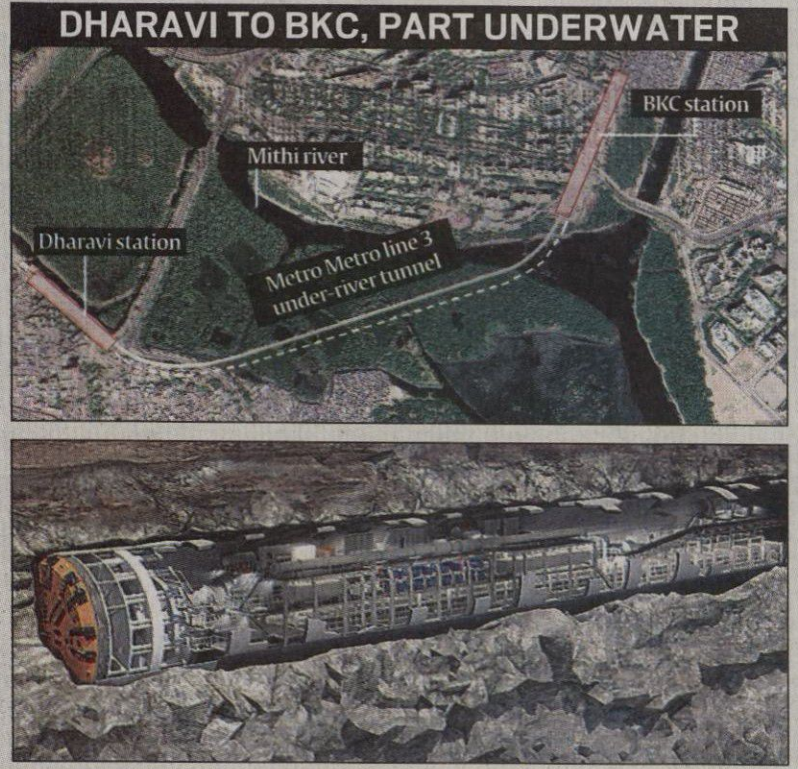
Tunnelling under the Mithi: how Mumbai Metro is meeting the challenge



33.5 km
Length of Colaba-Bandra-Seepz Metro, half completed

<2 km
Stretch from Dharavi to BKC stations, including underwater tunnel

15-20 m
Depth of tunnel below surface, equivalent to height of 4-storey house

Top: Layout of the underground Metro stretch between Dharavi and Bandra Kurla Complex stations, with part of it running underwater. *Above:* Typical illustration of a Tunnel Boring Machine excavating through rock. *MMRCL*

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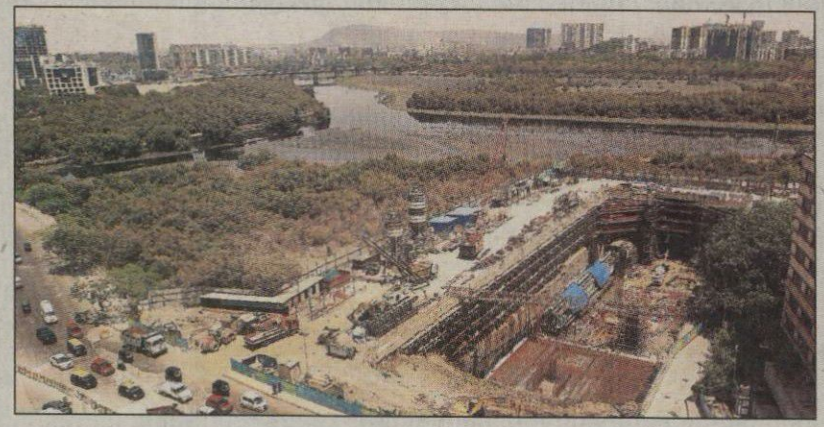
IN SPATE, the Mithi river in Mumbai rushed into headlines in 2005 when 944 mm of rain in the span of a single day saw much of the financial capital's suburbs under 4 to 15 feet of water. A clean-up of the river, which serves as the main drainage system and also an open sewer for large swathes of the suburbs, was carried out in fits and starts, but the river is back in the news for an ambitious technological milestone — India's second under-river subway tunnel.

