Tunnelling on Legacy Way Project.

M. Ortu
Ghella Pty, Brisbane, Australia.

G. Giacomin
Ghella S.p.A., Rome, Italy.

ABSTRACT: Legacy Way is Brisbane's tolled 4.6km road tunnel that will connect the Western Freeway at Toowong (western end) with the Inner City Bypass (ICB) at Kelvin Grove (eastern end). The Transcity JV, formed by Ghella, Acciona and local BMD, has been awarded with the AU$ 1.5 Billion contract to design and build as well as operate and maintain the tunnel for 10 years by the client Brisbane City Council in October 2010. Legacy Way Project included 2x4.250ml of parallel TBM Double Shield driven tunnel of diameter ϕ = 12,4m: in the paper we analyze geology, spoil transport via conveyor belt in conveyor tunnel; innovative two component grouting on a large diameter hard rock TBM double shield, cross-passages, backfill, smoke duct, innovative system for TBM startup, and innovative system for the TBM disassembly.

1 INTRODUCTION

Legacy Way is Brisbane's tolled 4.6km road tunnel that will connect the Western Freeway at Toowong (western end) with the Inner City Bypass (ICB) at Kelvin Grove (eastern end). The tunnel will reduce massively the travel time during peak hours and decrease the traffic on the busy Milton Road that previously picked up all traffic from and to the Western Freeway (Ortu and Huber, 2012, Ortu, 2013).

The Transcity JV, formed by Ghella, Acciona and local BMD, has been awarded with the AU$ 1.5 Billion contract to design and build as well as operate and maintain the tunnel for 10 years by the client Brisbane City Council in October 2010.

Construction commenced in April 2011 and opening and completion of the tunnel is expected to be in the first quarter of 2015.

The twin two-lane tunnel consists of 300 m of cut&cover sections at the portals and 4.3 km of mined tunnel and includes the following:

- 35 underground cross-passages, which will connect Legacy Way's two tunnels every 120m to provide safe access between the tunnels in the event of an incident;
- two underground substations, which consist of five additional cross-tunnels each;
- one additional cross-tunnel in the low point which includes the pump sump;
- longitudinal ventilation system to manage in-tunnel air quality;
- smoke duct with dampers every 60 m to manage the smoke in case of a tunnel fire;
- deluge system;
- fire protection and safety management systems;
- free-flow electronic tolling system.

1.1 *TBM Tunnelling*

The main tunnels have been excavated with two refurbished ∅ 12.4 m Double Shield TBMs delivered by Herrenknecht that have been baptized with the names "Annabell" and "Joyce" (see Figure 1).

The geology along the tunnel alignment with a cover between 20 and 40 m was predominately made of Bunya Phyllite, an intermediate grade metamorphic rock with variable foliation, UCS values between 30 and 60 MPa and an average quartz content > 40%.

Figure 1. Segmented lining.

The spoil has been managed with H+E conveyor belts rated for 1,400 ton/hr and 500 m of horizontal belt storage for each TBM which discharged onto a static conveyor belt system rated for 2,800 ton/hr that transported the excavated material from the portals through a 560m long tunnel that has been excavated by Transcity JV directly into Mt-Cootha Quarry that is owned and operated by Brisbane City Council. The tunnel spoil has been used to partially backfill the non-operative older areas of the quarry.

1.2 *Precast Lining*

Precast segments 2 m wide and 35 cm thick have been used to line the tunnels. The universal type ring with an 8+1 division has been designed with trapezoidal/rhomboidal shaped segments, waterproof gaskets, shear/tension connectors from FIP in the ring joint, spare bolts and guiding rods in the longitudinal joints. All segments were fiber reinforced with Maccaferri steel and PP fibers and additional rebar reinforcement along the longitudinal joints to cope with the splitting force (see Figure 2).

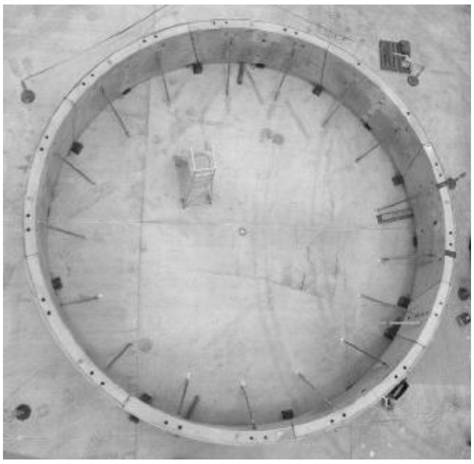

Figure 2. Segmented lining.

