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Enhancing Society Together

WG205 Design and Construction of Breakwaters on Soft Seabeds

PIANC-RHD-PP-001
Open
Stuart Bettington
5 September 2022

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Why do we care - sudden geotechnical failure

SH16 Construction Auckland

2

Why do we care - ongoing settlement failure

Westport Marina Auckland

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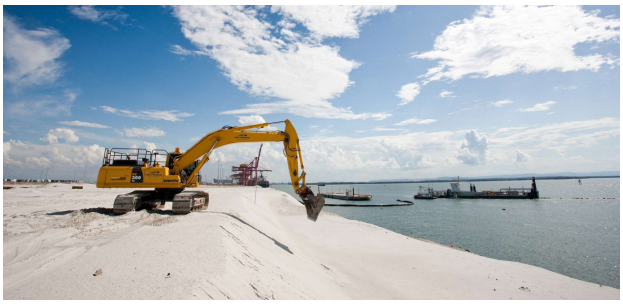
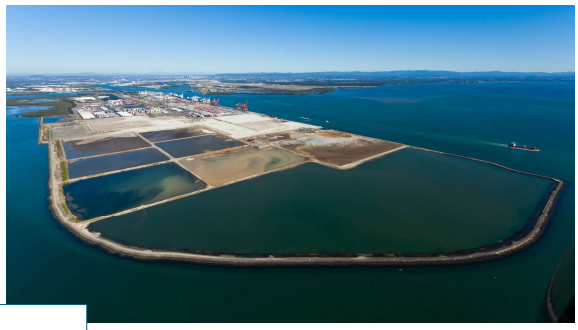
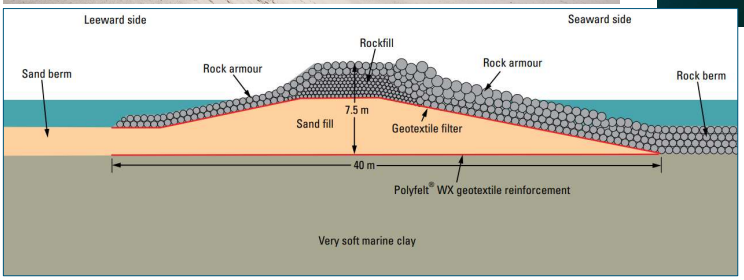
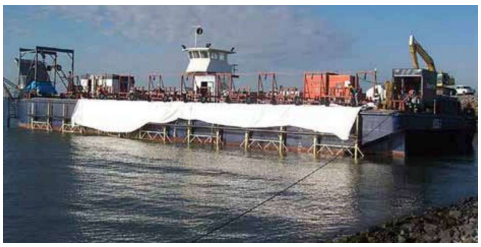
Why do we care – difficult/expensive to address









Port of Brisbane Expansion

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Authors

Leadership

- Chairman – Yoichi Watabe, Hokkaido University, Japan
- Mentor – Yoshiaki Higuchi, Oriental Consultants, MarCom
- Secretary – Hidenori Takahashi, Port and Airport Research Institute, Japan

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1. General Aspects - what is a soft soil

Soft soils include fine grained and organic soils with low undrained shear strength as well as loose to medium dense sands.

What is considered as soft soil depends not only on the consistency of the soil, but also on the type and the size of the breakwater, the method and pace of construction as well as the design loading conditions (e.g. seismic action). Indirectly the soils may be considered soft when:

- The soil conditions necessitates addition or shaping of breakwater elements such as stabilising berms or more gentle slopes in order to obtain geotechnical stability;
- The seabed soil has to be replaced by stronger materials in order to improve the bearing capacity and/or reduce settlements;
- Ground improvement method has to be implemented in order to improve soil strength and deformation parameters and reduce liquefaction risk.

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2. Geotechnical Characterisation of Site

2.1 Typical Soft Soil Conditions and Related Characteristics

- Examines where we might expect find soft soils and issues likely to be encountered.

2.2 Site Investigation Planning

- Discusses staging of investigations and what investigations may be required.

2.3 Data Collection

- Describes sampling techniques and when they should be considered.

2.4 Laboratory Analysis

- What analysis should be done on samples.

Soil test item	Type of ground survey and main surveying purpose				
	General			Earthquake countermeasure	
	Foundation	Stability	Settlement	Prediction of liquefaction	Residual deformation after an earthquake
Density of soil particles, moisture content, grain size	•	•	•	•	•
Liquid and plastic limits	•	•	•	•	•
Wet density	•	•	•	•	•
Uniaxial compression	•	•	-	▲	•
Triaxial compression and tension	•	•	-	▲	•
Consolidation (staged loading, constant strain rate loading)	•	-	•	-	-
Cyclic undrained triaxial (liquefaction)	-	-	-	•	•

Note: • = Test item normally required; ▲ = Test item required if necessary; - = Not required

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3. Design considerations on breakwater types

3.1 Breakwater types

- Looks at the different types of breakwaters such rubble-mound and caisson.

