HCC completes up-line tunnel for DMRC CC30

The 2.2 km twin-tunnel of DMRC's CC30 package, part of the 59km long Majlis Park to Shiv Vihar Metro Corridor of Phase III.

Background

Delhi Metro, the second metro system constructed in India after Kolkata Metro, is a modern public transport system. It consists of a network of 190 kilometers, servicing 141 stations of which 35 stations are underground, 5 are on ground and remaining are elevated. Delhi Metro Rail Corporation (DMRC), a state-owned company under administrative control of the Ministry of Urban Development is involved in the planning, implementation and operations of the Delhi metro system.

The Construction started on October 1, 1998 and the first section the Red Line was opened in 2002 followed by the Yellow Line in 2004, the Blue Line in 2005, its branch line in 2009, the Green Line and Violet Lines in 2010, and the Delhi Airport Metro Express in 2011.

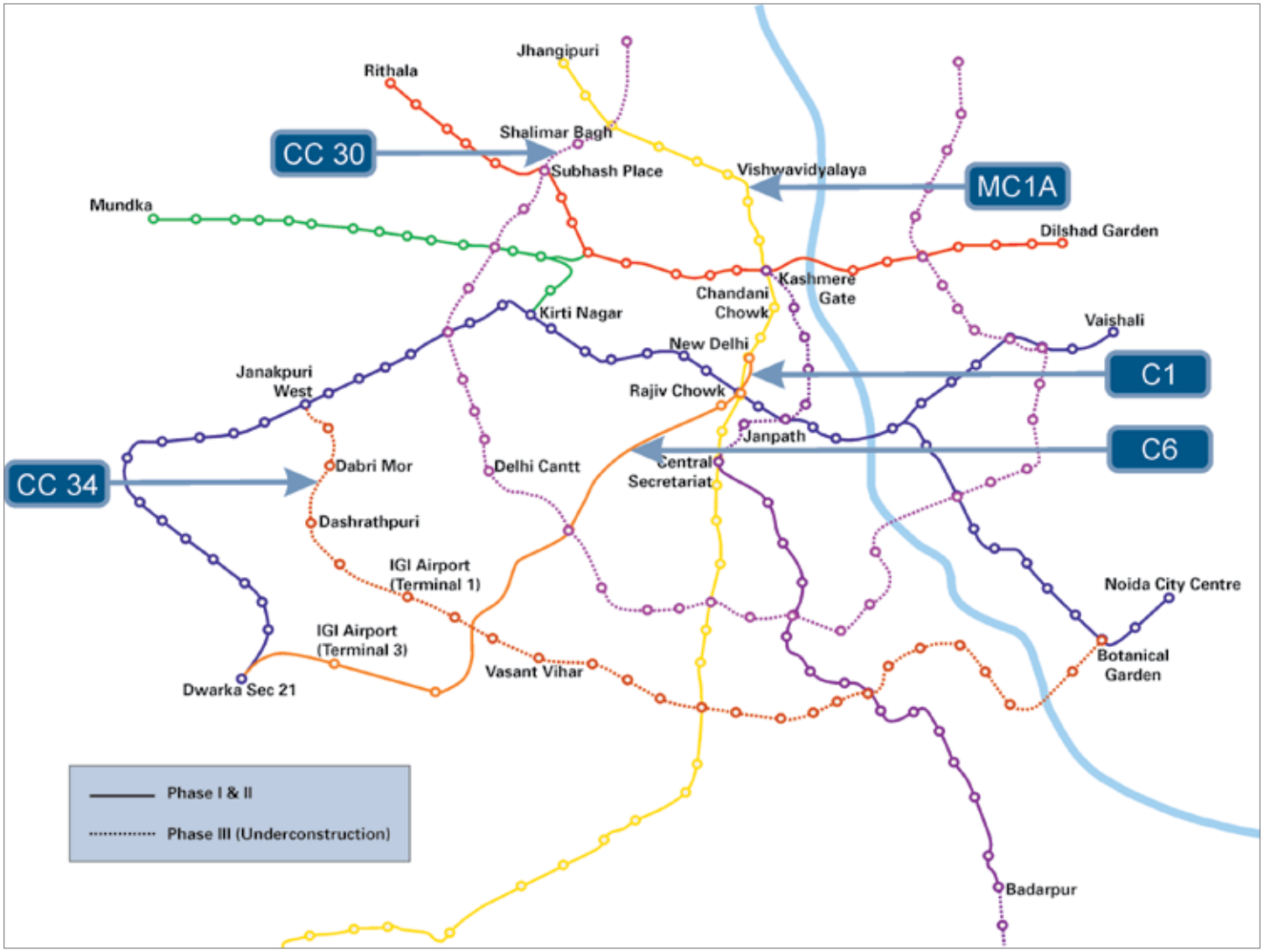
The entire network was planned to be built in phases spread over approximately 20 years. Phase I (65 km) and Phase II (125 km) were completed in 2006 and 2011, respectively, and Phase III and Phase IV are scheduled for completion in 2016 and 2021, respectively. Work on Phase III started in 2011 while planning for Phase IV has begun.