The tunnel segments have been produced by Transcity JV using a CBE carrousel plant. Segment transport inside the tunnels has been managed with a total of 4 hydraulic MSV transport vehicles that have been purchased from Herrenknecht.

1.3 *Grouting System*

For grouting the annulus gap Transcity has developed together with MAPEI a cement based two component grout that has been injected through the tail shield in the lower section of the tunnel during the regripping of the TBM and in the upper section through special cast in grout ports in the precast segments during excavation (see Figure 3).

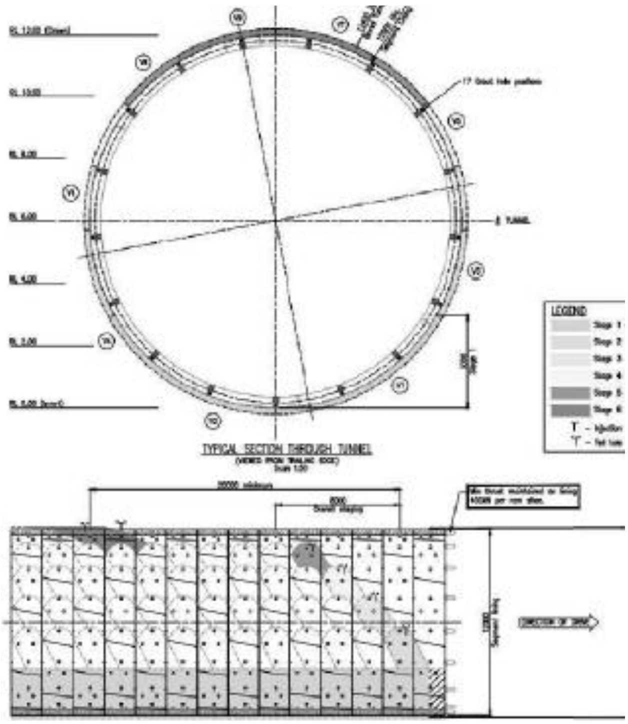

Figure 3. Grouting. Tailskin grouting 5m^3 in 10min during regrip. Segment grouting 10m^3 during excavation.

Ghella had successfully worked previously with two components grouts on EPB TBMs but this methodology has never been used before on hard rock TBMs, especially with Double Shield TBMs of this size. In this application it is important to achieve a quick set in order to avoid the grout flowing behind the shield and causing all kind of trouble with the TBM and at the same time to maintain sufficient viscosity until the complete filling of the void has been completed.

The result achieved demonstrates that it was worthwhile investing in the further development of this technology. The tunnel rings have maintained their shape, ring ovalisation and joint rotations have been well controlled. The volume of the injected grout has been monitored continuously and the TBM crews and management paid a lot of attention to completely fill the annular gap.

With this technology it has been managed to deliver a watertight segmental lined tunnel, what is not always easy to achieve in hard rock with open type TBMs and it would have been impossible with classical pea gravel backfill and contact grouting.

Another important advantage of two component grouts is the ability to pump the material over long distances from the portal to the TBM without the need to clean frequently the pipes when managed properly. This simplifies significantly the supply logistic of the TBM drive.

1.4 *Production Rate*

Transcity launched "Annabell" in August 2012, followed by "Joyce" in October 2012. The geological conditions allowed the TBMs to excavate with high penetration rates and the machines have been operated in double shield mode along the entire tunnel alignment. The well trained TBM crews have kept the cycle time under 50 min. A systematically scheduled maintenance of the TBMs and all production related plant and equipment helped to keep the plant availability high and together with a well-managed supply logistic impressive production rates have been achieved with 49.7 m on the best day, 858.1 m in the best month and a 772.7 m monthly average which are new world records for this size machines (see Figure 4).

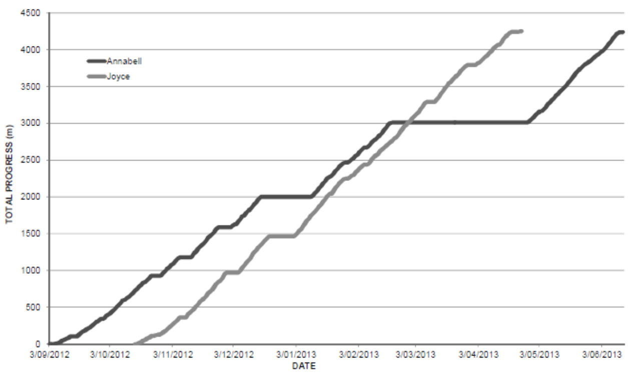

Figure 4. TBM1 and TBM2 production advances.

