

Enhanced tunnel monitoring at major iron ore mine in Western Australia

Country

Australia

Industry

Mining

Application Areas

Geotechnical
Environmental

Context

Many tunnel assets in Australian mine sites are operating beyond their original design life. Factors such as changes in loading conditions, varying degrees of deterioration, and evolving design standards add complexity to managing the integrity of these assets. Traditional theoretical assessments often lead to conservative load ratings, which can create discrepancies between a tunnel's predicted load-bearing capacity and its actual performance in service.

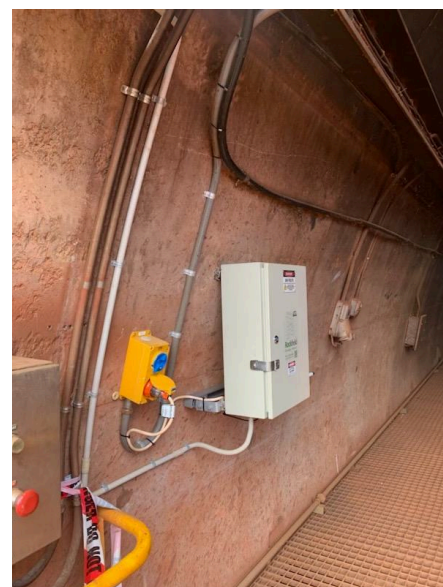
This case study presents the integration of tunnel monitoring data with finite element analysis to re-rate the structural capacity of an operational tunnel at a Pilbara mine site and support ongoing management. The concrete arch tunnel, constructed in the late 1970s, supported a 30m high stockpile above an internal rail corridor. When assessed solely using modern design standards without further complex analysis, the tunnel appeared overutilised, leading to the implementation of stockpile height restriction.



Solution

To refine the assessment, a higher tier structural analysis utilising a non-linear finite element analysis and real-time instrumentation were introduced. Wireless monitoring arrays installed at key cross-sections provided convergence data under stockpile loading. This data, combined with operational insights, allowed the team to challenge conservative assumptions about tunnel capacity, allowing for a more accurate re-rating.

The solution implemented by [Rockfield Technologies Australia](#) used a number of [Worldsensing 5-channel Vibrating wire nodes](#) with arc-weldable VW strain gauges monitoring hoop strains in the tunnel. A [gateway](#) at the tunnel entrance is sending data back to Rockfield's [Mercuto](#) platform for analysis, visualisations and alerts via a secure 4G router using the gateway's ethernet output option to meet stringent client IT security requirements.



“This case highlights the value of advanced monitoring and higher-tier assessments in managing ageing tunnel assets, bridging plausibility gaps, and enabling data-driven decision-making.”

Phil Cutter

Senior Market Lead, Principal Engineer
Rockfield Technologies Australia

The continuous monitoring system offers real-time feedback on tunnel response to varying loads and now serves as an operational tool. As a result, monitoring data supported the relaxation of the stockpile height limit, optimising productivity without compromising safety.

Because strain is a direct and reliable indicator of structural response, the effect of different stacking patterns can be assessed empirically without the need to re-analyse each case through time-consuming simulations. This approach also removes the need to explicitly model complex soil-structure interaction phenomena, such as soil arching, or account for stress-dependent backfill behaviour in the structural model.

Benefits

The strain gauge system has enabled the development of a real-time performance envelope that supports responsive stockpile management. For example, in the event of backfill saturation due to extreme weather or infrastructure leakage, the effective stiffness of the supporting ground may decrease, leading to higher strains in the tunnel structure. With continuous monitoring, excessive strain readings can serve as an early warning, prompting temporary restrictions on stockpile height while the source of the issue is investigated and addressed. This ensures that the tunnel remains within its elastic performance range and avoids the onset of damage or irreversible deformation.

The ability to monitor strain trends during both loading and unloading cycles also provides insight into the reversibility and resilience of the tunnel under varying operational conditions. No significant residual strain accumulation was observed over multiple stacking cycles, supporting the conclusion that the tunnel remains in an elastic response regime under current loading practices.

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Advantages

The tunnel was initially assessed as overutilised using linear-elastic based finite element models with simplified soil-structure interaction, resulting in stockpile height restrictions to manage structural risk. However, these models did not fully capture actual tunnel behaviour under operational conditions. Through the integration of advanced nonlinear finite element analysis validated with strain gauge instrumentation, it was demonstrated that the tunnel performed within acceptable limits, even under increased loads. This evidence supported the safe relaxation of stockpile restrictions.

This shift from assumption-based to performance-based management led to key outcomes:

- Justification for higher stockpile zones
- Reduced need for multiple model scenarios
- Early warning of structural or ground condition changes
- Improved coordination between engineering and operations

The study highlights how legacy infrastructure can be safely re-rated using real-time data and advanced modelling. It provides a scalable framework for similar buried assets, demonstrating the growing importance of instrumentation-informed strategies in modern asset management.

