



Introducing Key Indicators for Structural Integrity Risk Analysis of Port and Maritime Assets

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Structural Integrity of Port and Maritime Assets

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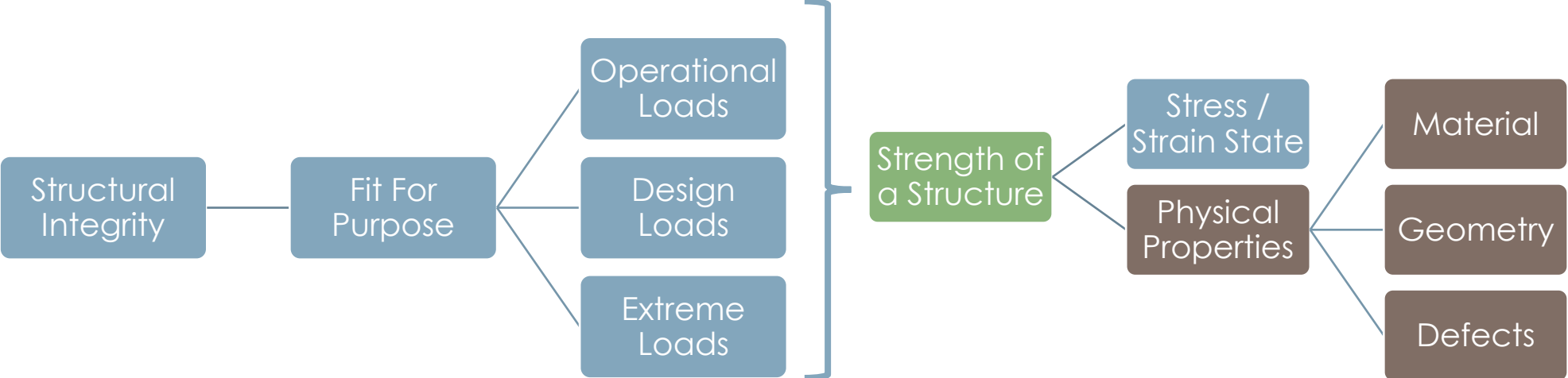
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Key Takeaways

