United Undersea – Connecting the Tunnels to Marine Risers at the Victorian Desalination Project

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ABSTRACT

The Victorian Desalination Project is being constructed near the town of Wonthaggi, in the South Gippsland region of Victoria, Australia. Construction of marine works began in January 2010 and was completed in June 2011. The marine works consisted of 4.0 m internal diameter inlet and outlet tunnels, four marine risers and four tunnel to riser adit connections.

This paper describes the construction methodology used to connect the tunnels to the marine risers. Connection works included temporary segmental lining support, ground pre-treatment, segmental lining breakout, adit excavation and ground support, riser dewatering, glass reinforced pipe installation and concrete encasement.

INTRODUCTION

Project overview

The marine works at the Victorian Desalination Project have been constructed to service the reverse osmosis desalination plant. The 1.2 km long inlet tunnel supplies seawater to the plant and is connected to two inlet risers that are approximately 850 m offshore in Bass Strait. The 1.5 km long outlet tunnel discharges brine into the ocean and is connected to two outlet risers that are situated approximately 1200 m offshore.

The tunnels were constructed using 4.74 m diameter fully shielded slurry tunnel boring machines (TBM). A 230 mm thick key, counter key segmental lining was installed as the TBM's progressed. The TBM tunnel invert level at the riser connection locations was approximately RL -42 m, with an estimated rock cover of 17 m.

The glass reinforced plastic (GRP) risers are 2.4 m internal diameter and each has been grouted into a 3.3 m diameter bored shaft. The design pillar width between riser and TBM tunnel was 3.6 m.

The marine risers were installed and grouted into position prior to TBM excavation passing each riser location. The TBM gantries were removed from the tunnel and then the tunnel connections to marine risers were completed. The connections consisted of an adit excavation between the tunnel and the marine riser. See Fig. 1

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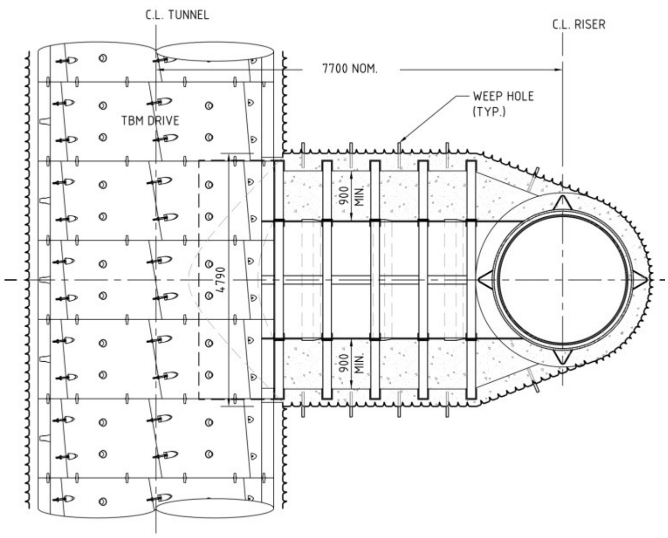

Figure 1 – Plan of tunnel to riser connection

Challenges

The connections between tunnels and risers at the Victorian Desalination Project encompassed many challenges. Geographically, both the tunnel and the risers had to be constructed to the designed position, to avoid the major risk of one hitting the other during the construction phase. To a smaller degree, a misaligned tunnel or riser could have resulted in an overly long adit excavation, which the construction schedule did not allow.

Limited geotechnical information, particularly the lack of physical sampling from the final riser locations presented a significant challenge. The available information indicated the presence of a low to very low strength fine grained sandstone, with varying degrees of jointing and a potential fault zones. The design and construction team responded on a risk management basis, and pursued a ground support design to cater for the worst case geotechnical conditions that could be inferred from the available data.

The potential impacts of groundwater on excavation, ground support and overall stability had to be addressed. At the outset, geotechnical information indicated the potential for direct connectivity between adit excavations and the seabed. A grouting campaign was undertaken prior to excavation to combat the potential 4 bar of ground water pressure.

