks, physical and digital platforms, innovations and solutions, but more importantly to test, evaluate and validate, in a number of pilots, demonstrations and case studies, their potential and practical applicability and scalability to solve real-life challenges in port environments faced by the partners and the industry.

The detailed methodology is illustrated in Figure 1. Given the multitude of business and technical operational complexities and uncertainties, necessary data is first collected to be able to gain a holistic and realistic understanding of the port environments and operating processes at three different levels, i.e., vehicle, fleet and port levels, and from both business and technical perspectives. The data is then ingested, standardized, curated, and further integrated into a seaport knowledge base. Next, thorough analyses are carried out using Big Data and AI methods to make sense of the heterogeneous business and technical operational data in the edge and cloud/cluster to identify the potential and find innovative ways for port decarbonization and digitalization. A number of sustainability-driven innovations and solutions, including digital twin platform, knowledge base, tools, algorithms and frameworks, are developed to address the major obstacles of improving port productivity, sustainability and cost effectiveness. All the developed innovations and solutions are further tested, validated and showcased with respect to their potential and practical performance improvements in a selection of case studies, pilots and demonstrations.

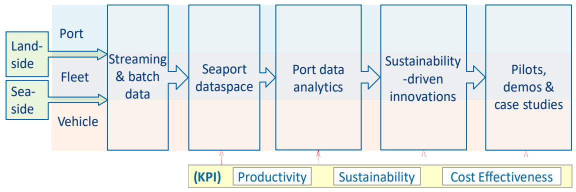

Figure 144 A general methodology and process flow of port digitalization and decarbonization for improved product-ivity, sustainability and cost effectiveness.

Collaborative innovation

Aiming to globally intensify the decarbonization and digitalization of ports, port operations and wider logistics chain, 11 partners from Finland and China join forces to explore innovative ways of enabling and enhancing cluster-wide collaboration and to collaboratively develop industry-leading innovations in port decarbonization and digitalization.

As shown in Figure 2, it includes major stakeholders of the entire value chain in the port and wider logistics operational businesses. They work interactively to address eight major challenges identified in the industries, specifically including 1) next-generation electric vehicles in ports, 2) port vehicle fleet and energy infrastructure integration, 3) AI-driven port business and technical operations optimization, and 4) collaborative intelligence in future ports, 5) multi-energy production and integration in ports, 6) multi-energy production and utilization scheduling, 7) intelligent operation and maintenance of port machineries and 8) human-computer interaction for improved remote operations in ports.

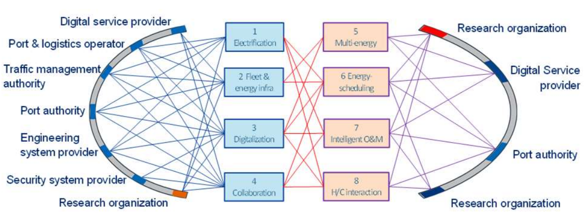

Figure 145 The network of the involved stakeholders and their mutual interest in a list of topics related port digitalization, decarbonization and optimization.

Federated operation intelligence

As an example, to facilitate the collaboration and operation between different stakeholders, we adopt a novel federated learning concept, proposed by Google in 2017 to decouple the data-driven tasks from the need of data centralization, [2] and develop a federated port operation intelligence framework. In practice, the concept is tailored to address the specific challenges and need faced in the siloed but highly-clustered port operational environment, where the problems in practical data sharing and collaboration are quite different and possibly even more complex.

Specifically, port operation involves various types of vehicles and cargos and different stakeholders, with conflicting interest, possessing heterogeneous data and knowledge valuable for operation. Novel algorithms [1] [4] were adopted to develop a federated collaboration approach to integrating the data owned by different stakeholders, without the need for sharing. The developed federated operation models can then be utilized by each stakeholder to fulfill their specific need and hence strengthen the cloud-based orchestration and synchronisation of port operation and logistics.

Discussion

Ports operations are challenged by tremendous complexities and uncertainties from both business and technical perspectives due to the dynamic operational environments, challenging schedules, and the involvement of huge number of entities and stakeholders. Truly business and environmentally sustainable ports could only become possible after breaking down existing functional silos.

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Relevant UN SDGs: 9, 11, 13, 17