Structural Integrity of Port and Maritime Assets

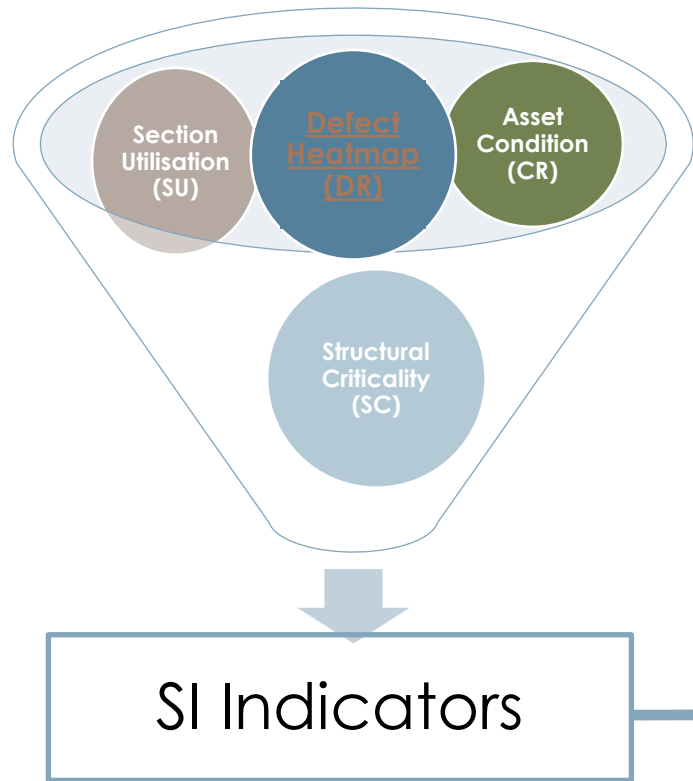
Condition Assessment



Life Service



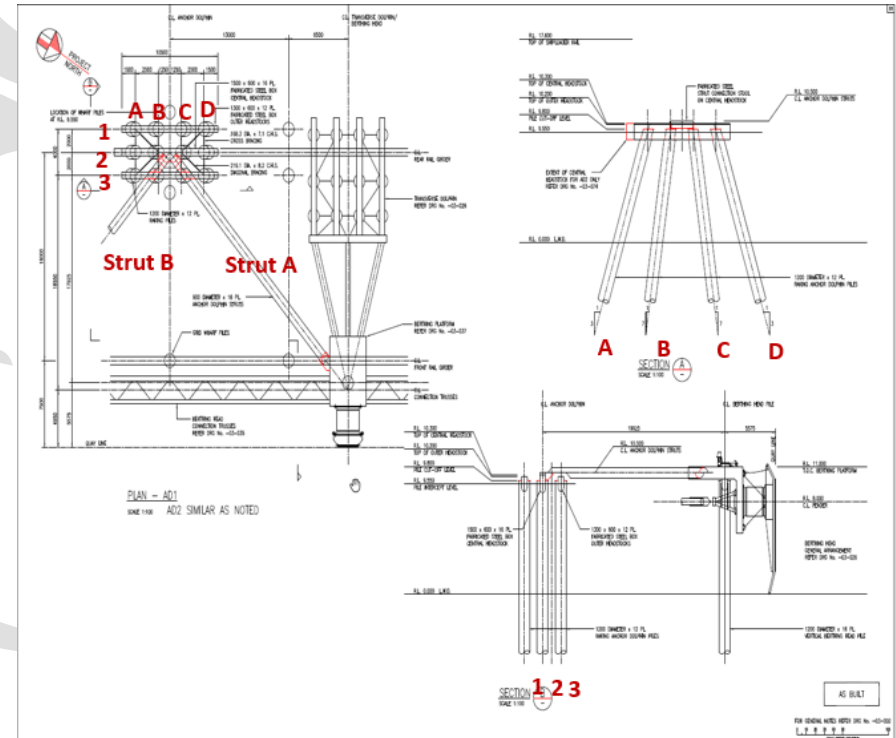
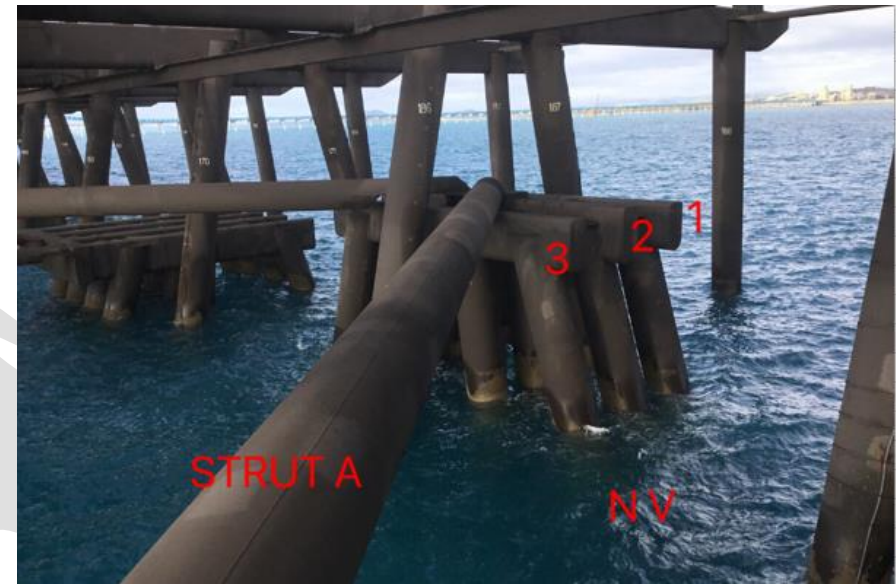
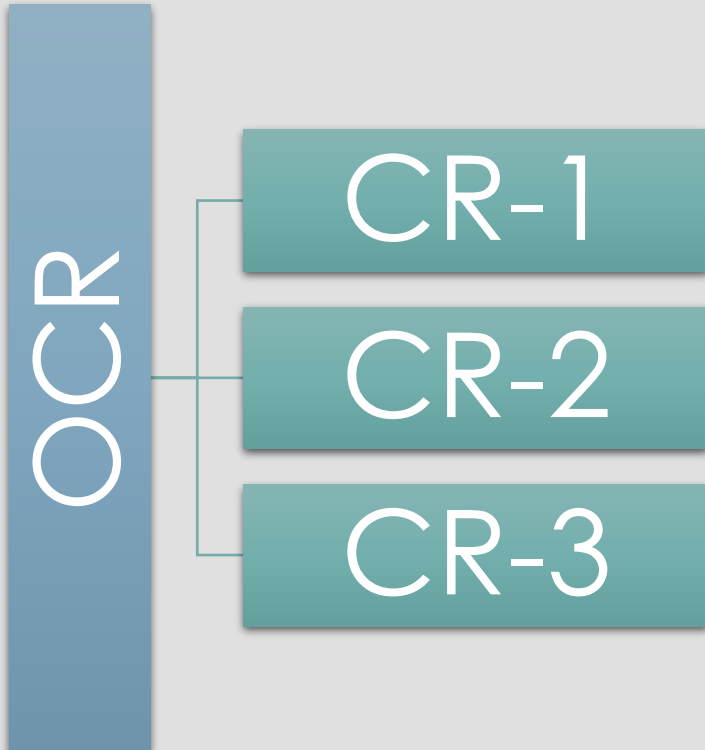
Structural Integrity Risk Analysis (SIRA)- Framework



