

Forrestfield-Airport Link

METRONET

Tunnel boring machines

Fact Sheet | March 2019



ABOUT THE PROJECT



The \$1.86 billion Forrestfield-Airport Link is jointly funded by the Australian and Western Australian governments and will deliver a new rail service to the eastern suburbs of Perth – with three new stations at Redcliffe, Airport Central and Forrestfield.

The rail link forms part of the METRONET vision to create liveable communities connected by world class public transport. The line will spur off the existing Midland Line near Bayswater Station and run to Forrestfield through twin-bored tunnels.

In April 2016 the Public Transport Authority awarded the design, construct and maintenance contract to Salini Impregilo – NRW Joint Venture.

First trains will operate on the new line in the second half of 2021.

Tunnel boring machines (TBMs) are large machines that excavate below the ground surface, while simultaneously installing concrete lining units to build a tunnel.



130m
long TBMs

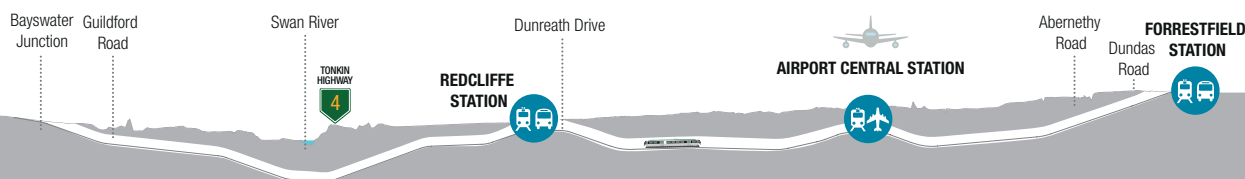
Tunnelling up to a depth of
26m

Each weighs
600T

With a driving force of
5000T

Two TBMs have been specifically designed for the Forrestfield-Airport Link by German company Herrenknecht, the world's leading supplier of TBMs. These machines, each costing approximately \$20million, will excavate 7m-diameter twin-bored tunnels between Forrestfield and Bayswater.

TBM Grace began tunnelling in July 2017, and TBM Sandy began in September 2017. The underground journey is expected to take about three years.



Specialised technology

There are various types of TBMs to cater for different project requirements.

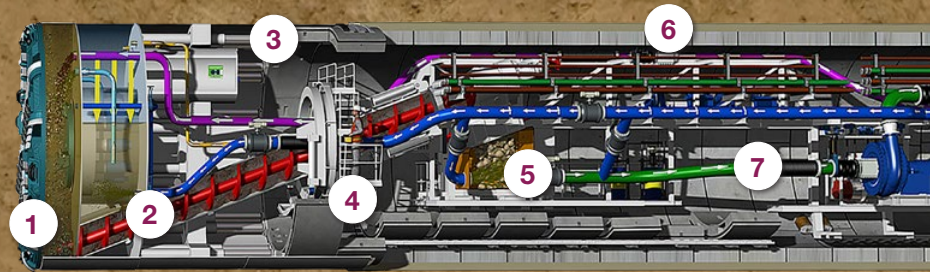
For this project, the TBMs are Mixshield which use the latest multi-mode technology capable of adapting to variable ground conditions, such as sand, rock and clay. These specialised machines combine two types of technology:

Earth pressure balance mode – uses a screw conveyor and valve to control the face pressure by regulating the amount of spoil in the machine. This mode will be used for clay and alluvial muds such as under the Swan River.

Slurry mode – uses pipes and fluid to control the pressure in the machine by turning the excavated material into a slurry and pumping it out. This mode will be used for sand and gravel such as under Perth Airport.

Both of these modes keep the pressure inside the TBM chamber the same as the outside ground pressure. This ensures maximum tunnelling safety and minimises the risk of heave and settlement on the surface.

How a TBM works



1. Picks and disc cutters remove the soil from the tunnel face.
2. A screw conveyor transfers the excavated material to the jaw crusher.
3. Hydraulic cylinders push the TBM forward.
4. A segment erector lifts concrete segments into place to form the tunnel lining. Approximately 9000 rings will be installed along the 8km long tunnels.
5. A rotary crusher breaks down stones or boulders into a granular mixture in the slurry box.
6. The gap between the excavated surface and concrete segments is filled with grout, this helps prevent ground settlement.
7. Excavated material is pumped as slurry out of the tunnel by pipe to the slurry treatment plant at Forrestfield. Once treated, the spoil will be tested, and where possible reused.

A TBM can tunnel 24 hours a day or intermittently. For this project, there are some planned stoppages required. Power must be supplied to the TBMs at all times, so even when they stop mining they are still turned on and monitored by a small team.



Like ships, TBMs are named before they begin work to bring good luck. TBMs are generally given female names as underground workers look to Saint Barbara for protection.

TBM Grace was named in honour of pre-primary student Grace McPhee, who was nominated by her classmates at Edney Primary School. They said Grace, who was undergoing treatment for leukaemia, was the toughest person they knew - a toughness the TBM would need to bore through the earth.

TBM Grace is decorated with artwork by Walliston Primary School student Georgia Fields.

TBM Sandy was named by High Wycombe Primary School student Sarah Spratt. Sarah was inspired after finding a sandgroper in her backyard, as the local insect is 'excellent at tunnelling, just like the TBM'. TBM Sandy is decorated with artwork by Rossmoyne Primary School students Faith Brand and Jood Al Jashammi.