Phase III will have 28 underground stations covering 41 km. After completion of Phase III the passenger traffic is expected to go up to 4 million. Till Phase II, Delhi Metro focused on expanding the reach of the metro and thus built long radial lines. However, in Phase III, Delhi Metro is aiming to interconnect existing lines by ring lines to improve connectivity. This will not only help in reducing distances but will also relieve radial lines of some congestion.

The total length of the underground corridors in Delhi Metro's proposed Phase III will be almost equivalent to the total underground sections built so far by DMRC in both Phase I and Phase II, making it one of the most challenging construction phases. The 59-km long Majlis Park-Shiv Vihar corridor of Phase III consists of about 14kms of underground lines. Presently, five other TBMs are working in different parts of the corridor across the city. In total, 19 TBMs are operational for the tunnelling works of Phase III. In addition to this, DMRC is slated to construct 53 km of underground Metro lines as part of its Phase III construction work for which about 34 TBMs are expected to be used. A total of 74 tunnels will be constructed in this phase.

Contribution in Delhi Metro

HCC is involved in five packages of the underground section of the Delhi Metro. The first package MC1A was awarded to construct a 4.142 km long tunnel from



Vishwavidyalaya Station to ISBT station on the Yellow Line. The project was completed eight months ahead of schedule in December 2004. The next two packages were part of the Airport Express Line which include C1: a 2.2 km long twin bored tunnel and a 1.3km cut and cover tunnel From New Delhi station to Rajiv Chowk and C6: a 2.6km long NATM tunnel from Talkatora area to Buddha Jayanti Park. The route alignment for this Metro line passed below various heritage structures and buildings of national importance. The tunnelling depth below the Rajiv Chowk Metro station at 44m was the deepest ever for the Delhi Metropolitan Region, going below two existing lines. C1 was awarded in September 2007 and completed in July 2010 whereas C6 was awarded in Dec. 2007 and completed in Feb. 2011.

