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

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Summary
There is no unique method to conduct the Structural Integrity Risk Analysis (SIRA) for port and maritime assets to ensure they are in fair condition and fit-for-purpose. Given that the chance that a structural risk assessment of an asset become inaccurate is likely high, particularly when the structure of an asset is complex, aged, subject to high imposed loads, and located in harsh environment. This paper tries to fill this gap by introducing some key indicators which can enhance the accuracy of SIRA and provide a better understanding for main decision makers to keep their assets in fair conditions and prevent any unwanted business interruption.

Keywords: asset condition, risk assessment, preventive maintenance, asset management

Structural Integrity Risk Analysis (SIRA)

Structural Integrity Risk Analysis (SIRA) is a crucial tool for any port and maritime asset owners to ensure the current condition of their port assets, particularly waterborne infrastructure, are safe and sound and there are no risks to personnel, business, and environment. Nevertheless, there is no unique way to conduct this kind of structural risk analysis and therefore, asset owners and port authorities are utilising different methods based on their best practice to come up with suitable structural risk figures for their assets.

Despite best efforts, there is a chance to miscalculate the actual risk and, in most cases, underestimate the current structural risk. This is particularly the case for assets that are complex and aged. To overcome this issue and reduce the likelihood of underestimating the actual structural risk, reliable indicators are introduced. These indicators can be integrated into current risk analysing method either to enhance and upgrade the analysing technique or to verify and cross-check the outcomes. This ensures the final structural risks analysis is closer to reality.

In general, a SIRA is the outcome of analysing several structural inputs/indicators as shown schematically in Figure 1. However, the method of analysing the structure plays a vital role in the outcome, with the most important aspect being the type of structural indicators being used as inputs. In this presentation we propose that by defining proper structural integrity indicators, the outcome of the SIRA would be more accurate.

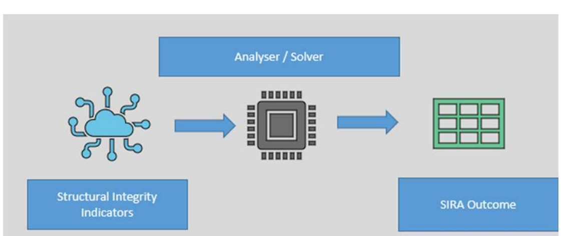

Figure 1: Schematic view of SIRA process

Key Structural Indicators

These key indicators should contain as much information as required to understand the current structural condition of an asset such as condition rating, section utilisation, defect heatmap, and structural criticality.

Condition Rating

Condition Rating (CR) and Overall Condition Rating (OCR) are indicators replicating the current condition of a structural component or a group of structural components that contribute together to provide the required strength of an asset as per design and expected functional performance of an asset. The CR / OCR scale, which is the range of 1 to 10, in accordance with individual port asset management strategy. This score is mainly based on either the expected service life [1] or the current structural integrity assessment [2] of a component / group of components – for more details refer to above references.

Section Utilisation

Section Utilisation (SU), in general, is an indicator which replicates an envelope of utilised capacity of a section in a percentage scale based on the worst imposed load case scenario. This normally illustrates as a colour code map on structural section such as the one shown below for better visualisation.

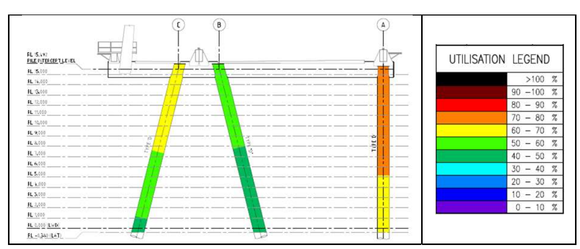

Figure 2: An example of section utilisation of a pile and deck structure above the minimum sea water level.

Defect Heatmap

Defect Heatmap (DH) is another useful indicator that maps the location and severity of the defects on a component or a group of components. Several techniques can be implemented to visualise the defect heatmap such the one shown in Figure 3 which depicts the remaining section thickness of a marine pile.

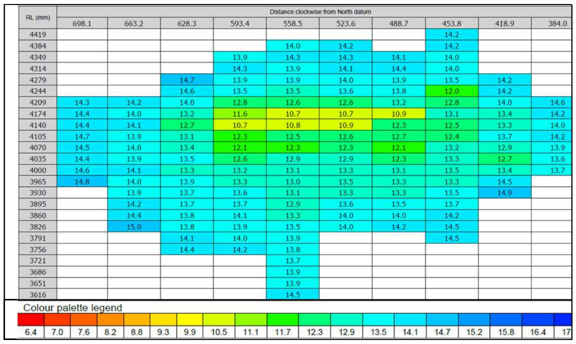

Figure 3: An heatmap example of section thickness around a marine pile

Structural Criticality

Structural Criticality (SC) is the other useful indicator which describes the contribution and performance of a component / group of components to the structural integrity of an asset. Fatigue life, stress concentration factor, tensile stresses due to high deadloads, and accessibility of a section are some of key structural integrity contributors to the structural criticality level. This level can be scaled from 1 to 5 and customised for different ports as the one shown in the Table 1.

Table 1 Structural criticality level

Criticality Level	**Description**
5	• 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	• 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	• Section is relatively utilised (between 50% and 75%) • Section is subject to relatively high tensile stresses (over 25 MPa)
2	• Section has low utilisation (between 25% and 50%) • Section is not subject to complex stresses
1	• 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

Risk Matrix (RM) is a business risk level system which is the results of integrating the probability and consequence of various incident scenarios. This is usually a five-by-five matrix as shown in Figure 4, however, it can be customised or displayed in other forms or arrangements to fulfill site requirements and business strategies.

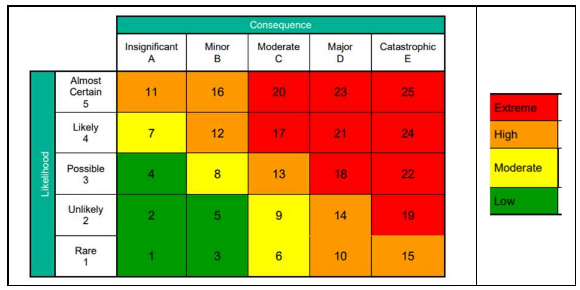

Figure 4 A typical five-by-five risk matrix

Analyser / Solver

SIRA is a function of structural integrity indicators – i.e., CR, OCR, CU, DH, SC, RM – as written in Equation 1. Analyser / Solver (SOL) can be a simple judgment system consisting of a group of experts that would be able to integrate the structural integrity indicators into a risk-based action list or it might utilise a comprehensive computer program / artificial intelligent system to process the indicators and develop a more detailed risk-based action list at the end. The former is more suitable for small ports and maritime terminals while the latter is more beneficial for large and complex maritime asset infrastructure system.

$$SIRA = f(CR, OCR, CU, DH, SC, RM) \qquad (1)$$

Concluding Remarks

SIRA can help asset managers and port authorities to assess the asset conditions directly into a risk-based system. Regardless of the type of the solver being used to get to SIRA, the quality of defined indicators plays a more crucial role in determining relevant risk actions and risk management accordingly.

References

[1] Ports Australia, "Wharf Structures Condition Assessment Manual," Ports Australia, Sydney, 2014.

[2] S. Mazaher and G. Turner, "Developing a New Asset Ranking Systeme and Condition Rating Scale for Prioritising and Managing Repairs of Aged Maritime Structures," in *Australasian Coasts and Ports* , Hobart, 2019.