$$f(CR, OCR, CU, DH, SC, RM)$$

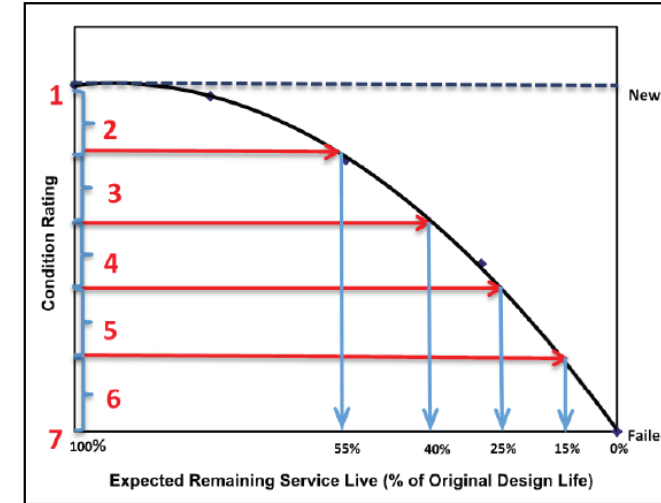
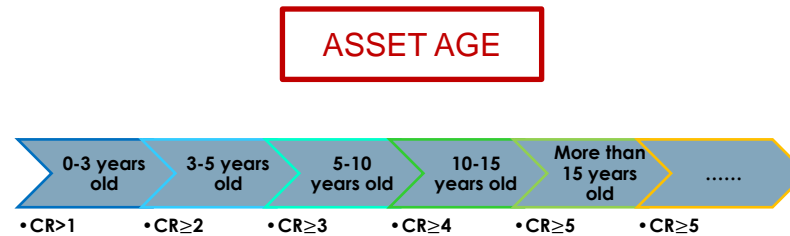
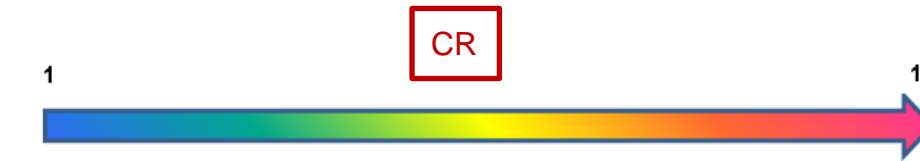


Key Structural Indicators – CR



Key Structural Indicators (ECR)

New Condition rate	Criteria	Description
1	New	<ul style="list-style-type: none"> New (less than 3 years in service) without any wear Without any changes/modifications/defects
2	Excellent Condition	<ul style="list-style-type: none"> As design (less than 5 years in service) Without any structural repair Coating effectively intact No defects
3	Very Good Condition	<ul style="list-style-type: none"> Less than 10 years in service Repaired/painted/fixd as new/design Coating effectively intact No defects
4	Good Condition	<ul style="list-style-type: none"> Less than 15 years in service Repaired/fixd/painted properly No defects
5	Acceptable Condition	<ul style="list-style-type: none"> More than 15 years in service Repaired/painted properly Minor defects without affecting structural performance and integrity in a long period (more than 24 months)
6	Fair Condition	<ul style="list-style-type: none"> Defects likely to affect structural performance and integrity in a period from 24 to 48 months
7	Bad Condition	<ul style="list-style-type: none"> Defects likely to affect structural performance and integrity in a period from 12 to 24 months
8	Very Bad Condition	<ul style="list-style-type: none"> Major defects affecting structural performance and integrity in a short period (6-12 months)
9	Near Replacement	<ul style="list-style-type: none"> Major defects affecting structural performance and integrity Section/structure shall be reinstated/replaced within 6 months timeframe
10	Due for Replacement	<ul style="list-style-type: none"> Unsafe for operational performance Significant reduction in structural integrity Section/structure can potentially damage other structural elements



Key Structural Indicators (OCR)

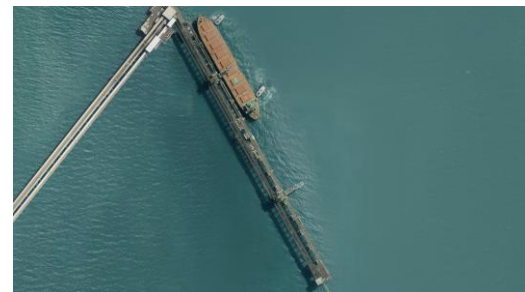
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Table 6 Element Weighting Factor (EW)

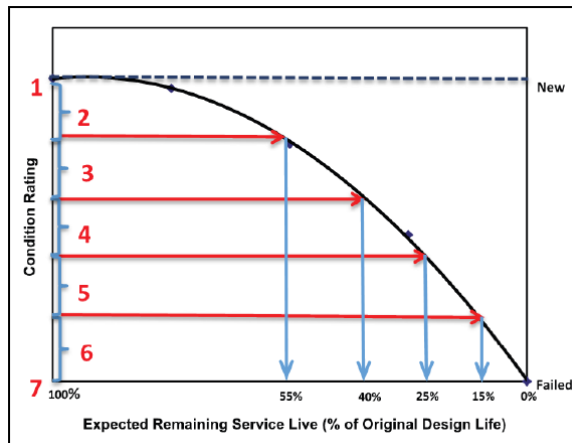
EW	Description	Example
1	Minor elements Very simple access for inspection/repair	Secondary horizontal diagonal braces Gratings Stairs
		Guards
2	Subjected to axial stresses Simple access for inspection/repair	Truss members Horizontal braces with simple connections
3	Subjected to bending stresses Having a potential for buckling Fair access for inspection/repair Subjected to water/chemical products/coal spillage	Horizontal wharf members Horizontal frame members
4	Important elements Hard to access for inspection/repair Subjected to combined axial and bending stresses Subject to high stress concentration Placed in spray zone /wave run-up/ wave slamming/wave over topping areas	Mooring and berthing dolphins Bollards Fenders Main cyclonic horizontal and diagonal members
5	Major frame structures/elements Fatigue based elements/joints Require special arrangements (isolation, rope arrangements, crane) for access/inspection/repair Subject to combined axial and bending stresses Complex structures Placed in tidal zone/splash zone	Offshore pile Headstock Wharf bridge substructure Prestressed concrete decks/slabs