2 CROSS-PASSAGES

2.1 *Cross-passages excavation*

The excavation of 46 cross-tunnels over a 4.3 km long tunnel is a particular challenge, especially with such ambitious program requirements as on the Legacy Way project.

The majority of the cross-tunnels have been excavated after TBM breakthrough and in parallel with other tunnel activities occurring at the same time, as backfilling of the tunnel invert or construction of the smoke duct (see Figure 5).

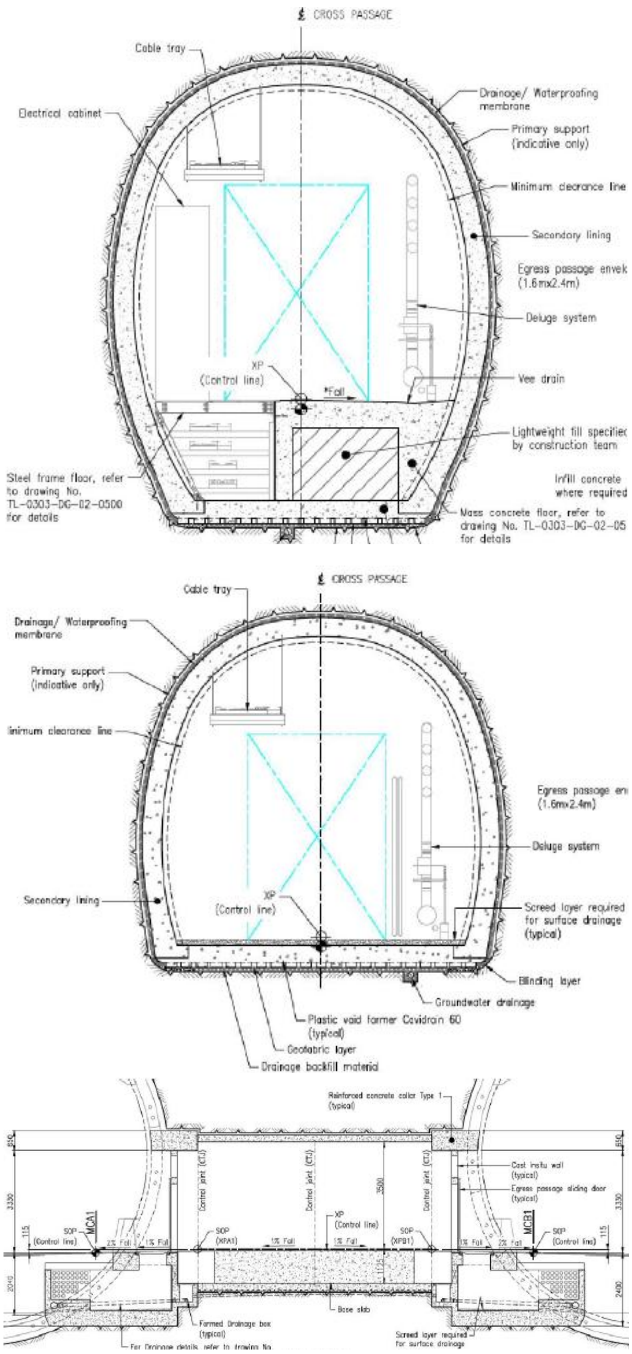

Figure 5. Cross-passages type numbers 1 and 2, cross-sections and longitudinal section.

The cross-passages in areas on the lower range of the rock strength have been excavated by use of hydraulic jack hammers for which Transcity procured Brokk 400 and Brokk 800 excavators.

Where the rock strength has been too high for efficient rock hammering, the cross-passages have been excavated with drill & blast. In order to keep the segment vibrations within the admissible limit of 500 mm/s single hole firing with the use of electronic detonators had to be applied (see Figure 6).

Figure 6. Cross-passages excavation in D&B.

Jack hammer excavation and the application of drill and blast methods remain to be a challenge in urban environment. The first one is due to the impact on the community, resulting from the generation of vibrations and generated noise and the second one to the impact of the required evacuation procedures on other activities inside the tunnel.

The cross-passages construction quantities are summarized in the Table 1.

Table 1. Cross-passages construction quantity.