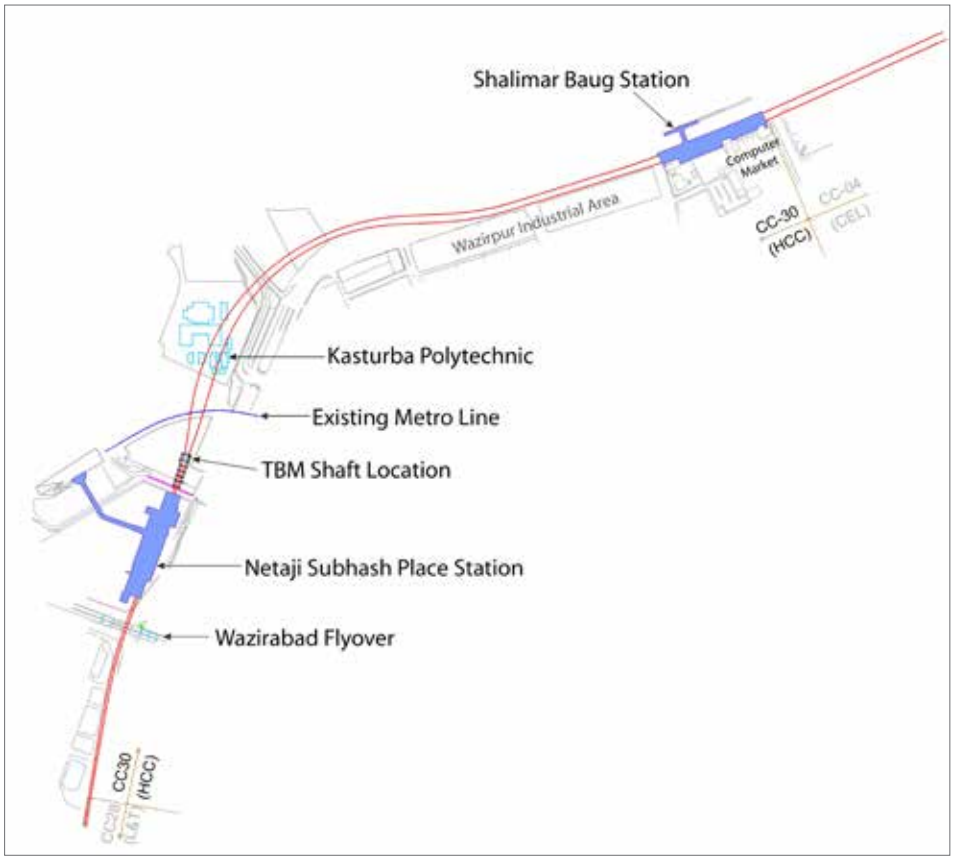
The CC30 package of the 2.2km twin tunnel between Shalimar Bagh and Subhash Place stations (Pink Line) on the Mukundpur-Yamuna Vihar corridor was awarded in October 2012. The most recent package awarded to HCC is CC34 package involving design and construction of a 4.4 km long tunnel on Janakpuri West–Kalindi Kunj Corridor (Brown Line) under Phase III of the metro development.

CC30 Package

The CC30 package of DMRC is part of the 59km long Majlis Park to Shiv Vihar Metro Corridor (Pink Line) of Phase III. The scope of work includes design & construction of the twin tunnel between Shalimar Bagh and Subhash Place stations by Shield TBM, twin box tunnels by cut & cover method, underground ramp, architectural finishing of Shalimar Bagh station (underground) and Netaji Subhash Place station (semi-underground).

The notice to proceed with the work was issued on October 29, 2012 and HCC immediately undertook the detailed geo-technical investigation of the project along the alignment of the project. The soil was tested by drilling boreholes at nine locations and samples extracted were tested in the laboratory. The detailed investigation revealed that the soil along the project alignment was sandy silt and silty fine sand primarily. It was medium dense to highly dense at the depth of 30 meters. The ground water was encountered at about 11 to 15 meters depth. The geology along the alignment of the tunnel was of mixed type. (graphical representation of the geology).