No.	Substructure Name	Description	WF	OCR	5.01
1	Wharf Superstructure	Precast concrete deck units, spans from N6-N28	3	4.64	
2	Wharf Substructure - Strong Point	BH10, BH11, BH12, Strongpoint top anchor braces	5	5.36	
3	Wharf Substructure - Wharf Berths	Wharf Berth W20-W52	5	4.93	
4	Wharf Substructure - Berthing Dolphins	BH13-BH20	4	5.53	
5	Wharf Substructure - Mooring Dolphins	MD21, MD21	4	4.15	
6	Wharf Substructure - Anchor Dolphins	AD1, AD2	4	5.40	
7	Wharf Substructure - Berth 2 Access	BH9 to BH20, MD21-MD22, Stairs	2	4.77	
8	Wharf Substructure - Piles (Below Water)	Report7	3	5.00	
Total WF			30		

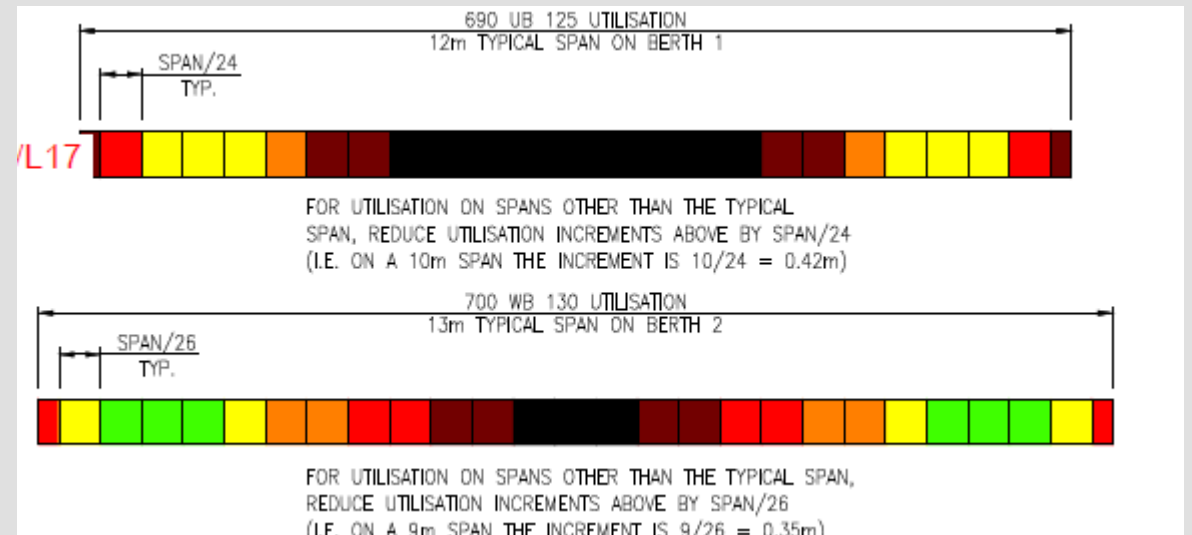
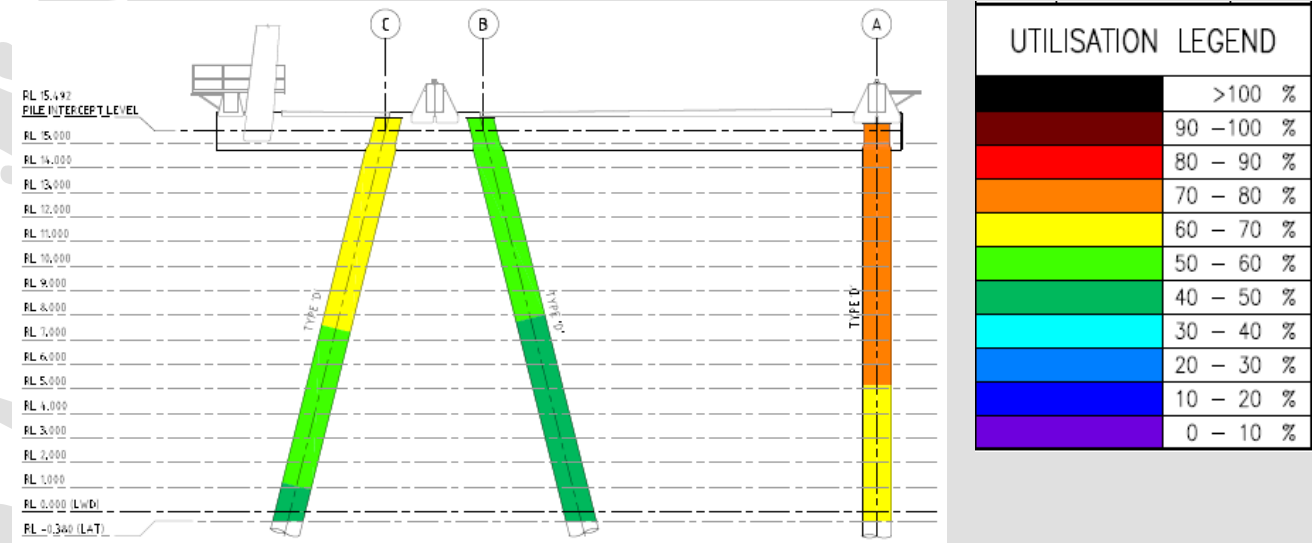