3.2 Discussion of breakwater types

- Examines how different types of breakwaters perform, including piled structures.

3.3 Selection criteria (for soft soils)

- Develops section criteria and decision tree.

3.4 Relevant loading types and associated soil-structure response characteristics

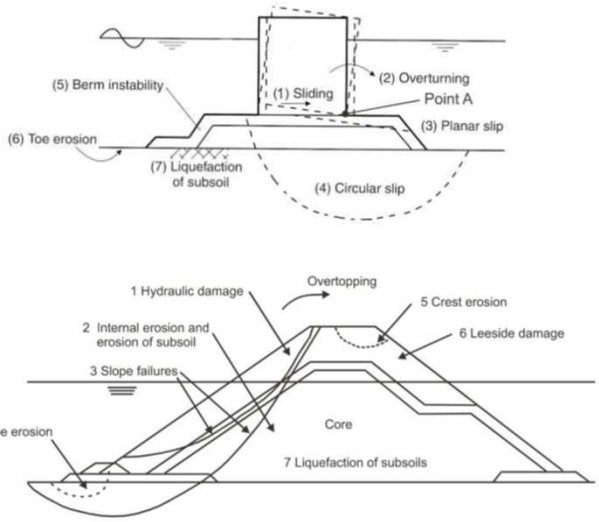
- Considers wave, current, tsunami, earthquake, ship and construction loads on the structure and soils.

3.5 Typical failure modes on soft soil

- Examines the various ways soft soil failures occur.

3.6 Modelling of fluid-soil-structure interaction

- Reviews models used for assessing soft soils.



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4. Construction considerations on breakwater types

4.1 Interfaces between the Design and the construction procedures

- Reviews how construction methodology and soft soil considerations impact design.

4.2 Materials and construction equipment availability

- Explores the role soil conditions have on materials and construction techniques.

		Angle of shear resistance (°)	Unit weight		Slope gradient
			Above residual water level (kN/m³)	Underwater effective weight (kN/m³)	
Rubble	Ordinary type	40	18	10	1 : 1.2
	Brittle type	35	16	9	1 : 1.2
Unscreened gravel		30	18	10	1 : 2 – 1 : 3
Cobblestone		35	18	10	1 : 2 – 1 : 3

	Classification	Vessel types
Main work vessels	Dredge and reclamation	Pump dredger Sludge dredger Grab dredger Backhoe dredger Portable dredger Reclaimer barge Unloading barge Air pressure vessel
	Structure	Hopperbarges / Split barges Crane ship Crane barge Piling barge Floating mixing plant barge Caisson fabrication barge or floating docks Jack Up barges
	Soil improvement	Deep mixing barge Sand drain barge Sand compaction barge
Ancillary work vessels	Self-propelling operation	Multicat Anchor handling boat Tugboat Pusher boat Traffic boat Diving support vessel
	Self-propelling operation and carriage	Self-propelling grab hopper barge
	Non self-propelling operation and carriage	Grab hopper barge Stone carrier Hopper barge Barge-type platform
	Others	Spud barge

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5. Existing codes, standards, and guidelines

5.1 Codes and Practices

- Listing key standards and references documents.

Subsequent sections examines codes etc. as they pertain to specific design issues:

5.2 Limit state design

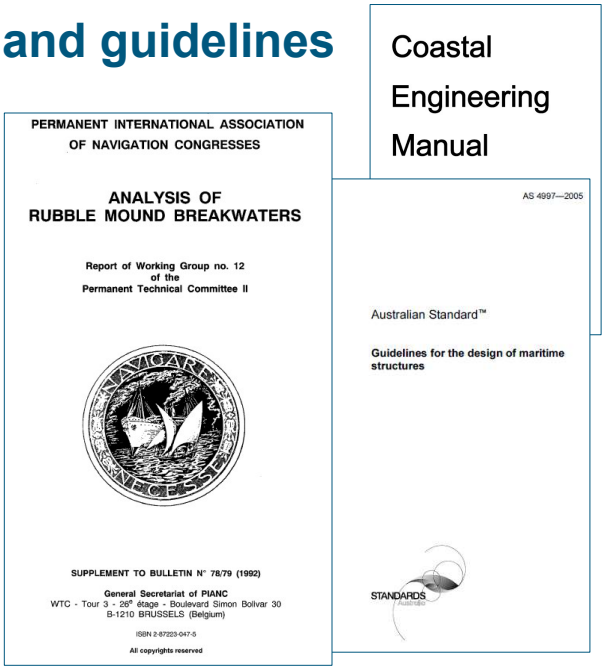
5.3 Performance based design

5.4 Environmental design parameters

5.5 Soil investigation

5.6 Geotechnical design

5.7 Seismic design



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6. Stability and settlement analysis

6.1 Constitutive behaviour of Soft Soil

- Soil strength and modelling of soil.