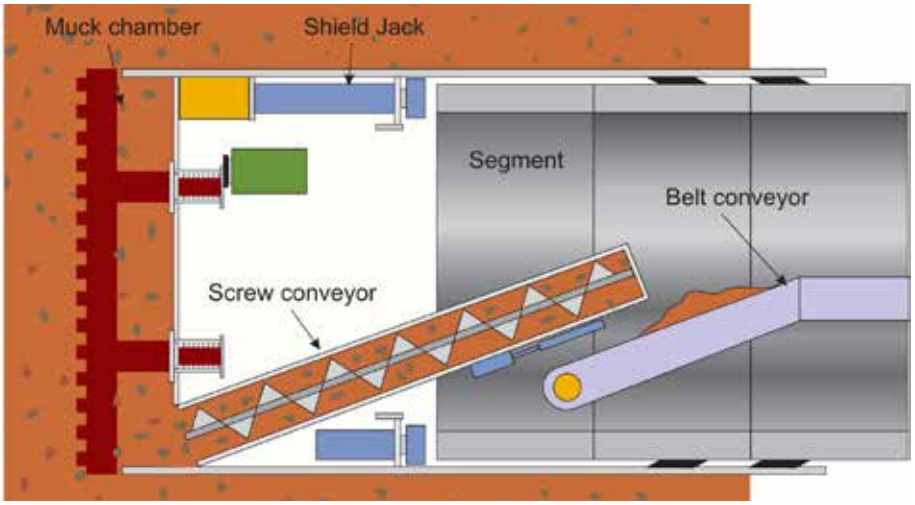
Based on the geo-technical study done by DMRC during the tender stage, Earth Pressure Balance Tunnel Boring Machine was finalised for the tunnelling. Earth Pressure Balance (EPB) TBMs are used in excavation of soft ground or soil condition. The EPB method consists of cutting chamber located behind the cutter head of the TBM. This chamber is used to mix the soil with water foam. It is maintained under pressure by the mucking system. The ground at the cutting face is supported by earth pressure by balancing the advancement of the tunnel



with the discharge rate of the excavated soil.

The underlying principle of the EPB method is that the excavated soil itself is used to provide continuous support to the tunnel face by balancing earth pressure against the forward pressure of the machine. The thrust force generated from the rear section of TBM is transferred to the earth in the cutter head chamber so as to prevent uncontrolled intrusion of excavated materials into the chamber. When the shield advances at the face of excavation, the excavated soil is then mixed together with a special foam material which changes its viscosity or thickness and transforms it into a flowing material. This muck is then stored and is used to provide support and to balance the pressure at the tunnel face during the excavation process.

The CC30 package orientation is north-south with Shalimar Station located on the northern end and an underground ramp on the southern end of the project. The northern boundary of the project is shared with CEC who is working on DMRC's CC04 package and on the southern boundary where L&T is working on the elevated corridor package of CC28.



Operations of Earth Pressure Balance Tunnel Boring Machine

Construction sequence

The Shalimar Station location was the first area handed over to HCC for work. It is a complete underground station and goes up to 30 meters deep. After barricading the area, underground utilities shifting was the first task undertaken before commencing the excavation work. First the 1500 mm diameter PSC pipe line and MTNL Lines were shifted, after which the electrical lines of 11 KV and 33 KV were shifted. Prior to shifting, the permissions from TATA Power Delhi Distribution Ltd. were taken.

Shaft location next to the Netaji Subhash Place station on the southern part of the CC30 package, was the second area handed over to HCC for construction. The shaft is of 20 m in length, 17 mtr in width and is 12 mtr deep. Soldier piles are drawn at the periphery of the shaft to stabilize the ground. Between the shaft and Subhash Place station area is a 75 mtr long tunnel done by the Cut and Cover method. The entire length of shaft plus the cut and cover tunnel area was utilized for installation of TBM. After lowering the TBM part by part and assembling it in the Shaft and Cut and Cover area, it started its drive towards Shalimar Bagh Station. The Cut and Cover area was an added advantage to assemble the TBM in one-go before the start of the Initial Drive. The Subhash Place station was the next area handed over to HCC to begin work. This station is semi-underground as only 12 mtr of this station is below the ground level and the balance is above.

