Maroshi-Ruparel Water Tunnel Project: Revitalising Mumbai's Water lifelines

The 12.24 km Maroshi-Ruparel Tunnel is the longest underground water tunnel inside Mumbai city limits.

Supplying water for the megacity

Mumbai, 'the city that never sleeps,' ranks amongst one of the most densely populated urban regions in the world. The Mumbai city region – which stretches from Churchgate to Dahisar on the west and from Chhatrapati Shivaji Terminus to Mulund and Mankhurd on the east — receives a water supply of 3,350 million litres per day (mld) from five lakes. Out of these five lakes, the Tulsi and Vihar Lakes fall within the city limits while the Tansa, Vaitarna and Bhatsa Dam are situated outside the city limits. The water from these dams is conveyed to the city and the suburbs through a very complex distribution network of primary and secondary transmission pipelines.

Prior to Independence, Tansa was the major source of water for the city. The pipelines from Tansa run along the Bombay - Agra road. After independence, the Vaitarna-cum-Tansa project provided a tunnel between Vaitarna and Tansa lakes and water supply to the Malabar Hill Reservoir and Bhandarwada Reservoir increased, besides serving the remaining areas directly from the main trunk. The Upper Vaitarna Scheme, in 1973, provided water through tunnels under the Thane Creek. Subsequently, the Bhatsa Scheme was developed, which also provided for the construction of pumping, treatment and conveyance at Pise, Panjrapur and Bhandup. The water from Bhatsa is pumped into the Vaitarna mains and brought through tunnels to Bhandup's water treatment-cum-pumping-cum-reservoir complex. From Bhandup's Master Balancing Reservoir I (MBR I) and MBR II at Yewai Hills, water is supplied to the city and suburbs through 27 service reservoirs and 650km transmission mains, 3,000km of distribution mains and 3,200km of service pipes and allied pipeline system for inlets and outlets – altogether feeding a total of 112 water supply zones.

Piped water supply was introduced into the city over 136 years ago and a major portion of Mumbai's water distribution network has been laid down in the colonial era. Though the city has also seen water distribution projects post-independence, these are more than 60 to 80 years old.

With a view to meet the ever rising demand for water, and to rehabilitate and improve the ageing water supply and distribution system in Mumbai, the Brihanmumbai Municipal Corporation (BMC) has undertaken a series of initiatives, namely - create new water sources by building dams, rehabilitate existing pipelines and also

construct new underground water tunnels which require low maintenance and are less prone to leakage and pilferage of water. Till date, tunnels covering a total length of 26 km are in operations of which HCC has constructed 21 km of tunnel length and around 23 km of water tunnels are under construction of which 12 km are being constructed by HCC. The operational tunnels include: King Circle – Sewri tunnel, Ruparel College – Malabar Hills tunnel, Maroshi – Yari Road tunnel, Bhandup – Malad tunnel and East – West tunnel.