$$OCR = \frac{\sum_{k=1}^p ECR_k \cdot EW_k}{\sum_{k=1}^p EW_k}$$



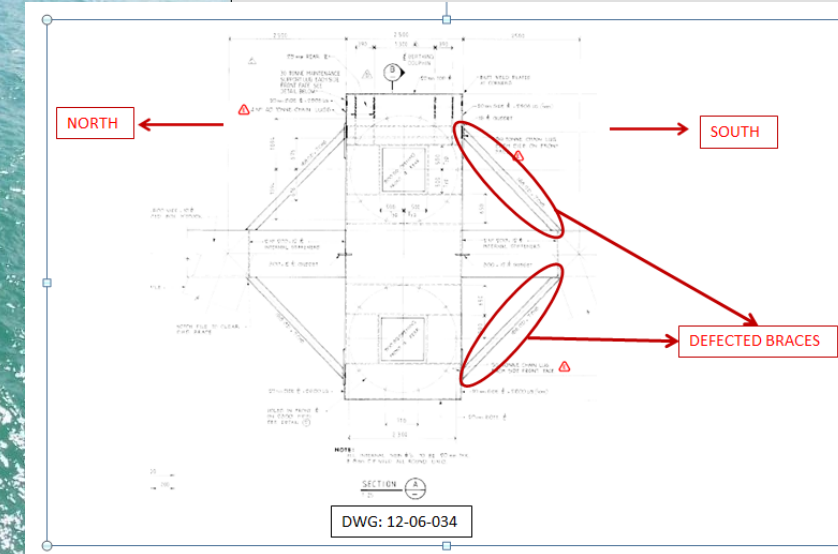
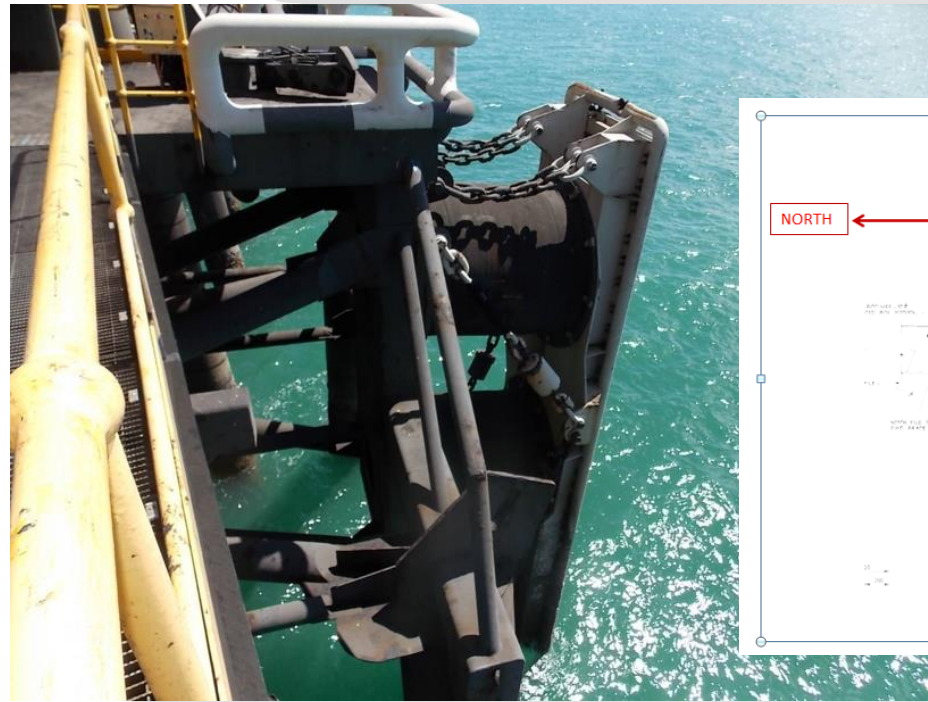
Key Structural Indicators (SU)

- Envelope of utilised capacity of a section
- Can be developed from the design and as-built documents
- Normally illustrates as color code map
- Primary / critical structural components

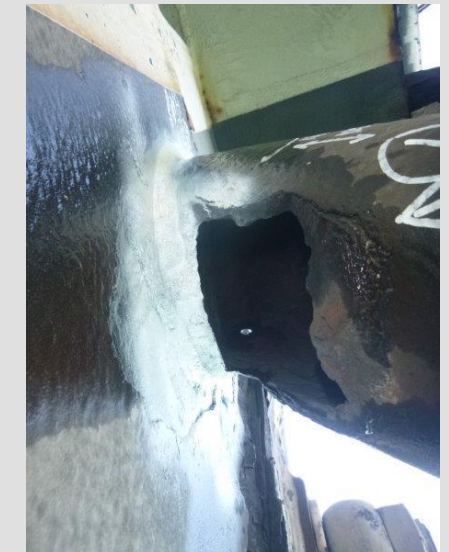
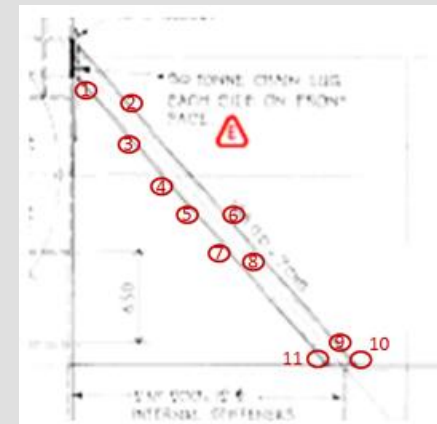