In the Cut and Cover area there were three PSC pipe lines of 800mm, 900mm and 1100mm diameters which were to be diverted before the start of the excavation for which the approval from the owner agency was to be obtained. HCC initiated the documentation to seek approval. However, the permission formalities for shifting these utilities was taking considerable time. Hence, in consultation with DMRC, it was decided to hang these pipelines with the help of a temporary bridge to proceed with the work on the station and the excavation was completed. The station was built with the bottom-up approach where soldier piles are built first to stabilise the ground, then the excavation starts followed by the intermediate construction sequence.

Challenges encountered

While tunnelling in an urban environment, utmost care is taken so that the underground construction activities do not disturb the buildings on the ground. Along the alignment of the CC30 tunnel, there are various new and old buildings. A detailed study was undertaken to find out the status of various structures, their building foundations and adequate steps were taken including stabilisation of ground and continuous monitoring during the TBM drive so that these structures were not disturbed. For instance, adjacent to the Shalimar Bagh station there is a shopping centre where the distance between the two is bare minimum. A rigorous scheme of instrumentation was set-up on this structure to measure deflections if any. Instruments like 3D tilt meters, Ground Settlement Markers (GSM), inclinometer...etc were set-up to measure the slightest variations as minute as few millimetres. These were monitored continuously during the construction phase.

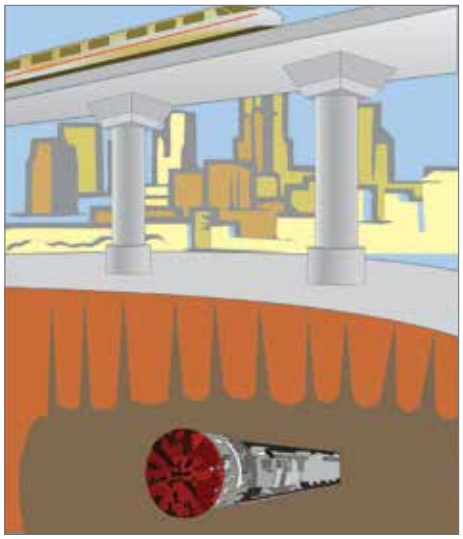
The first major challenge encountered after commencing the TBM operations was crossing the via-duct. Around 138 meters from the TBM entry point the tunnel was crossing between the piers of the via-duct of an existing metro line. The depth of tunnel below the ground level under the viaduct was only 10 meters. While planning the project, DMRC had taken care to draw the tunnel alignment between the two pillars. The challenge was tunnelling between these pillars without disturbing the pillars in any way. HCC did a three dimensional analysis of the area using "Plaxis" software suggested by its Drawing Design Consultant (DDC). The instrumentation was in place to measure the volume loss during tunnelling and it was not allowed to cross 0.3 per cent. The soil condition was clayey with significant water presence. Hence the ground between the pillars was strengthened by TAM Grouting. TAM grouting is done by drilling boreholes in the soil and injecting cement slurry under pressure so that all cracks or fissures gets filled with the slurry. This process consolidates the ground so that there is no lateral deflection on the piles during tunnelling. Around 90 boreholes were drilled between these two pillars to make the muddy ground hard for tunnelling. After consolidation of the ground a sample piece was tested for the required strength and then tunnelling process began under the viaduct. While tunnelling the vibrations caused by the TBM drive were measured. The vibrations during tunnel driving was less than the one caused by the movement of the train on the viaduct.

The TBM is lowered in the shaft piece by piece and assembled for the drive towards Shalimar Bagh Station

The next challenge was tunnelling under an existing canal. The tunnel was passing under the canal at a depth of 14 meters. Though the canal had very less amount of water in that season, the lining of the canal was weathered. Due to seepage of water, the ground under the canal was muddy. A similar exercise was carried our while tunnelling under the canal by putting various instrumentation and regular monitoring of the soil conditions during tunnelling. Thus the TBM could successfully be used without disturbing the canal.