The confined nature of small scale tunnel works also presented the construction team with a challenge to select the correct equipment. The selection of plant capable of working within the confines of the excavation, but still powerful enough to complete the works was a key factor in the safety and success of the operation.

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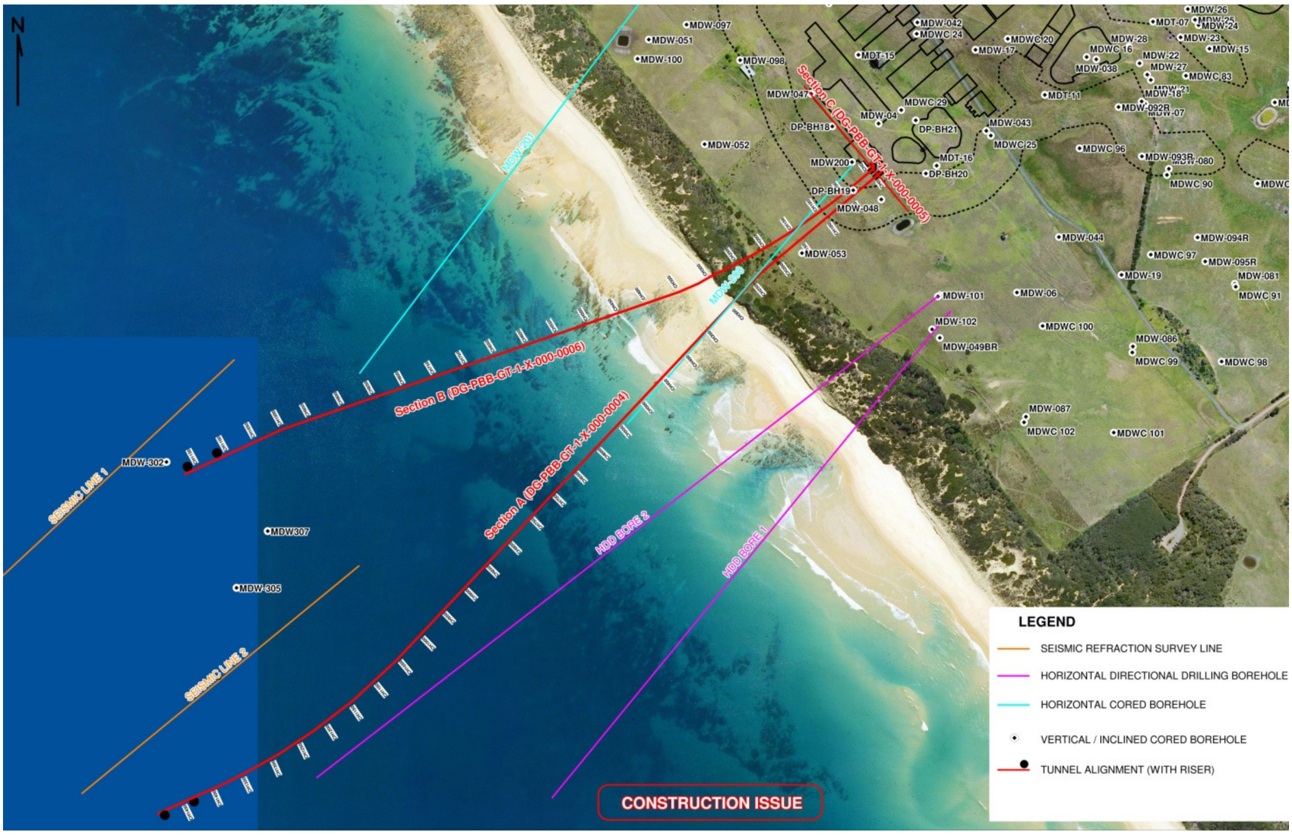

Figure 2 - Tunnel Alignment

Lastly, the marine risers were filled with water as part of the construction methodology, so excavation operations had to be controlled to avoid an inadvertent release of approximately 200,000 L of water into the tunnel work area.