Key Structural Indicators (DH)

- Location of defects
- Type of defects
- Severity of defects



RL (mm)	Distance clockwise from North datum									
	698.1	663.2	628.3	593.4	558.5	523.6	488.7	453.8	418.9	384.0
4419								14.2		
4384					14.0	14.2		14.2		
4349				13.9	14.3	14.3	14.1	14.0		
4314				14.3	13.9	14.1	14.4	14.0		
4279			14.7	13.9	13.9	14.0	13.9	13.5	14.2	
4244			14.6	13.5	13.5	13.6	13.8	12.0	14.2	
4209	14.3	14.2	14.0	12.8	12.6	12.6	13.2	12.8	14.0	14.6
4174	14.4	14.0	13.2	11.6	10.7	10.7	10.9	13.1	13.4	14.2
4140	14.4	14.1	12.7	10.7	10.8	10.9	12.3	12.5	13.3	14.0
4105	14.7	13.9	13.1	12.3	12.5	12.6	12.7	12.4	13.7	14.2
4070	14.5	14.0	13.4	12.1	12.3	12.3	12.1	13.2	12.9	13.9
4035	14.4	13.9	13.5	12.6	12.9	12.9	12.3	13.3	12.7	13.6
4000	14.6	14.1	13.3	13.2	13.1	13.3	13.1	13.5	13.4	13.7
3965	14.8	14.0	13.9	13.3	13.0	13.5	13.3	13.3	14.5	
3930		13.9	13.7	13.6	13.1	13.3	13.3	13.5	14.9	
3895		14.2	13.7	13.7	12.9	13.6	13.5	13.7		
3860		14.4	13.8	14.1	13.3	14.0	14.0	14.2		
3826		15.0	13.8	13.9	13.5	14.0	14.2	14.5		
3791			14.1	14.0	13.9			14.5		
3756			14.4	14.2	13.8					
3721					13.7					
3686					13.9					
3651					13.9					
3616					14.5					



Key Structural Indicators (SC)

Criticality Level	Description
5	<ul style="list-style-type: none">• Section is extremely utilised (over 90%)• Section is subject to permanent fatigue loads, or its fatigue life is due shortly• Section has been repaired several times• Section has a crack history
4	<ul style="list-style-type: none">• Section is highly utilised (between 75% and 90%)• Section is subject to frequent dynamic and fatigue loads, or its fatigue life passed more than 50%• Section is subject to high tensile stresses (over 50% utilised)• Section accessibility is limited (complex joints at height, immersed sections)
3	<ul style="list-style-type: none">• Section is relatively utilised (between 50% and 75%)• Section is subject to relatively high tensile stresses (over 25 MPa)
2	<ul style="list-style-type: none">• Section has low utilisation (between 25% and 50%)• Section is not subject to complex stresses
1	<ul style="list-style-type: none">• Section has a very low utilisation (less than 25%)• Section is not critical• Defects don't impact structural integrity, or the impacts are negligible

Risk Matrix (RM)

- Consequence Assessment
- Likelihood Assessment
- Development of Risk Matrix

LEVEL	TERM	CONSEQUENCE					
		HEALTH / SAFETY	ENVIRONMENT	LEGAL / CONTRACT	COMMUNITY	OPERATIONS	COMMERCIAL
E	Catastrophic	Multiple Fatalities caused by a work-related incident/illness	Serious Environmental Harm - wide scale irreversible damage - destruction of ecosystems	Loss of Operating & Maintenance Contract (OMC)	Community concern at the National level involving hundreds of complainants, National adverse media attention and ongoing long term (>1 year) scrutiny by Regulator or NGO's	Loss > 4 000 000 tonnes	Corporate - Loss of cash flow or an event that results in insolvency Equipment / property damage - Greater than \$5m
D	Major	Single Fatality caused by a work-related incident/illness	Significant environmental harm - long lasting impact on ecosystem function or displacement of species	Serious breach of Operating & Maintenance Contract (OMC)	Community concern at the State level involving many complainants, serious adverse State media attention or longer term (6 months - 1 year) scrutiny by Regulator or NGO's	Loss > 1 000 000 & < 4 000 000 tonnes	Corporate - An unbudgeted event which will cause a variance greater than 5% of the total approved operating budget but does not result in insolvency Equipment / property damage - Loss from \$1m to \$5m
C	Moderate	Permanent Disability / Serious Bodily Injury / Long Term Chronic Work Illness may result in permanent impairment	Material Environmental Harm (not trivial or negligible in nature - wide scale environmental nuisance or impact but not affecting ecosystem function)	Moderate departure from Operating & Maintenance Contract (OMC)	Heightened regional community concern involving several complainants, moderate adverse media attention or medium term (3-6 months) scrutiny by Regulator or NGO's	Loss > 50 000 & < 1 000 000 tonnes	Corporate - An unbudgeted event which will cause a variance greater than 1% but less than 5% of the total approved operating budget Equipment / property damage - Loss from \$300k to \$1m
B	Minor	Lost Time Injury / Reversible Disability / Restricted Work Injury / Short term work caused illness may involve hospitalisation	Minor effects on environment - short term effects before environment restored	Departure from an Operating & Maintenance Contract (OMC) condition	Community concern involving adverse local public opinion, adverse media attention, or short term (1-3 months) scrutiny by Regulator or NGO's	Loss > 100 000 & < 500 000 tonnes	Corporate - An unbudgeted event which will cause 1% or less variance to the total approved operating budget Equipment / property damage - Loss from \$100k to \$300k
A	Insignificant	First Aid Injury / Medical Treatment Injury / Symptomatic illness only may require intervention by a medical practitioner	Environmental nuisance having an immediate adverse long-lasting low level effect on local amenity (noise, dust, smoke, odour, waste)	Insignificant difference in actions and OMC requirements (failing to adopt 'shoold')	Community concern restricted to a local complainant or involves immediate (1 month) scrutiny by a Regulator	Loss < 100 000 tonnes	Corporate - An unbudgeted event or expense that can be absorbed within the current budget Equipment / property damage - Loss up to \$100k