Rajesh Kumar, HCC's Project Manager for CC30 project explains, "All along the tunnel alignment we installed intensive ground instrumentation and monitoring schemes such as ground settlement monitor and settlement markers in order to study the impact of TBM on above ground structures.

The tunnel passed under some of the landmark structures such as Kasturba Polytechnic building, Kendriya Vidyalaya and even the slum area where the building conditions are very poor. In addition, while carrying out the tunnelling work, proper care was taken while finalising the alignment of the tunnel that it did not infringe the Pile area of the 'Azadpur



Tunnelling below two pillars of the viaduct

HCC team celebrating the break-through of up-line tunnel achieved on March 13, 2014 at DMRC's CC 30 project

TBM begins the drive from the shaft area

Concrete slurry being sent inside the tunnel

to Prem Bari fly over'. TBM steering was difficult in the last 500 mtr excavation as the strata encountered in this stretch was clayey wherein driving of TBM was difficult. Despite these challenges we managed to complete construction of Tunnel 1 without causing any damage to the structures on ground and also without affecting the movement of the Traffic which runs over Ring road."

The tunnel boring began in October 2013 and completed the 1,247 meter long tunnel from Netaji Subhash Place to Shalimar Bagh consisting of 1,037 rings with a finished diameter of 5.7 meter in 111 days. The average monthly boring progress achieved during the construction was 337 meters with installation of over 9 rings per day.

Mr. Mangu Singh, Managing Director DMRC said, "This was the last package awarded on Line 7 of Phase III of Metro and despite starting last, HCC has completed the work ahead of all other contractors. This was a very challenging job as the tunnel is built without any disturbance to the surface traffic running on the Ring Road above. The tunnel crossed the elevated viaduct of the currently operational Dilshad Garden — Rithala Metro corridor near Netaji Subhash Place, which also was a major engineering challenge."

"Despite delays in handing-over the land for construction, HCC engineers have managed to achieve all the planned milestones within time. It is one of the best examples of meticulous planning and execution. Above all, I am proud that we have achieved this feat without a single reportable accident or incident and without losing a single man-hour due to injury. Around 500 workers worked round the clock to complete the up-line tunnel and till the completion of up-line tunnel the total man-days worked were 219,507. This has been made possible only because of the passion and commitment shown by the entire project team," said Raman Kapil, Project Director, HCC.

Finishes section of the up-line tunnel

Equipment Used

Name	Quantity
Grouting Plant -18 cum	01 No
Tower Crane 10 Ton @30 mtr	01 No
Locomotives – Schoma / Atlas Copco 25 MT	03 Nos
Gantry Crane – Demag 25 MT	01 No
Compressor GA 45	01 No
MAI Pump	01 No

DID YOU KNOW ?

History of TBM used in CC 30 Project

HCC has used a tried-and-tested tunnel-boring machine (TBM) for CC30 package of DMRC's Phase-III development. This is one of the oldest TBMs to be used in Delhi Metro projects.

- TBM was built in Schwannau, Germany at Herrenknecht AG 1995 for Tunnel Construction in Taiwan. The Serial No Specification of the machine during that time was HK-EPB-S-81. After Completion of works the TBM was relocated to Thailand Bangkok for Tunnel Construction
- Then it was sent back to Germany for refurbishment. Once the refurbishment was completed, the machine was sent to India for Delhi Metro Project. It was used for construction of Line 2 in Phase-I and for extension of Line 2 in Phase-II of Delhi Metro.
- After Completion TBM was refurbished in Delhi itself and used for MTG – Tunnel Project.
- This Machine was then refurbished by HCC for DMRC CC 30 Project in 2013. The second Drive (Tunnel 2) of DMRC CC 30 is expected to start on 1 st May 2014.
- HCC Plans to refurbish the TBM on completion of the second drive (Tunnel 2) – DMRC CC 30 Project and use the same for New Project DMRC CC 66 Project.

This machine can still tunnel for 10,000hrs or 8-9km.