Cross-tunnel	Excavation Volume (m^3)	Concrete Volume (m^3)
XP Type 1	320	154
XP Type 2	260	141
SST HV Room	460	229
SST LV Room	510	265
SST C&C Room	510	265
LPS	730	479
TOTAL	15.560	8.158

3 BACKFILL

3.1 *Tunnel Invert*

The road design foresees an invert fill with embedded drainage line and electrical conduits, a sub base built with RCC (roller compacted concrete), a concrete pavement and a top layer of asphalt.

Due to its optimal characteristics it was possible to use the excavated tunnel spoil as backfill material. In order to achieve high production rates a conventional spoil transport via trucks was excluded as an option and Transcity JV decided to revert the conveyor system in order to bring back the material form the quarry into the tunnel via the belt. Special pneumatic scissor units have been installed along the tunnel to discharge the material from the belt on various locations form where the material has been distributed to the different work fronts (see Figures 7 and 8).

The conveyor has also been used to transport RCC for the installation of the sub base layer.

With this methodology exceptional production rates could be achieved while still maintaining live other tunnel construction activities, like cross-passage excavation, in parallel.

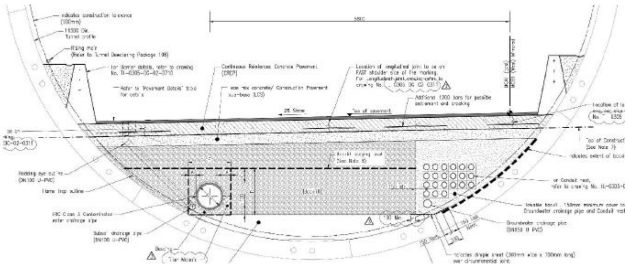

Figure 7. Typical invert cross-section.

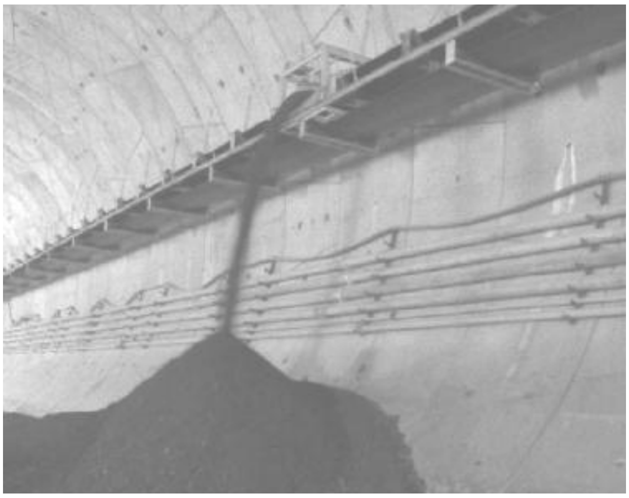

Figure 8. Discharge material along the tunnel.

4 SMOKE DUCT

4.1 *Smoke duct methodology*

The smoke duct has been designed with cast-in situ corbels as a support structure and pretensioned precast slabs for the separation of the ventilation (see Figure 9).

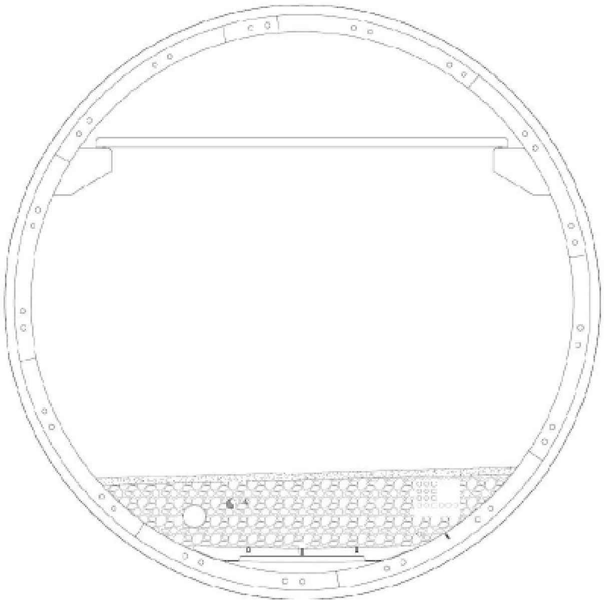

Figure 9. Smoke duct typical cross-section.

In order to industrialize the work process as much as possible and to allow for safe through traffic at all-time which was required to keep up the supply of the other tunnel activities that were performing in parallel, special gantry systems have been developed and procured.

The first gantry of the production chain was used for the drilling and installation of the large number of anchors that were required to attach the corbel structure to the tunnel segments. This gantry was fitted with electrical drilling units running on hydraulic carriage systems (see Figure 10).