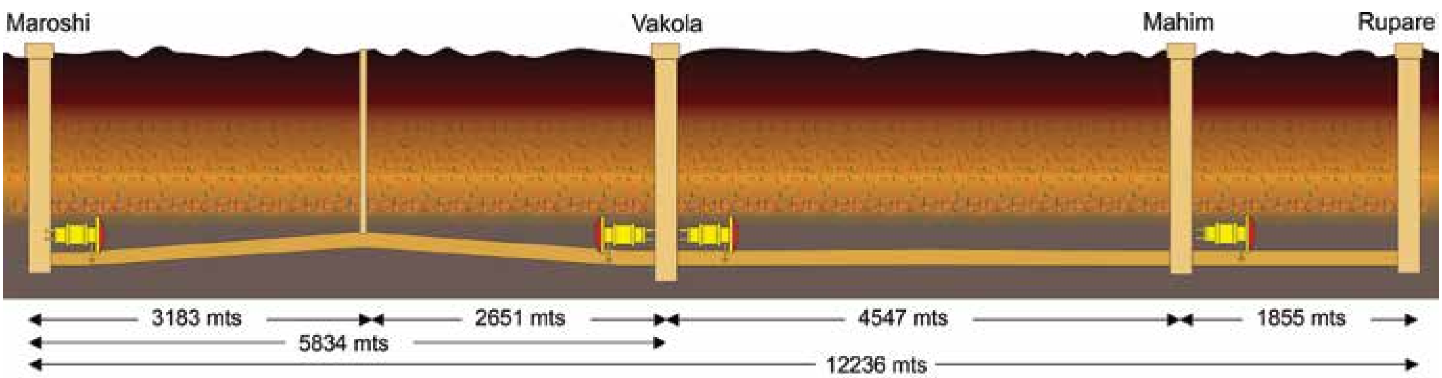
Maroshi-Ruparel Tunnel Project

As part of these ongoing initiatives, in September 2007, HCC was awarded a Contract by BMC for constructing the longest underground water tunnel inside the city limits – from Marol Maroshi in Andheri East to Ruparel College in Mahim spanning a length of 12.24 km with a diameter of 3.60 m. Upon completion, this tunnel will ensure uninterrupted water supply (1,100 million litres daily) to the western suburbs and south-west part of Mumbai. This is a Water Supply Project executed under the Jawaharlal Nehru National Urban Renewal Mission (JNNURM) and is funded by the Government of India, Government of Maharashtra & Municipal Corporation of Greater Mumbai. The other two tunnels that are being built by other agencies include the 3.6-km tunnel from Malabar Hill to Cross Maidan and the 6.1-km tunnel from Veravali to Yari Road.

The Maroshi-Ruparel underground pipeline will replace the existing Vaitarana Tansa (East) and Tansa (West) main surface pipelines which are almost a century old or more. This new tunnel will offer many advantages over the existing surface pipelines. As it is secured at a depth of 70 meters below ground level, it cannot be tampered with as in the case of surface pipelines. The new pipelines will require minimum maintenance as the entire tunnel is made of concrete - unlike surface pipelines which corrode over a period of time.

This underground water tunnel is divided into three sections namely, Maroshi-Vakola (5.83 km long), Vakola-Mahim (4.55 km long) and Mahim-Ruparel College (1.86 km long). This tunnel is connected with shafts at Maroshi, Vakola, Mahim and Ruparel College locations. The

Marol Maroshi - Ruparel College Tunnel Overview



shafts are 10 m in diameter and about 70 to 80 meters deep which is equivalent to a 20-storey building.

The shafts at Maroshi and Vakola were started first, as the land handover for the Mahim shaft was delayed by over 12 months due to local issues. Both the Maroshi and Vakola shafts were excavated using a drill & blast method in around 60 days after constructing a circular well chamber upto 6m through open excavation. After finishing the shaft lining work, the assembly tunnel was also completed using the drill & blast method.

Passionate Commitment: Whatever it takes

Reflecting on the project, Raman Kapil, Group Project Manager observed, "Our team at the Maroshi Ruparel Tunnel project encountered a series of engineering challenges for mechanized tunneling in an underground terrain - ranging from the inconsistency of the strata, to excessive seepage encountered from proximity to a marine environment, to complexities posed by the route alignment. The project team displayed exceptional courage, intensity of focus and sustained commitment to tide over all the challenges. Particularly, the realignment of the tunnel route at the Mahim shaft demanded a lot of ingenuity and out-of-the box thinking, and once again, our engineers rose to the occasion. This project has been a very special experience for all of us and full credit goes to the entire project team for all their achievements."

The 500 odd workforce team engaged on the tunnel boring was required to work 200 feet under the ground in dank and humid conditions for about 8 to 10 hours at a stretch. A comfortable, well-ventilated working environment was maintained inside the tunnel and regular power and electric supply was arranged to the work locations inside the tunnel

Aerial view of the Mahim Shaft

to ensure efficient progress. Two independent ventilation systems were provided from both the work fronts.