TUNNEL TO RISER CONNECTION

The horizontal connections between the tunnels and each riser were made by excavating a 4.8 m wide 4.7 m high adit through the segmental lining and across to each riser. Excavation length was 4.5 m. Temporary structural steel rings and framing beams were installed around each future adit opening to resist loads induced from ground pressure, water pressure and grouting pressure. A grouting campaign was undertaken prior to excavation in order to minimise potential ground water inflows into the excavation. Lugeon testing was undertaken post grouting then excavation commenced. The excavation was undertaken with hydraulic excavator and was temporarily supported by a primary shotcrete layer, steel sets and final shotcrete layer. The riser was exposed from the surrounding grout annulus and was subsequently dewatered. A penetration was cut into the face of the riser to receive the adit-riser GRP mating piece. The GRP liner was extended through into the TBM tunnel and the entire arrangement was backfilled with concrete to the segmental lining profile.

Geology

An amount of geological testing was undertaken including onshore boreholes, mapping of Horizontal Directional Drilling for the pilot plant, mapping of horizontal cores, seismic tests and three offshore vertical boreholes. See Fig. 2.

The predominant geology in the area of the tunnel to riser connections was defined as moderately weathered fractured sandstone. The rock mass permeability was estimated to be generally low with high permeability zones present should any local fault zones be encountered. Prior to construction commencing, the estimated groundwater inflow in faulted areas was up to 22 L/sec/m of excavated adit length. Some parameters assumed for design purposes were UCS of 2.0 MPa with a working bond capacity of 350 kPa. RMR and Q rock-mass qualification systems were used to provide guidance on ground support requirements during the design phase. A lower bound Q value of 0.13 and RMR of 40 (poor) were assigned. Empirical observations during TBM cutter-head interventions at adit locations confirmed the presence of low strength fine grained sandstone, with saline groundwater flowing freely through the joint sets.

Interface between TBM Tunnel and Risers

A critical factor in the works was ensuring that the risers were installed the correct distance away from the TBM tunnel. This was essential to avoid three distinct possibilities:

- Design minimum pillar width not being achieved, resulting in a potentially unstable excavation.
- Excessive pillar width, resulting in a longer adit drive.
- Collision between TBM excavation and riser installation, with potentially catastrophic results.

Co-ordination between marine and tunnel survey teams was essential to achieve the correct positioning of TBM tunnel relative to each riser. Both marine and tunnel surveys were conducted using the Map Grid of Australia 1994 (MGA94) Zone 55 co-ordinate system. The tunnel survey control network was used to establish the marine survey GPS base station location. The TBM drive position was also checked independently by way of gyro-theodolite survey.

The jack-up barge used to install the risers was setup twice, first for the two inlet risers and then for the two outlet risers. The horizontal alignment design for inlet and outlet tunnels was modified slightly to accommodate the actual positioning of the jack-up barge. The TBM tunnels and marine risers were subsequently installed within design tolerances of ±50 mm and ±150 mm respectively. This maintained the design pillar width of 3.6 m.

Excavation Size

The excavation size was deliberately set such that a 0.9 m clearance zone remained outside the adit GRP liner, to facilitate installation. This resulted in an excavation span of 4.8 m and height of 4.7 m. The overall excavation length was 4.5 m. A panel of 3 segments wide (4.5 m wide) by 2 segments high (3.8 m high) was removed from the segmental lining to make the adit opening. See Fig. 3.

