M4-M5 Link Tunnels

By David Oliveira

Fig. 1 Shallow ramp tunnel before water-proofing treatments

The M4-M5 Link Tunnels in Sydney, Australia, is approximately 7.5 km (4.7 mi) long and accommodates up to four lanes of traffic in each direction. It connects the New M4 Tunnels with the M8 Tunnels to form the 33 km (20 mi) long Westconnex Motorway, mostly underground.

The project decided to use a high-performance shotcrete specification in the structural design of the tunnels' 100-year design life permanent support. This decision targeted reducing shotcrete quantities, thus providing cost savings and achieving better sustainability.

Previous attempts in preceding projects failed to achieve this high specification during production consistently, which resulted in many non-conformance reports and design checks. As a result, at the start of the project, a decision was made to

Fig. 2 Spray of field-scale test panels loaded with hydraulic pressure bags installed behind geotextile fleece that promoted debonding.

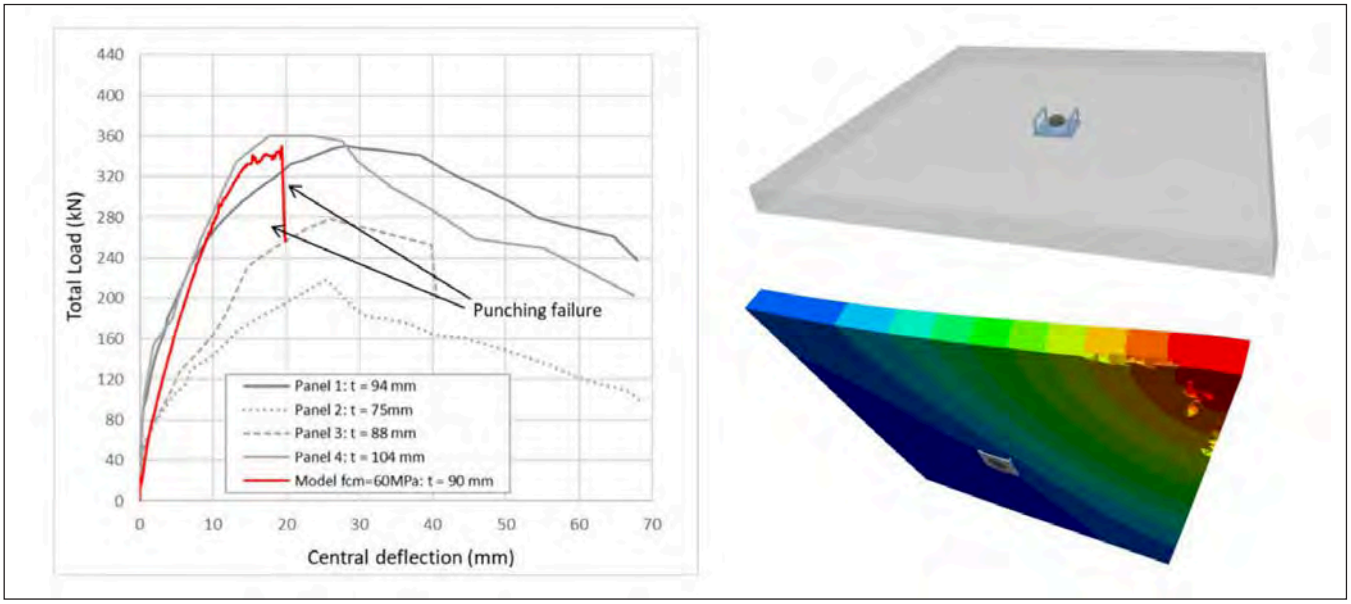

Fig. 3: Results of field-scale tests with examples numerical models used in design predictions.

adopt high-performance end-hooked steel fibres to overcome the challenges previously experienced. Although relatively common in TBM segment design, such high-performance fibres had not been previously used in sprayed concrete in Australia. The M4-M5 Link Tunnels was thus the first project to utilize these fibres in Australia.

The final mix design achieved the targeted structural performance with a strength of 40 MPa (5800 psi) and characteristic values of residual flexural strength of fr1 > 3.5 MPa (510 psi) and fr4 > 3MPa (435 psi). This performance was achieved using only 35 kg/m^3 (59 lb/yd^3)of fibres, which also promoted a saving of 10 kg/m^3 (17 lb/yd^3) from previous experience and compensated for the higher cost of the high-performance fibres.

Besides regular production testing of the shotcrete, including beam testing for residual flexural strength and ASTM C1550 round panel testings for toughness, the project conducted several field-scale tests to confirm the structural performance of its rock bolted-shotcrete lining. These field-scale tests provided greater confidence in the load-bearing capacity of the permanent tunnel linings since up to 6 times greater capacity was estimated compared to previous designs.

After more than 250,000 m^3 (330,000 yd^3) of steel-fibre reinforced shotcrete sprayed in the project, the project confirmed a successful and consistently conforming application of this higher performance shotcrete with an overall quantity reduction in shotcrete of up to 20%.

Dr David Oliveira *is a Technical Director for Jacobs Engineering Group with a focus on Tunnels and Rock Engineering projects. He has 24 years of experience in the design and construction of major infrastructure and mining projects in several different countries. David is a Fellow Member of Engineers Australia, an Adjunct Fellow Researcher with the University of Wollongong and a causal lecturer at a few universities such as the University of Sydney and Monash University.*

2021 OUTSTANDING INTERNATIONAL PROJECT

Project Name
M4-M5 Link Tunnels

Location
Sydney, Australia

Shotcrete Contractor
Acciona Bouygues Samsung Joint Venture

Architect/Engineer
Jacobs Aurecon Joint Venture

Material Supplier
Bekaert

Equipment Manufacturer
Normet Asia Pacific Ltd

General Contractor
Acciona Bouygues Samsung Joint Venture

Project Owner
Jacobs Engineering Group