Construction of Underground Metro Stations and Associated Tunnelling

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The population of Chennai in 1639 was 40000 and today the city is estimated to have a population of 7.5 million, which gives a population density of about 6482 per sq. km. The city, with its present population generates about 11 million trips in a day, with about 6 million vehicular trips. The ever growing vehicular and passenger demands coupled with constraints on capacity augmentation of the existing network have resulted in chaotic condition during peak hours of the day.

A number of transportation studies were carried out in the past for Chennai Metropolitan Development Authority (CMDA). These studies discussed travel pattern, network characteristics and the degree of traffic saturation on the existing roads in the Study Area. The proposed high capacity, high frequency metro will not only be a cheaper mode of transport but also provide for a safer, reliable and better customer service. A feasibility study was carried out in 2003 to select and priorities the corridors for Chennai metro. Based on detailed traffic surveys seven corridors were identified.

The Metro rail will wind its way at a speed of 80 km/hr through the city over a distance of 45.1 kms of which 24 kms will be entirely underground. Total area of land required for the construction of Metro is approximately 50 hectares equivalent to 100 football fields. The project is estimated to cost 14000 Crores INR of which 41% will be contributed by the Central and State Governments. The remaining amount will be funded by a loan from Japan International Cooperation Agency (JICA).

L&T has been one of the leading construction company having prior experience working in similar projects however, the Chennai Metro construction comes with its share of challenges and difficulties. In the construction industry each site is unique in various aspects and the features of the site should be analysed and incorporated right from the tendering stage of the project. In case of metro construction, even though the basic methodology remains same for Delhi and Chennai Metros, the variation in the soil and climatic conditions of the two cities will result in variation of project duration and equipment and labour deployment.

The contract value of the project is 930.8 crores. Chennai Metro Rail Limited (CMRL) is the client for the project and they have nominated M/S Embye as the general consultant for the project. The design consultant for the project is the award winning consultants: M/s Mott MacDonald Pvt. Ltd.

After successful completion of many stations in Delhi Metro Project, L&T in a JV with Shanghai Urban Construction Group (SUCG) is now executing the project comprises of the design and construction of all works and services necessary to complete the underground section from the west end of Egmore station (Egmore station not included in UAA-04) to the south end of Shenoy Nagar station (Shenoy Nagar station not included in UAA-04) in Corridor 2, i.e. Nehru Park Station, Kilpauk Medical College Station and Pachaiappa’s College Station each of 228m. Design and construction specifications, include the following:

- Survey and Handing over of the project land and associated site clearances.
- Traffic Diversion for undertaking station works with alternate roads and steel decking
- Diverting utilities from the station zone.
- Construction of Diaphragm wall including temporary & permanent plunge columns as station retaining structures and load bearing columns respectively.
- Construction of launching shaft for TBM Drive.
- RCC Slabs Construction at three different levels i.e. at roof level, concourse level and base level.
- Selection of tunnel Boring Machine (TBM- Earth Pressure Balance type) manufacturing and shipment to site.
- Construction of TBM launching chamber
- Lowering, Assembly and commissioning of TBM for...
construction of tunnel.
- Segment Ring Casting at precast yard for feeding as liner to tunnel.
- Tunnel Drive for down line till next shaft and relaunching.
- Tunnel Drive for up line till next shaft and relaunching.
- Construction of TBM retrieval chamber
- Cleaning of tunnel and installing accessories including walkways and cross passages.

8. Interface and support for various system works like track laying, the overhead catenary for power, passenger gates, signalling and telecom, VAC and AHU systems along with lifts and escalators

9. Architectural works matching with heritage structure nearby for main station box and entrances including signages.

10. Electrical & Mechanical works including plumbing, drainage, fire fighting and electrification.

11. System integration and trial testing.

12. Provision of station and substation structures, utility diversion and relocation etc.

13. All works necessary to provide inter-modal transfer facilities for pedestrians & road user of ground level and access into station.

14. All temporary and permanent utilities including foul drainage to be connected into public services.

<table>
<thead>
<tr>
<th>Major quantities</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diaphragm wall</td>
<td>55,000 sqm</td>
</tr>
<tr>
<td>Piles</td>
<td>4250 rmt</td>
</tr>
<tr>
<td>Excavation</td>
<td>3,40,000 cum</td>
</tr>
<tr>
<td>Concrete</td>
<td>1,35,000 cum</td>
</tr>
<tr>
<td>Reinforcement Steel</td>
<td>18,600 mt</td>
</tr>
<tr>
<td>Structural steel</td>
<td>1850 mt</td>
</tr>
<tr>
<td>Waterproofing</td>
<td>41,000 sqm</td>
</tr>
<tr>
<td>Tunnel Segments</td>
<td>5670 Nos</td>
</tr>
</tbody>
</table>

Major Plant and Machinery Availability

We cannot imagine Metro without machineries, as it presents many civil engineering challenges at sites involving greater heights and deeper depths. Many challenges have been met successfully through deployment of new expertise, sophisticated machinery and equipment at the site to execute any work. So we have mobilised many high capacity cranes like TFC-280 and QUY-80, medium capacity cranes of make P&H 335, P&H 440,EOT cranes, casagrande rigs BH 180, DG’s of various capacities ranging from 250 Kva to 62.5Kva , and many excavator including long arm excavators, overhead gantries for executing various activities of the project. This is in addition to tunnel boring machine and related specialised equipment required for tunnelling with 5 nos. of silent diesel generators of 1012 Kva capacity each and batching plant for concrete and grout production.Cranes are provided with Safe Load Indicators (SLI) and tools & tackles are all inspected by an external agency before implementing at work.