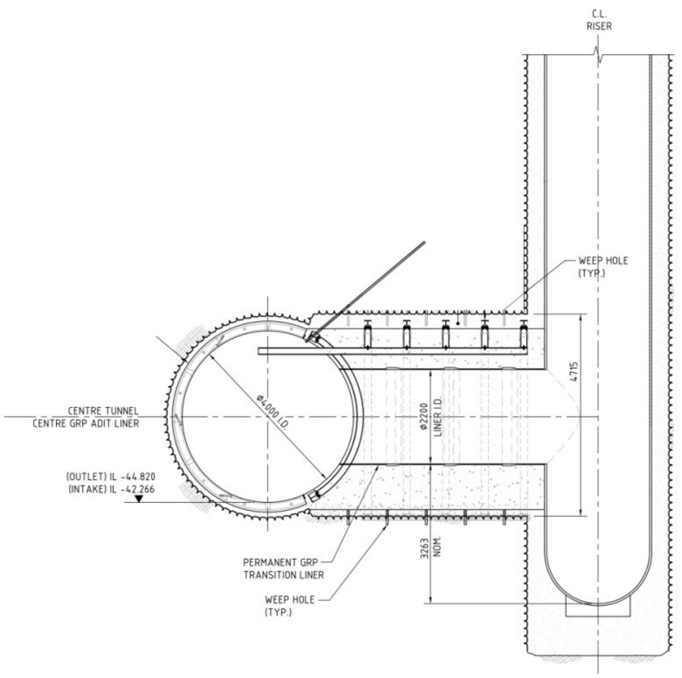

Figure 3 – Elevation of riser to tunnel connection

Temporary Support of Segmental Lining

Due to the lack of available bond stress in the host rock, a passive support system was adopted to maintain the integrity of the segmental lining during the excavation, grouting and final lining works. The support framework consisted of 250 and 200 UC rings tied together, with the adit opening framed by 250 UC sill and lintel beams. The temporary steel rings extended 4.0 m either side of the adit opening. 17 tonnes of structural steel were installed at each adit location. The 25 mm annulus around each steel ring was grouted and wedged to provide load transfer between the segmental lining and temporary works. See Fig. 4.

Grouting

A grouting campaign was undertaken prior to excavation of each adit. Hydro-geological information indicated the potential for substantial water inflow, should any faulting be encountered. In addition to this, the excavation needed to be suitably dry to allow the application of steel-fibre shotcrete for temporary ground support. The high slake-ability of the rock also warranted precautionary measures to make the excavation as dry and stable as possible.

The aim of each grouting campaign was to block any water bearing joints within 4 – 5 m of the adit excavation line. During TBM excavation, face inspections were undertaken for 20m before and after each riser and it was determined the rock mass had sufficient structure negating the requirement to undertake ground consolidation using traditional cementitious grouting. The area to be excavated was also grouted, with an aim of sealing any ground water from entering through the riser bore and riser grout annulus. A drilling array with 45 mm diameter holes on a 1.5 m grid was adopted. 25 primary holes were used at each adit. Secondary holes were used in the spiling bar locations and when re-drilling indicated continued inflow.

Each adit was grouted with a two part urea-silicate resin, injected under pressure of 90 – 120 bar. The resin had a set time of 2 – 3 minutes, eliminating concerns regarding wash-out. The grouting works were successful. Lugeon testing after grouting resulted in test values of 0 - 1 lugeons. Subsequent excavation revealed joints full of resin with minor local seepage in places.

Figure 4 – Installation of Temporary Support at Adit

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Excavation and Ground Support

The segmental lining at the adit locations was constructed of steel fibre reinforced precast segments. 32mm diameter 3.6 m spiling bars were installed and grouted above the adit crown prior to excavation commencing. The segments to be removed above spring-line were further restrained by rock-bolting them to the face. The segments were then stitch drilled and broken down into small fragments with an excavator – hammer combination. The same plant was used to excavate the material from each round.

The ground support design was developed with risk management always at the forefront. The limited geotechnical information resulted in a ground support design that would cater for the worst feasible conditions based on the available knowledge. For this reason, a passive ground support design of steel fibre shotcrete with steel sets at one metre centres with a one metre advance was adopted.

