Mahatma Gandhi Road Sewer Extension Micro-tunnel

FINALIST
Technical Excellence Category

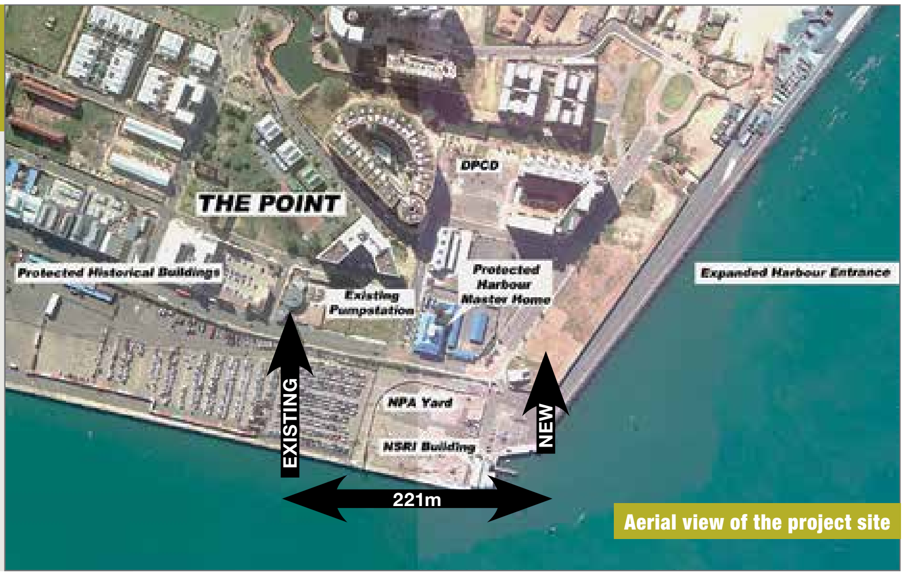
KEY PLAYERS

Client
eThekwini Municipality: Water and Waste Services

Professional team
Goba Consulting Engineers and Project Managers, Drennan Maud and Partners

Main contractor
Group 5

Sub-contractors
Coleman Tunnelling, Esorfranki



Aerial view of the project site

OVERVIEW

The old Mahatma Gandhi Road Sewage Pump Station occupied a prime site within the Durban Point Development Corporation's (DPDC) upmarket development zone, bordering Mahatma Gandhi Road and Albert Terrace, and served the greater Durban catchment area including the CBD and Berea areas from the Umgeni River in the north to the Umbilo River in the south. Because of its prime position within the upmarket development zone it was decided to relocate it to a site adjacent to the north shaft of the recently commissioned Durban Harbour Tunnel, i.e. 250 m from its original position.

A gravity sewer of 1 350 mm in diameter served the original pump station. In order for it to continue supplying the pump station in its new position, it required the extension of the gravity sewer inlet pipeline by 221 m.

Because the pipeline is 6 m below the very busy Mahatma Gandhi Road, and 4 m below the groundwater table, any open trench method of pipe installation would have been too risky to the client. Therefore the works were undertaken via a trenchless micro-tunnelling operation.

DESIGN CONSIDERATIONS

The gravity sewer extension of the existing pipeline at the upper end, and the hydraulic design levels of the new pump station at the lower end resulted in design restraints – these levels resulted in a pipeline ranging in depth from 7 to 9 m below ground level, while the groundwater table was at 2 m below ground level.

Another consideration was the alignment of the new pipeline, which had to run in the centre of the road – a double-lane road in both directions and the main feeder road for the Point Precinct. Furthermore, there is a protected historical Harbour Master Building between the start and end points of the new alignment, which meant that a straight-line design was not possible.

DESIGN

An initial study was carried out to evaluate the various possible sewer pipe extension installation options within the constraints of the site and alignment. Some of the constraints and risks identified within the vicinity of the pipe installation and appurtenant works were:

- Disruption to the traffic on the busy Mahatma Gandhi Road.

- Numerous buried services criss-crossing the road, ruling out the use of shallow installations and open-trench methods.
- Ground settlement associated with construction procedures which could result in the lowering of the groundwater table or loss of implementation of ground stabilisation, and could cause significant and costly damage to the protected historical building, sewer extension alignment, services and road.
- Ground conditions in the area consisting primarily of dense sands and lagoonal sediments with permeability of k≈10^{-1} cm/s.
- Limited working space and strict alignment controls using the Horizontal Direction Drilling (HDD) method.
- Concerns regarding the structural integrity of the 50-year old underground chamber adjacent to the existing pump station.

These constraints and the available technology, together with environmental and economic aspects, were considered to determine the most favourable sewer pipe extension method – pipe jacking using a micro-tunnel boring machine (micro-tunnelling method).


The micro-tunnel boring machine

MICRO-TUNNELLING

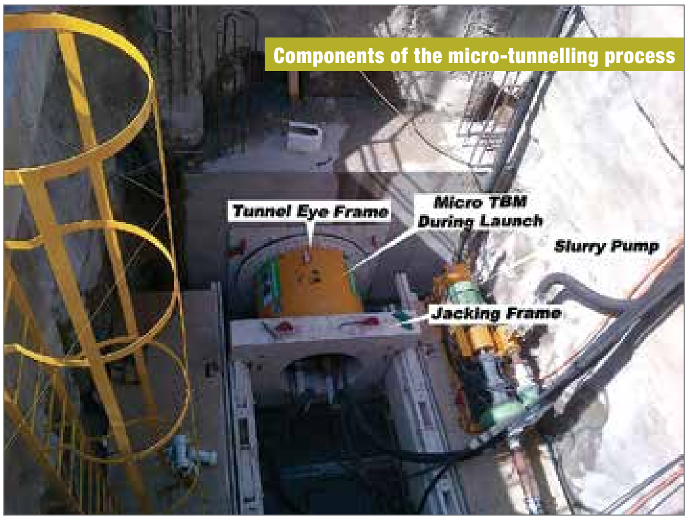
The micro-tunnelling machine used was an AVN 1200TC with a mixed ground cutting wheel. This AVN-type machine is used specifically for 1 200 mm internal diameter jacking pipes. The tunnel extension of 221 m consisted of:

- 113 m straight section from the jacking pit
- 102 m arc length with a 350 m radius and curved section to bypass the protected Harbour Master Building
- 6 m straight section breaking into the existing Harbour Tunnel north shaft.

The 221 m tunnel was in excess of the designed length for the conventional hydraulic drive from container to machine and, as a result, an electrically-driven hydraulic power pack within the micro-tunnel was used to accommodate the longer distance tunnel drive. Due to the length of the tunnel, as well as the curved section, two intermediate jacking stations, with eight 646 kN and 700 mm hydraulic cylinders were installed to reduce the jacking pressures on the front pipes. Intermediate jacks were installed at 33 m and 133 m behind the machine.

The control cabin on the surface was located so that the operator had uninterrupted views of the jacking pit bottom where the hydraulic rams "pushed" the pipes forward. A laser guidance system was fixed in the jacking pit to the set reference alignment and grade to monitor the relative position of the tunnel boring machine's (TBM) cutting head. The laser target position was relayed to the control cabin to allow the operator to effect steering adjustments as necessary. When the tunnel reached the curve, a gyroscope guidance system was used to control line and level. The systems were checked manually every 40 m using standard surveying equipment to ensure that the positioning system remained accurate. The TBM reached the end point within a deviation of less than 20 mm.

The lubrication system used bentonite to reduce stress development on the jacking pipe due to friction between the jacked pipes and surrounding ground. Every third pipe had a system of bentonite injection positions at three equal orientations on the internal surface of the pipe. The lubrication is able to be injected into the small annulus between the pipe and the ground, reducing the friction created in this area. The system sends feedback to the control cabin regarding lubrication flows at each position, thus informing the operator where additional lubrication is needed at any time during the drive.



Components of the micro-tunnelling process

This type of TBM uses a pressurised slurry system to generate a positive pressure at the cutting face of the excavation. As the horizontal alignment of the tunnel was some 5 – 6 m below the natural water table, this resulted in a positive pressure at the cutting face. The slurry was pumped into this area to maintain a pressure slightly higher than the ground pressure so that the face did not collapse.

The excavated material was transported back to the surface via a slurry return pipeline into a separation plant. Water was initially used as the transporting medium; however, the bentonite was added in extreme ground conditions when the use of water became unsuitable.

The separation plant, with a capacity of 250 m³ per hour, was equipped with a vibrating shaker screen rack, two 15 inch hydro cyclones, and an agitator to prevent solids from settling out, which was connected to a sedimentation tank. The excavated material was separated from the slurry medium, which was in turn recycled and re-used in the system.

Each pipe was lowered into the jacking pit via a crane and inserted into the collar of the previously inserted pipe. Wooden packing was inserted between the two pipes so that no point loads occurred during jacking, which would have cracked the concrete. The hydraulic jacks were then closed onto the other end of the pipe and the drive was then continued. The entire pipeline was jacked forward from the rear end of the pipeline. The pipes needed to be designed not only for the permanent loading conditions, but also the temporary forces experienced on the pipes during installation. Should the forces on the jacks have become too high, then the operator had the option of using the inter-jack stations to reduce the forces on the pipes.

The breakthrough of the TBM at the end of the drive in the reception shaft was undertaken through a specially designed steel receiving eye with a double rubber ring seal. As the TBM was driven through this ring the rubber seal prevented ground water and slurry from draining into the shaft.

PIPE DESIGN

Due to the difficulty in gaining access to the sewer line and the importance of the sewer system, the 1 200 mm internal diameter reinforced concrete pipe was designed for a 100-year life span.

Each pipe was lowered into the jacking pit via a crane and inserted into the collar of the previously inserted pipe

The reinforced 145 mm thick concrete pipe walls with characteristic strength of 40 MPa were designed taking into account the highly corrosive Durban marine environment.

This, combined with the fact that the concrete sewer pipe would be below the saline groundwater table, required high-durability concrete.

Although the extrados of the pipe would be permanently submerged, possible salt water damage to materials had to be minimised using stainless steel collars and rubber seals for pipe joints. A special grade (AISI 32507) duplex stainless steel was used for its resistance to pitting corrosion. To eliminate sewage gases and hydrogen sulphide attacking the concrete, the pipe intrados was lined with a cast-in, continuously-welded thin sheet of HDPE.

The selection of the pipe material in this application was based on constructability and corrosion resistivity. The unique combination of the concrete for strength, the HDPE liner for corrosion and abrasion, and the duplex stainless steel collars resulted in a final design of the pipes that achieved all the objectives of the brief.

The design of the jointing system also gave the flexibility for the pipe jack to negotiate the 350 m radius without having to construct additional reception shafts.

The pipes furthermore had to be constructed to match the dimensions of the TBM jacking rig exactly.

CONCLUSION

The installation of the 221 m micro-tunnel took 24 days to complete. The project is unique and innovative as it was the first of its kind in South Africa regarding size, length and curved environment. ◻

Final breakthrough