6.2 Stability analysis

- Looks at modes for different types of breakwaters including bearing capacity, sliding, overturning and slope stability.

6.3 Settlement and consolidation analysis

- Settlement behaviour and how different types of breakwaters perform.

6.4 Dynamic analysis

- Looking at wave and seismic loading.

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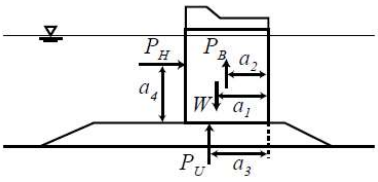
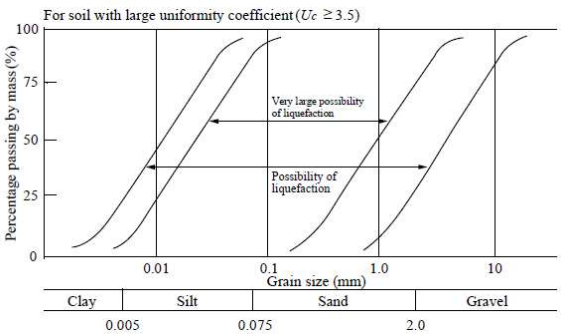


$$S = h\frac{C_c}{1+e_0}\log_{10}\frac{\sigma'_{v0}+\Delta p}{\sigma'_{v0}}$$



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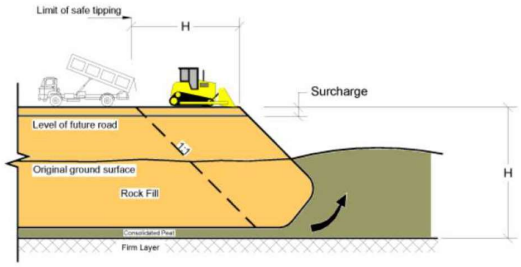
7. Ground improvement techniques

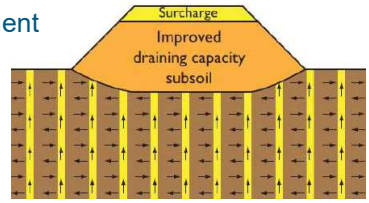
7.1 Considerations in constructing on soft soil and Ground Improvement (GI) methods

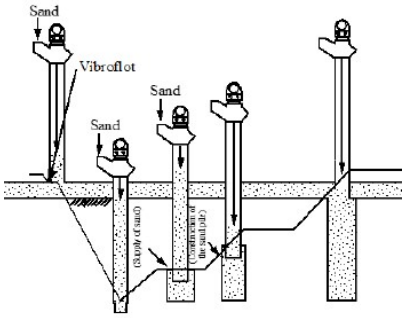
- Reviews factors that impact the selection of GI method.

7.2 Ground improvement methods

- Staged Construction.
- Ground replacement
- Ground removal by displacement
- Consolidation acceleration
- Dynamic compaction
- Stone or sand columns
- Soil mixing
- Geosynthetics – reinforcement
- Compaction by blasting
- Micro-piling







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8. Monitoring

8.1 General

- Overview of why and how we monitor structures.

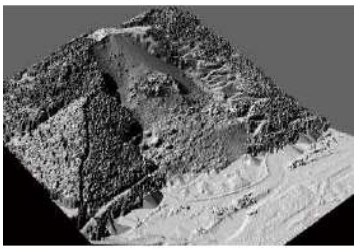
8.2 During construction

- Explores monitoring methods in this early phase and how it is used to manage risks.

8.3 Settlement and consolidation analysis

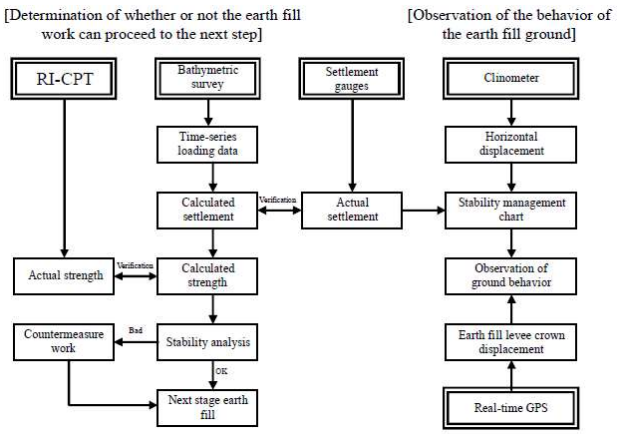
- Primarily focussed on survey techniques and settlement monitoring.

UAV's increasingly popular



DSM of slip

Stability management flow chart



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Where to now

Progress and Timelines

- Some chapters are still in a preliminary stage
- Draft for review (internal) to be provided to MarCom late 2022
- Internal review process with publication in mid 2023.

How can you help

- We are looking for example projects
- If you have an example you would be happy to publish, please contact either
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  - Secretary – Hidenori Takahashi takahashi-h@p.mpat.go.jp

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Questions?

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