Gantries

Each TBM has nine gantries, which support the various equipment, electronics, transformers and hydraulics that are required to operate the TBM.

Consumables such as segments, grease, bolts and pipes are transported into the tunnel by multi-service vehicles (see more on MSVs overleaf).

The gantries contain the following: an operator's cabin, tanks of water, hydraulic oil, bentonite, grout, accelerator, waste water, compressor, emergency generator, transformers, crib room and engineer's office, secondary ventilation (the main ventilation system with chillers is on the surface), electrical cabinets, hydraulic pumps, segment cranes, gas detection systems, fire suppression system, slurry pumps, pipe extension area and toilet.

A number of pipes, linked from the Forrestfield construction site to each TBM, are used to transport compressed air, cooling water, grout, industrial water (for cleaning and firefighting systems), waste water and slurry.

Each section of pipe is 6m long and must be extended every three to four advances of the TBM, or approximately every three to four hours.



TBM operating roles

A crew of approximately 18 people operates each TBM. Some of these positions are inside the large machines, others are located above ground – however, each role is vital in keeping the TBMs in operation.

A number of positions require skilled operators with previous tunnelling experience. These include:

- TBM supervisor and TBM foreman – these two roles involve managing the TBMs and the crews, and advising the yard supervisor what the TBMs require
- TBM operator – drives the TBM
- Segment erector operator – operates the erector which installs the tunnel rings
- Grout operator – controls the grouting system.

Maintenance

Like any machine, maintenance is required to ensure effective and continued operation.



The frequency of maintenance depends on the soil. Sometimes, with abrasive soil, maintenance is required every 100m, other times the machine can travel 500m before maintenance is required.

The cutter face has various cutting tools including cutter disks, knives, rippers and buckets. Each one is designed to work in different conditions. For example, cutter disks are used for concrete and rock, while the knives, rippers and buckets are for soil and clay.

During inspections of the cutter face, the wear and tear of the tools is evaluated and if they exceed set values the tools are replaced.

The length of time it takes to replace the tools depends on what needs to be replaced and the conditions of the job (hyperbaric mode or atmospheric mode). In atmospheric mode, all cutting tools can be replaced in three days. In hyperbaric conditions, it takes longer. The task requires three workers in the cutter head and one supervisor.



When maintenance of the cutting tools is required and the TBM is below the water table or the soil is not stable, a compressed air bubble is created. Referred to as hyperbaric mode, this supports the ground in front of the cutter head and stops seepage of water.

Each TBM has a hyperbaric chamber, called a Man Lock. The workers, trained and certified as hyperbaric workers, must be compressed to the pressure of the air bubble, then decompressed later. The decompression time changes depending on the air pressure and the duration of the maintenance work.

An additional hyperbaric chamber, known as a Medical Lock, is located at surface level. This is used for training purposes and can also be used in case of an emergency or decompression illness.

Arrival at stations

The project includes three new stations, two of which are underground at Redcliffe and Airport Central.

Before the TBMs arrive at these sites, the underground station boxes are completed and the soil within the structures excavated.

The TBMs tunnel through the concrete walls and into the station box, where they remain for several weeks for maintenance.

As was done when the TBMs launched at Forrestfield, a thrust frame will be installed in each station box.

The TBM will push against the frame to travel through the station box wall before resuming tunnelling.

Building the tunnels

Approximately 9000 concrete rings are required to build the two tunnels for the Forrestfield-Airport Link.

Each ring is made up of six segments, has an external diameter of 7m and is 1.6m long. The segments are made at a Forrestfield factory and trucked to the dive structure or station boxes. A multi-service vehicle (MSV) then delivers the segments into the TBMs.



A special transfer crane lifts the segments from the MSV on to the TBM's segment feeder, which transfers them to the front of the tunnel.



A hydraulically-controlled crane arm, known as an erector, lifts the segments and puts them into position using vacuum plates.



Once the full ring is in place, hydraulic cylinders push the TBM forward, ready to build another ring of segments.

Vibration

With such large machines tunnelling underground, it is natural for people to ask what they will hear or feel while the machines are operating.

Vibration monitoring for the project has shown that the ground vibration, caused by the TBMs, is less than what is caused by local traffic, an air conditioner or a fridge.

Monitoring equipment is in place across the rail route to provide updates in real time to the construction team.

The monitors are installed 50-100m ahead of the TBMs, then removed once the machines have tunnelled under the area and travelled a further 50m. This enables the construction team to record natural vibration in the area to compare to vibration during tunnelling. Records to date have shown results are below natural vibration levels.

Multi-service vehicles

Six MSVs have been tailor-made to transport tunnel segments and other equipment into the TBMs. The MSVs come in two different sizes.

The larger MSVs are 27m long, weigh 28 tonnes and have a load capacity of 60 tonnes, enabling the transport of two rings at the same time.

The smaller MSVs are 19m in length, weigh 19 tonnes, with a load capacity of 30 tonnes. These MSVs can transport one ring at a time, one set of pipes or the personnel rider.

The vehicles have a double operator cabin (front and rear) allowing the MSV driver to enter and exit the tunnel in a forward motion. Each MSV makes up to eight trips a day to the TBMs.



More information

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