Seventeen Tunnel Boring Machines (TBMs) lowered by contractors of the Mumbai Metro Rail Corporation Ltd into Mumbai's belly have now completed burrowing through about half the 33.5-km route of the Colaba-Bandra-Seepz Metro Rail, India's first fully underground Metro system.

Tunnelling has also begun between the Dharavi and Bandra Kurla Complex Metro stations, a distance of less than 2 km. Along this route, serving as a putrid partition between the throb of the slum's small scale industry and the affluence of the international commerce hub, is a mangrove thicket, part of the Mithi's estuarine mudflats, and a section of the river itself just before it meets the sea at Mahim creek. For the MMRCL, this means a 170-m section of tunnel that will be dug at depths of 15-20 m below the surface, equivalent to the height of a four-storey building placed just under water.

Why is this a milestone in tunnelling?

The pitfall here is not the depth — it's the challenges that come with tunnelling below a water-body, mainly preparing for unexpected behaviour of soil owing to water, the pressure, and the possibility of mud and water rushing into a just-constructed tunnel section. The only other under-river tunnel for a mass transit project in India runs beneath the Hooghly in Kolkata, completed two years ago.



Metro construction in progress near the Mithi, as seen from BKC. *Pradip Das*

The soil under the Mithi is not even — it's mostly brecciated basalt, some of it weathered brecciated basalt, and with silty or gravelly weak points, all mapped out meticulously.

The main tunnelling is done by TBMs with Earth Pressure Balance (EPB) shields. The EPB face monitors and adjusts pressure inside the cutterhead of the TBM, balancing the earth's pressure. The EPB shield is also sealed against fluid pressure outside.

In addition, a 153-m section at BKC station, part of which will be in the water-body, includes cross-sections for a third line, meant for stabling, emergency turnarounds, etc. This cross-tunnelling will be built with the New Austrian Tunnelling Method (NATM), which uses traditional excavators very slowly, minimising damage to the soil formation around the tunnel by immediately "shotcreting", or spraying concrete on excavated section walls. According to S K Gupta, Director (Projects) at MMRCL, the philosophy of NATM is to use the strength of the soil or geological formation around the tunnel to support it. "NATM tunnelling is be carried out slowly, in three parts — the top of the tunnel or heading, the centre or benching and the floor or the invert. As you proceed, you have to almost feel the ground, watch it closely and see how it's behaving, to understand to what extent it needs to be supported," said Gupta.

Why use NATM over regular TBMs?

While TBMs need to achieve a breakthrough at the far end, through a second shaft or retrieval shaft, NATM machines can be halted and reversed. MMRCL is using NATM wherever a third or siding line is to be built and also where narrow station spaces do not have room for a TBM shaft.

Also, NATM is ideal for substrata such as under a riverbed, as the design relies on the strength of the surrounding rock or soil to support the tunnel, while shotcrete protection minimises damage to the rock. Shotcrete is concrete sprayed immediately upon tunnelling. As the machine advances, the construction of the permanent lining takes place.

How do they prevent rock face collapses?

Various support measures are used during NATM work, including wire mesh and lattice girders. To reinforce the surrounding terrain, rock bolts and steel arches are affixed to prevent loose soil or water from entering the tunnel. Simultaneously, holes are drilled in advance to place steel pipes that will provide added support to the tunnelling machine.

Are other support measures in place?

TBMs do not only bore through rock or soil, they also provide support on the inside of the tunnel. As the machine advances, the cutter drills the rock even as grout is pumped out and bolts are attached to make sure no collapses occur. A permanent lining on the inside is also laid mechanically — six precast concrete segments forming a ring for every step forward, laid mechanically by an erector arm. The gap between the excavated radius and the radius of the precast ring is filled with grouting. In fact, according to MMRCL engineers, the only risk is during the tunnelling — once the permanent lining is erected, the balance is restored.