The second gantry has been developed to unload, lift and install 8 m long prefabricated reinforcement cages that had to be fixed to the previous installed anchors.

The third gantry system carried the 48 m long formwork for pouring the cast in-situ corbels. Two gantries were running per tunnel (see Figure 11).

The fourth gantry has been developed to unload the 12 m long precast slabs, lift and rotate them above the corbel level and install them in the final position (see Figure 12).

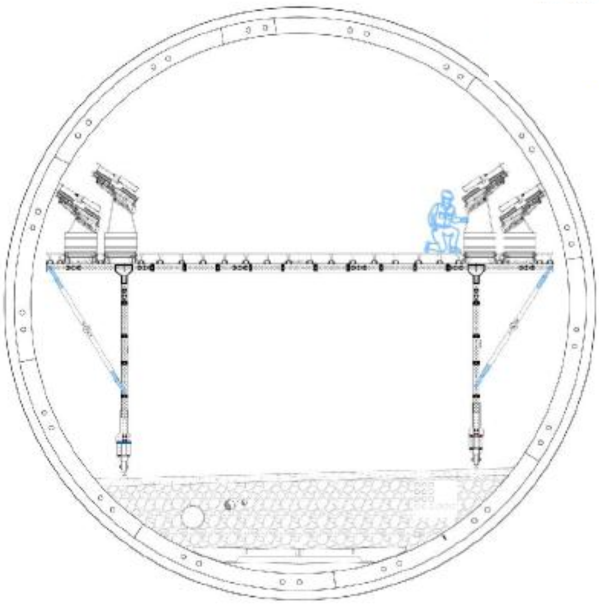

Figure 10. Smoke duct drilling gantry.

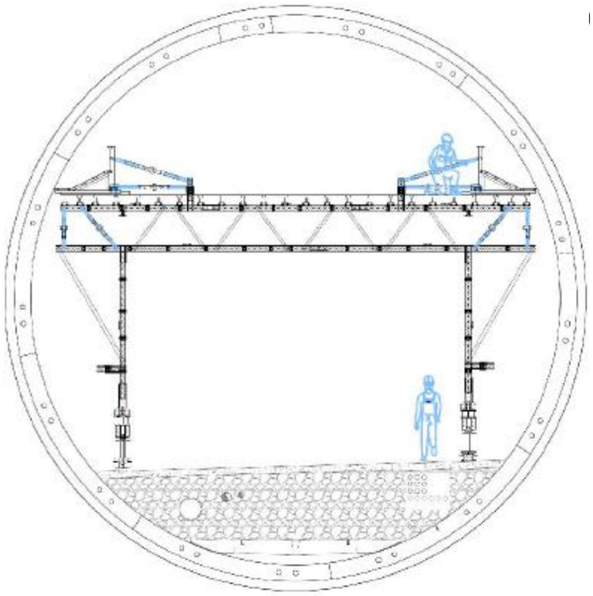

Figure 11. Corbel concreting gantry.

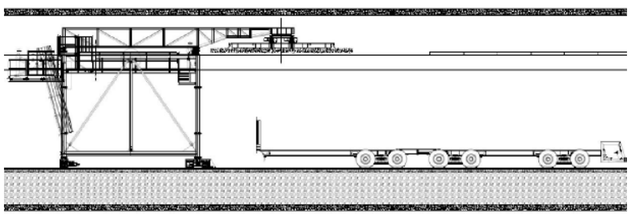

Figure 12. Smoke duct slab installation.

With this arrangement a very linear production process has been achieved.

5 CONCLUSIONS

Innovative methodologies and industrialized processes helped to build the Legacy Way tunnel in an efficient way and maintaining high production performance which was mandatory in order to keep up with the tight program schedule.

The application of the two component grout on a large diameter double shield machine played an important part in the delivery of a watertight segmental lined road tunnel in hard rock.

The execution of this work has proved to be an international success because in just six months the excavation of the two TBM tunnels was completed, achieving world records for best progress of excavation: 49.7 m daily, 248.8 m weekly, and 858.1 m monthly.

Thanks to this important result, Legacy Way Project has won the Major Tunneling Project of the Year (over $500M) at the International Tunneling Awards held in London the last November.

ACKNOWLEDGEMENTS

A particular acknowledgement to Transcity JV team for the great effort and the great result achievements.

REFERENCES

Ortu, M. and Huber, M. 2012. TBM Tunnelling on Legacy Way Project. 11th *Australian Tunnelling Conference*.

Ortu, M. 2013. Tunnelling on Legacy Way Project. *ATS Presentation.*