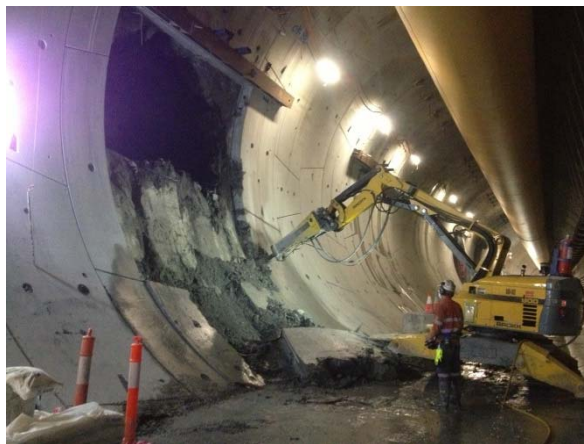


Legacy Way – Brokk machines as the perfect choice for cross passages

What is the best choice for excavation of tunnel cross-passages in hard geological conditions? What alternatives and supplements to drilling and blasting are available, considering the sensitive urban location of works? Can you excavate cross-passages without interfering with the TBM operations and other tunnel activities?

These were all questions that Transcity faced in 2012 when planning the work for the 4.6 km Legacy Way tunnel project in Brisbane. And they found that the answer to several of these questions was Brokk machines.

But let us back up and start from the beginning. In 2011, Transcity, a joint-venture between Ghella, Acciona and BMD Constructions won the bid for the Legacy Way project in Brisbane, Australia. The heart of the project and the most challenging part was the 4.6 km long twin-drive tunnel, aimed at bringing traffic underground and shorten travel times with a modern two-lane motorway.



The challenge

While the excavation of the two parallel tunnels was to be carried out in parallel by two TBM-machines, the method for the excavation of the 35 cross-passages measuring 4.5 x 5 x 10 meters was not clear. The traditional options all had significant downsides:

- Drill and blast generates impulsive vibrations which was particularly restrictive given the sensitive urban location of works. A full scale drill and blast operation also causes significant interruptions to the other work in the tunnels. And, considering the excavation profile was larger than the segment opening available, machines would inevitably be required to finish the excavation after blasting.

- Road headers are large in size and would block logistical access past the cross passage at which it is working. Thus when working, this would prevent concurrent tunnel activities and slow TBM progress.
- Tunnel excavators with large size hydraulic hammer attachments could cause significant sustained vibrations through the geological conditions present. This in turn would cause regenerated noise through surface structures potentially affecting production hours available and create community problems for Transcity and client Brisbane City Council. In addition, traditional tunnel excavators would also block logistical access past the cross passage at which it is working.

With the geology in the tunnel, where rock hardness could surpass 100 MPa, drill and blast was still considered the best option of the traditional methods, but it was not a satisfying solution on its own.

Fortunately, members of the Transcity team had experience of another method used in earlier projects - Brokk machines.

The solution

Transcity realised Brokk machines potentially had significant advantages because of their size which satisfied a number of the key logistical and space proofing problems whilst using relatively powerful hammers.

Hence, the team decided to perform a test using a Brokk 400 with a 550kg hammer in similar geology as expected in the cross passages. This was to measure the sustained vibration caused by hammering in these conditions and thus the resulting regenerated noise through surface structures could be modelled. It also offered an opportunity to quantify the expected instantaneous breaking rate this Brokk and hammer combination could achieve. Transcity understood from early management strategy that the construction of the spoil conveyor tunnel to a nearby quarry offered the perfect opportunity to perform this test and enlighten realistic expectations for the TBM tunnel construction phase.

The result? The Brokk 400, with its high frequency hammer operation, was measured to have a low vibration output when compared to larger tunnel excavator and hammer combinations whilst still achieving a high instantaneous breaking rate of approximately 2.5 cubic metres / hour.

Thus, Transcity procured two Brokk 800 demolition machines with 1,000 kg hydraulic breakers and two Brokk 400 demolition machines with 550 kg breakers to carry out this extensive tunnelling project. The plan was to use these machines as the primary method of excavation in cross passages with more favourable geology, whilst offering the perfect supplement to drill and blast operations in harder geology.

"Transcity was fortunate enough to test rock hammering and controlled blast methodologies before work started on the Legacy Way tunnels, enabling the team to better understand ground conditions

and the machinery required to construct features like cross passages," said Transcity Project Director Fernando Fajardo¹.



Fantastic production rate...

Where excavation was carried out solely using Brokk machines, the procedure was to use the Brokk 800 for initial bulk volume excavation with the Brokk 400 to follow in order to trim the edges of the profile. Once the Brokk machines had completed an excavation advance to the permitted distance, spoil was completely removed and primary support was installed in the form of fibre reinforced shotcrete and rock bolts.

In cross passages where drill and blast operations were required; the Brokk machines were used to trim the blasted void to the required profile in extremely hard geological conditions. Given the complex geometry of the cross passages, this proved to be approximately 20% of the overall excavation volume that could not be removed through blasting.

"In certain cross passages, we were able to achieve 40% more productivity from the Brokk 400s than we concluded from the results of our trials", says Sean Ivers, Project Engineer of Ghella. "The maximum production outcome achieved was approximately 3.5 cubic meters an hour – over twice the capacity of an over two times heavier excavator. The Brokk machines' abilities were also challenged immensely in the trimming of blasted cross passages and they proved a very capable solution to the problem at hand. In various geological conditions, the Brokk machines achieved production rates like nothing else I have seen close to their size!"

...with increased safety...

The Transcity team also appreciated the other Brokk advantages; especially the possibility to operate in confined spaces combined with the operator safety features thanks to the remote control was another valued asset. "The advantage of using Brokks is their capacity to operate in confined spaces,

while still achieving the same performance as larger excavators, and their remote control safety features," said Construction Manager Matteo Ortu of Ghella¹.

...leading to project success

By using Brokk machines for the cross-passages and sub-stations, interruptions to the TBM progress could be kept to a minimum and Transcity completed the 4.6 km drive in only six months. "This is an outstanding performance and there are only a few projects worldwide that can show similar achievements" said Matteo Ortu¹.

By using TBM cutter head data, the Transcity team could plan the cross passage excavation work and add complementary drilling and blasting in areas where the rock hardness spiked. The cross passage and substation work with the Brokk machines started February 2013 and was finished in November that year. The complete Legacy Way project is scheduled for completion in the first half of 2015.

"We finished the cross passages on time and I would definitely recommend the Brokk machines to other similar projects. We like all the Brokk features; safety, production rate, weight, physical size, reach – a great machine that delivers everyday" said Sean Ivers.

In conclusion, Noel Power, Conventional Tunnelling Manager of Ghella sums up the experience; *"The Brokk machines remind me of Super Mario: They were the heroes of the day who tirelessly never let us down while tackling all obstacles in the way!"*

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¹ "Rapid excavation breaks through in Brisbane", 25 Apr 2013, Peter Kenyon, TunnelTalk
(<http://www.tunneltalk.com/Australia-25Apr13-Brisbane-Legacy-Way-traffic-tunnel-first-breakthrough.php>)