Excavation at the Mahim shaft

The Mahim shaft is located closer to the sea in comparison to the Vakola and Maroshi shaft. Following hand over of the site, the project team initially excavated a borehole up to a depth of 70m depth for assessment of ground strata. Marine clay, sandy soil and weathered rock was encountered up to a depth of around 20 m (where seawater seepage was also anticipated), and beyond this depth, hard rock strata was prevalent. As a result of the sandy surface layer, open excavation methodology could not be adopted. To stabilise and hold the shaft wall in this sandy surface layer, curtain grouting was done on the shaft periphery up to a depth of 60 m and then a well sinking methodology was deployed up to a depth of 20 m till hard rock strata was encountered.

The Mahim shaft was located in a densely populated area where the surrounding buildings were old - therefore, the drill and blast method was not permitted for subsequent shaft excavation. The project team extensively deployed hydraulic breakers to excavate the rock strata. This method was very time consuming in comparison to the drill and blast method. While the Vakola and Maroshi shafts were completed in around 60 days, the Mahim shaft took over nine months to complete.

Deployment of TBM

Two Tunnel Boring Machines of Aker Wirth make, around 80 meters in length, were deployed for the project. The tunnel boring machines were lowered part by part from the respective shafts and assembled inside the assembly tunnel. The first TBM started working 11 months after the start of the project from the Maroshi end towards Vakola, while the second TBM commenced operations in 14 months from the Vakola end towards Maroshi. On an average, 13-14 meters of tunnel excavation was achieved in a single day. A record of 40 meters of tunneling was executed in a single

day with one tunnel boring machine, and a maximum progress of 543 m was achieved in a month. After completion of the tunnel boring, a concrete lining was provided, to give the tunnel a finished diameter of 3 m.

Heavy water seepage

For the tunnel stretches that were in close proximity to the coast line, saline water seepage was expected during the tunnel boring process. The Geotechnical survey conducted by the client had estimated seepage of 2,700 litres per minute during tunneling activity. However, during execution, very high seepage of the saline water was encountered to the tune of 20,000 liters per minute. This was equivalent to a volume two tankers of water per minute. This posed a severe challenge in the execution of the project. The project team deployed experts from Canada to tackle the situation. They proposed a new methodology where polyurethane foam was used as a grouting material beside the regular cement grouts. The entire amount of polyurethane for this process was imported from Belgium. Through extensive grouting, the seepage was lowered from an intensity of 20,000 liters per minute and controlled to a level of 100 liters per minute. To drain out the seepage water from the tunnel, heavy pumping arrangements were installed at each of the shafts. After pumping the saline water up from the shaft, it was sent to a sedimentation tank before being discharged into the drainage system.

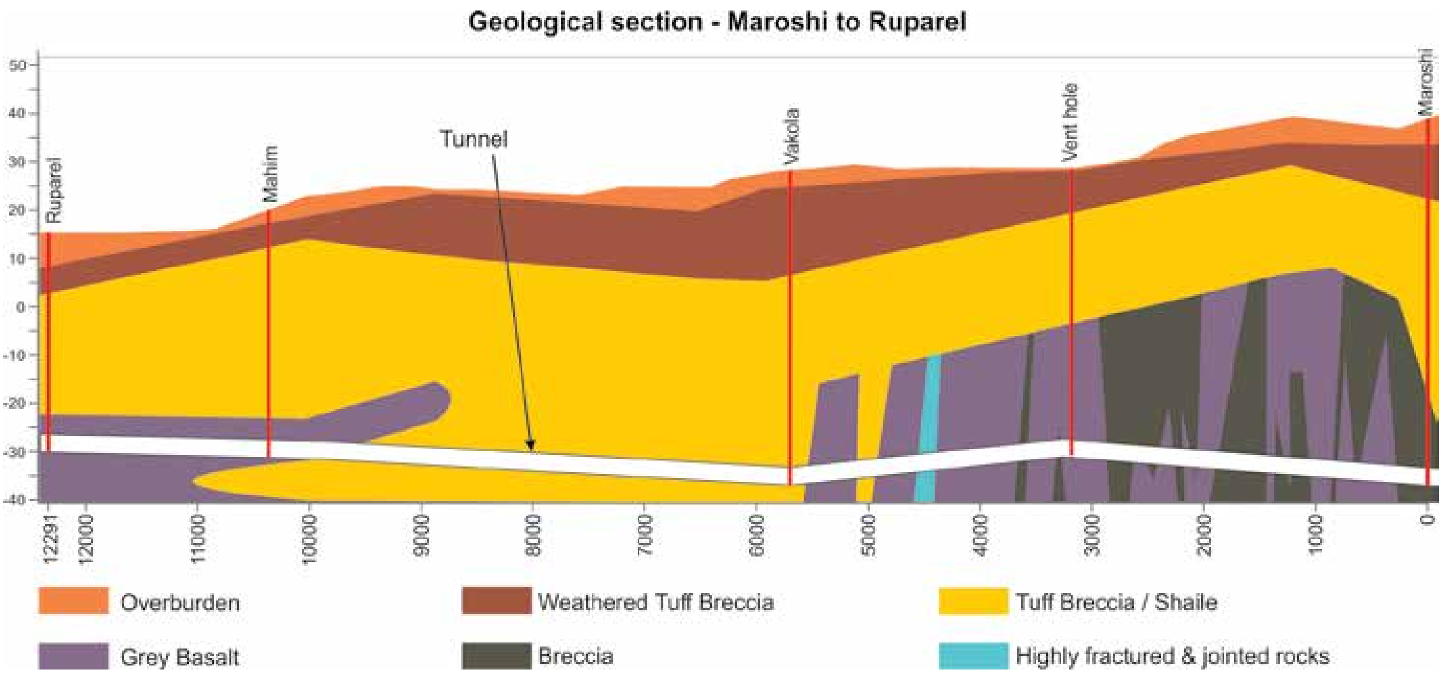
Poor Geology and variation in rock classes