FIVE BY FIVE RISK MATRIX

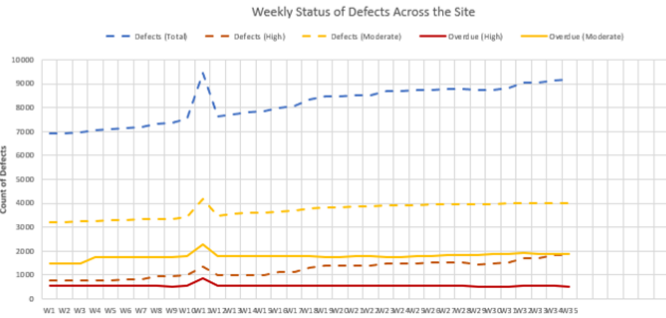
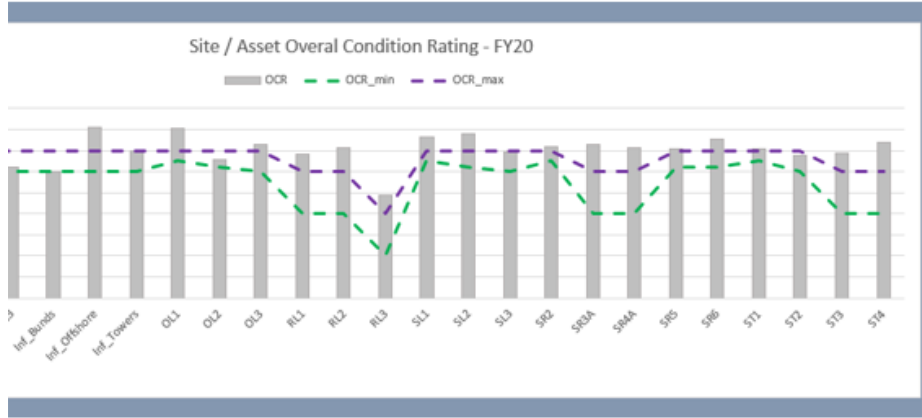
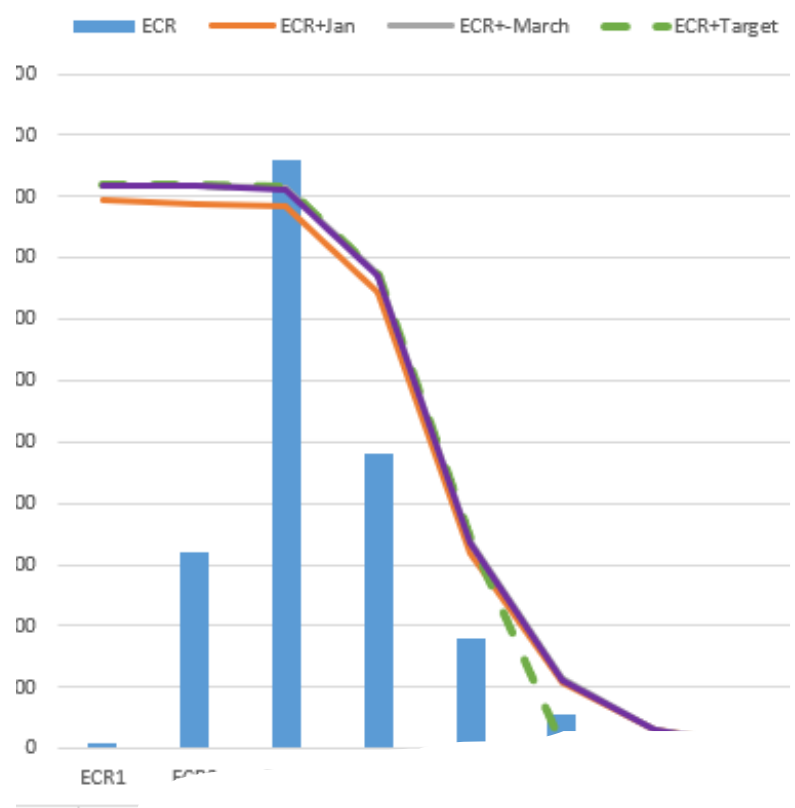
		Consequence				
		Insignificant	Minor	Moderate	Major	Catastrophic
Likelihood	Almost Certain	A	B	C	D	E
	5	11	16	20	23	25
	Likely	7	12	17	21	24
	4	4	8	13	18	22
	Possible	3	5	9	14	19
	2	2	3	6	10	15
Unlikely	1	1	2	3	4	
Rare	1	1	2	3	4	