Excavation proceeded in 1 m rounds with each round following a sequence of geotechnical inspection, excavation, 75 mm initial shotcrete, installation of 150 UC steel set then 150 mm final shotcrete.

Progressive geotechnical inspection during each round confirmed that the rock quality was better than the worst case assumed in the design. Convergence monitoring of the adit opening and adit excavation itself was undertaken during the works on a daily basis. Minimal movement was observed.

A key issue in the excavation was avoiding any mechanical damage to the riser. This was achieved by adding red dye to the annulus grout around the riser, to provide a visual indicator for tunnelling crews that arrival at the riser was imminent. The red dye in the riser annulus grout contrasted well with the predominantly grey sandstone of the area. See Fig.5

Once the red grout was exposed a controlled probe drill was undertaken to establish the exact distance from the excavation face to the riser. This allowed tunnelling crews to take adequate care and avoided any mechanical damage to the GRP riser.

Figure 5 – Adit excavation and ground support

Riser Dewatering and Adit GRP Installation

Each riser was capped at the top with a double isolation seal to avoid inrush of seawater into the tunnels during the adit construction. The primary seal was a steel plate bolted to the top flange of the riser. The secondary seal was a GRP hemisphere, equipped with a hydraulic Pronal seal, seated inside the riser, directly underneath the top cap. These seals provided double isolation between Bass Strait and the crews below.

Each riser was filled with water to facilitate installation and remained as such until the riser was exposed during the adit excavation works. Upon exposing the GRP riser, a dewatering portal was accessed and the tunnel crews were able to dewater each riser through the use of a valve bank inside the dewatering portal. The valve bank allowed compressed air to be forced into the riser whilst the water was displaced into the tunnel dewatering system to avoid any internal vacuum effects.

Once dewatering was complete a 2.2 m diameter hole was cut into the face of the riser and the adit GRP pipes installed. The pipes were installed on sliding cradles and strapped down to resist the buoyancy during concreting works. See Fig. 6.

Each adit was formed up to the profile of the original segmental lining and backfilled with a 40 MPa self compacting concrete, placed at a slump of 200 mm. Concreting was completed in successive lifts of 600 mm to avoid flotation or deformation of the adit GRP liners.

Figure 6 – GRP installed in adit

Plant Selection

The available working room, nature of the rock and excavation size dictated the plant selection.

Erection of the structural steel rings to support the segmental lining was undertaken with a 2.5 tonne tele-handler equipped with a set erecting attachment and a jib.

Drilling was completed with a Tamrock Micromatic DH103 single boom jumbo drill fitted with an HL300 drifter. The particular machine was selected for its shortened feed rail which allowed increased manoeuvrability underground. A small number of holes were completed with conventional hand held rotary percussive rock drills.

The excavation was undertaken with mini excavators in the size range of 1.7 to 3.0 tonnes. The 3.0 tonne excavator had the dipper arm removed and a hammer attached directly to the main boom. This was the primary machine used for breaking the material from the excavation face. The material was mucked out into 1 m^3 site dumpers with a 1.7 tonne excavator.

Concrete and shotcrete were conveyed to the work front using the same site dumpers used for mucking out. The shotcrete was applied with a Jacon Midjet shotcrete rig.

CONCLUSION

Key elements in the safe and timely completion of the connections between the tunnels and marine risers at the Victorian Desalination Project were:

- Detailed risk assessments and planning of the works well in advance of commencement.
- Developing a design and construction method to suit the worst case scenario based on the available information.
- Experienced personnel at the underground work front.
- Selection of appropriate plant and equipment.
- Regular communication and coordination between the tunnel and marine teams.

The tunnel to riser connections at the Victorian Desalination Project employed many different techniques in underground construction. These techniques allowed four horizontal connections to be made between the TBM tunnels and the water filled riser shafts in a safe and productive manner.

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- RPC Technologies – design and fabrication of GRP risers and adit liners.
- RUS Mining – adit grouting.