The Geological survey of the entire work stretch from Maroshi to Ruparel College showed a wide variety of rock strata: including Weathered Tuff Breccia, Tuff Breccia / Shaile, Breccia, highly fractured and jointed rocks as well as Grey Basalt. Elaborate and systematic planning was done while tunneling through bad geological strata of the rock, including adequate safety measures. Across sections with loose rock, safety was ensured through widespread tunnel protection works: by fixing rock bolt, wire mesh, shotcrete, rib fixing and steel liner fixing.

Volcanic cavity

At one location on the Mahim stretch, the tunnel boring machine encountered a huge volcanic cavity. Luckily, it was located on one of the sides of the tunnel and a major catastrophe was avoided. It was lined with shiny calcite rocks that are generally formed by sedimentary mineral. The cavity was huge and the depth of the cavity could not be ascertained. Since the TBM had breached one of the sides of the cavity, it had started collapsing. The project team quickly began to deposit muck bags into the cavity. Initially, the depth of the cavity could not be ascertained and the bags being deposited kept disappearing into it. The team kept dumping muck bags into the cavity till the muck bags became visible and thereafter, the cavity was filled with concrete. Approximately, 40 cum muck and 90 cum of concrete was used to seal the cavity before proceeding with the tunneling.

Safeguard against poor geology: a) Rock bolt and wire mesh for shortcrete, b) Rib fixing, c) Steel liner fixing