Extreme	Unacceptable Level of Risk
High	As Low As Reasonably Practicable
Moderate	
Low	Acceptable Level of Risk

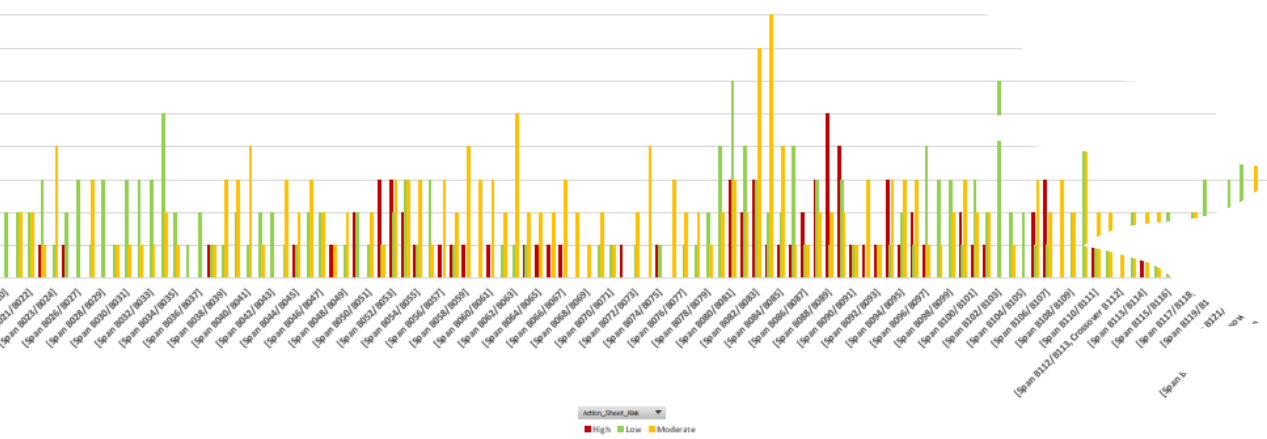
Potential Risk	Likelihood / Probability	Frequency / Exposure
Almost Certain	5 Happens often	Once a week or more
Likely	4 Could easily happen	Once a month or so
Possible	3 Has happened or could happen	Once or twice a year
Unlikely	2 Hasn't happened yet / not likely	Once or twice in 10 years
Rare	1 Practically impossible	Once or twice in a 100 years

Time	Week	Defects (Total)	Defects (High)	Defects (Moderate)	Overdue (High)	Overdue (Moderate)
3/01/2022	W1	6916	758	3224	543	1467
10/01/2022	W2	6916	758	3224	543	1467
17/01/2022	W3	6986	776	3247	546	1466
24/01/2022	W4	7075	793	3270	552	1753
31/01/2022	W5	7104	796	3297	552	1746
7/02/2022	W6	7148	806	3310	554	1736
14/02/2022	W7	7174	807	3320	557	1735
21/02/2022	W8	7343	945	3335	546	1728
28/02/2022	W9	7379	953	3344	527	1764
6/03/2022	W10	7527	974	3415	533	1780
14/03/2022	W11	9428	1344	4166	866	2260
21/03/2022	W12	7626	975	3489	534	1780
28/03/2022	W13	7718	982	3553	533	1775
4/04/2022	W14	7790	986	3593	540	1787
11/04/2022	W15	7843	987	3627	542	1787
18/04/2022	W16	7998	1126	3652	543	1789
25/04/2022	W17	8062	1147	3692	543	1789
2/05/2022	W18	8325	1304	3776	551	1784
9/05/2022	W19	8487	1393	3832	549	1763
16/05/2022	W20	8491	1393	3835	553	1763
23/05/2022	W21	8520	1390	3856	556	1772
30/05/2022	W22	8527	1397	3856	558	1772
6/06/2022	W23	8695	1468	3932	552	1749
13/06/2022	W24	8689	1468	3931	553	1750
20/06/2022	W25	8717	1498	3927	542	1810
27/06/2022	W26	8751	1516	3939	539	1803
4/07/2022	W27	8762	1513	3960	546	1836
11/07/2022	W28	8776	1514	3970	555	1835
18/07/2022	W29	8719	1453	3973	505	1832
25/07/2022	W30	8744	1469	3977	510	1877
1/08/2022	W31	8822	1539	3984	523	1882
8/08/2022	W32	9039	1705	4002	535	1906
15/08/2022	W33	9068	1717	4009	546	1902
22/08/2022	W34	9135	1815	3986	534	1880
29/08/2022	W35	9161	1817	3996	529	1880

Structural Condition Rating of DBCT Plan



L05 Conveyor Jetty - Distribution of Actions

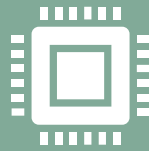


Outcome - Typical

Key Takeaways



Risk Analysis of structural part of assets is a complex and challenging task



Key Structural Indicators such as CR, OCR, SU, DH and SC can facilitate this process to a better SIRA system



This can lead to a better asset management

Thank You