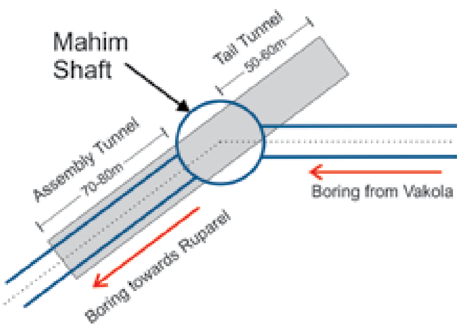


Realignment of tunnel route at Mahim shaft

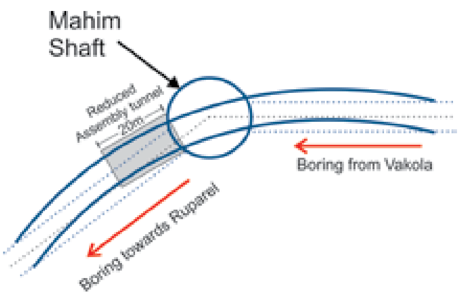
The tunnel stretch from Maroshi to Vakola to Mahim fell on a straight line alignment, whereas at the Mahim shaft it took a 35 degree turn to proceed towards the Ruparel college shaft. If the tunneling had to be proceeded at the same angle, it would have required an assembly tunnel and tail tunnel of 70 meters and 30 meters respectively at an angle of 35 degrees to the tunnel. Since the excavation and other activities at the Mahim shaft was executed by hydraulic breaking, all this would have consumed a lot of time to complete before beginning the TBM operations towards Ruparel College. The project team explored several options for realigning the tunnel between Vakola and Mahim so that it takes a smooth curve at Mahim shaft. However, making the 80 meter long tunnel boring machine to take a turn was a difficult proposition.

Nirmalya Deb, Acting Project Manager, elaborated, "The TBM had a conveyer belt that carried the muck to the wagons at the back which was around 50-60 meters long. It could have got stuck while taking the smooth curve inside the tunnel. To overcome this problem, the project team came up with an innovative idea. The engineers broke the conveyer into two parts with a flexible connection between them. This arrangement completely avoided the tail tunnel and required a very small assembly tunnel of 20 meters instead of 70 meters."

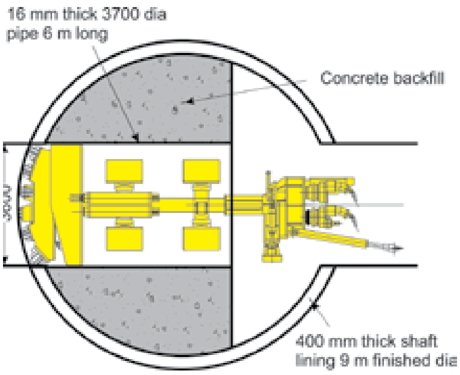
Conventional Method



Innovation



However, adopting this methodology was not very simple. It threw up another challenge. When the TBM came out at the Mahim shaft from one side, to further proceed in the same direction, it required a gripper. Building a gripper inside the shaft was a challenge. The project team came out with another innovative idea to construct the gripper inside the shaft. It lowered a 3.6 meter diameter pipe of around 3 meters length at the precise location inside the tunnel and covered the pipe with concrete to give it rigidity. This pipe acted as a gripper for the TBM boom and it enabled the progress of work towards the Ruparel shaft without any interruption.



The TBM kept boring till around 200 meters towards the Ruparel shaft. Subsequently, the gripper was removed from the Mahim shaft to make room for muck removal, dewatering and other ancillary activities. This operation not only saved the cost of digging the tail tunnel and assembly tunnel and later refilling it, but also saved a lot of time as the maintenance and assembly of the TBM could be executed in the already excavated space.

The inaugration of the project was done by Shiv Sena chief Uddhav Thackeray.

Major Quantities:

Excavation	1, 60,000 Cum
Concrete	55,000 Cum
Reinforcement	5500 MT
Chemical grouting	23500Kg
Cement grouting	1000MT

Equipment used

TBM	2nos
Probe drilling equp.	2nos
SLD Crane	3nos
Gantry Crane	1nos
Locomotive	14nos
CIFA Shutter	2 Set (36M each)
Mine Car	40nos
Agitator Car (6Cum)	6nos
Concrete Pump	2nos
Main Ventilation Fan	2nos
Muck Hoist Winch	2nos
Shotcrete Machine	2nos
DG	7nos
Compressor	6nos
Dewatering pumps	27nos
Excavator	2nos
Dumper	20nos

DID YOU KNOW ?

Underneath the 'Maximum City'

Even as hundreds of trains, flights and vehicles use the tracks, runways and roads above the city surface – yet deep down, about 200 feet below Mumbai, a team of engineers from HCC have been quietly burrowing a tunnel over the last six years as part of the Maroshi Ruparel water tunnel project.

An interesting aspect of the route alignment of the tunnel is that it passes below the Mahim creek, underneath the tracks of the Western Railway line and below the Mithi River near Bandra Kurla Complex. This water tunnel also runs beneath both the runways of the Mumbai Airport at a depth of around 70-80 meters below the ground level.