Tunnelling by Tunnel Boring Machine and Related Instrumentation

Since tunnelling can result in a significant range of vibrations to the adjacent buildings, instrumentation in all locations adjacent to the tunnelling areas is required. Monitoring instruments which are given below and many more are installed to monitor the movement and of structure on a daily basis.

1. Settlement Points used for monitoring vertical settlement on horizontal and vertical surfaces of a building or a structure.
2. Piezometer which is used for measuring magnitude and distribution of pore water pressure and its variation with time.
3. Inclinometer which is designed for measurement of lateral movement of any structure.
4. Load Cell used for measuring and monitoring forces on a modular structural strutting.

The Tunnel Boring Machine is a huge, incredible piece of equipment that can forge its way through hard rock, sand or soil, hollow out tunnels without any disturbance to the surroundings. In CMRL UAA-04 project, two nos. TBM is being used for the project to match with the project speed. The TBM have been especially design for encountering mix strata and accordingly the cutter disk and other components are design by specialist with various design parameters which took nearly six months of manufacturing and two months of shipment from Shanghai to Chennai.

Major Components of TBM

1. Cutter Disc- To excavate rock or soft ground by the rotation of an assembly of teeth or cutting wheels under pressure against rock face.
2. Shield Skin- keeps the soil from getting into the machine and to provide a safe working space for the workers.
3. Pushing Jack- To be in full contact with the erected segment and hydraulically extend as the cutter disk turns and thrusts forward.
4. Main Drive- To provide a force in rotating the cutter disc.
5. Screw Conveyor- To move the spoil at the cutter disc and feed onto a conveyor system.
6. Erector- To erect the segments to form a complete ring after shifting upto the tail of the TBM.
7. Backup facilities- To travel with the TBM and to service the operation of annulus grouting, welding, extension of ventilation, power and track etc.

The TBM goes in four sections, both up line and down line through the tunnel alignment.

The TBM can work continuously for 10,000 hours and can bore at an average speed of 8mm/min. The total weight of all the components of the TBM is more than 400 tonne with maximum weight of one of the component is 120 tonne which requires a great deal of logistics to handle from the port to the project site and lowering into the 20m deep shaft. The TBM while in operation exerts a maximum force of 45,184 kN. The TBM will operate at an average speed of nearly 6m/day in rocky strata and of an average speed of 10m/day in soil strata and the boring will continue at depths of 22 to 27 m below ground level.

The length of the TBM is 78 metres in total and the outer diameter of the cutter head is 6.3 m. The initial drive of the TBM will be to a distance of 10 m which is equal to the length of the cutter head and associated accessories. We are providing every safety measures for the tunnelling as the TBM alignment passes below many high buildings. We are providing every safety measures for the tunnelling as the TBM alignment passes below many high buildings. The ring consisting of 6 segments of 1.2 m width, 275mm thickness and 3.7 m length for each of the 5 segments and 1.3 m for key segment used for lining of the tunnel which is being cast at the casting yard in Vayalanallor. The surface logistics for the transportation of the segments has been planned in such a way that the segments can be brought to site with minimum hindrance to the public while minimising the travel time of the segments from the casting yard to site. One 40 tonne trailer can carry 2 segments and each shift will be requiring 6-8 trailers of delivery depending upon the progress of the tunnel.

Planning for the Construction

Considering the complex nature of project involving various disciplines and interface with many system wide contractors spreading over more than 4000 activities interlinked to each other hence a Detailed Works Programme (DWP) required to be prepared in the beginning of the project considering base line and key dates, target dates of the contract. The programme is updated regularly based on the actual site condition and land availability and other parameters. The construction team follows the programme and update regularly based on various inputs from time to time. The micro schedule which has been prepared is regularly updated. The scheduling is being maintained in Primavera for easy updating and monitoring.
Project Details

Our Project Construction Mainly Consist of

The project mainly consists of the construction of Diaphragm wall, which act as a retaining structure and boundary for our station. The diaphragm wall is constructed for every 5 meters of the station length and goes upto the depth of the station. Koden test and sonic logging test are done for checking the verticality and D-Wall integrity respectively. Some of the chemicals like Geosoil Polymer are used in the trench for its stability during 25 m of trenching work before putting the reinforcement cage inside.

Launching shaft is constructed to launch and retrieve the tunnel boring machine. For Launching Shaft construction excavation has to be done depending on the Top Down Construction (excavation from top to base with the use of struts to retain the structure) or Bottom Up Construction (excavation from base to top with the construction of slabs). Dewatering is also being done before the excavation for removal of the water through dewatering wells. The excavated muck is transported to the dumping yard situated at 35 km away from project site at night time ensuring the cleaning of each dumper on wheel washing bay to prevent the dust accumulation on road.

Metro station slabs are to be constructed in three levels; viz. base slab, concourse slab and roof slab level having 6m vertical clearances in each level. The slabs will be constructed using a combination of top down method at the shaft locations and bottom up method at the station areas. Waterproofing above and below slabs wherever necessary is being done to prevent the water leakage.

Cross Passage

Cross passages(CP) are connecting tunnels and are to be provided at regular intervals to evacuate passengers in case of any emergency. The cross-passages will be provided at 250 m intervals. Before starting the cross passage excavations, it is necessary to improve the soil characteristics around CPs. High pressure jet grouting method will improve the soil stabilization.28 days later,

there will be a core test to confirm the soil is strong and stable. The cross passage will be constructed using NATM method with suitable waterproofing measures having a provision of sump at the deepest location of the tunnel

Internal Activities and Finishing Inside Tunnel

<table>
<thead>
<tr>
<th>Location</th>
<th>Area in m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nehru Park</td>
<td>17522</td>
</tr>
<tr>
<td>Kilpauk Medical College</td>
<td>12460</td>
</tr>
<tr>
<td>Pachiappa College</td>
<td>13328</td>
</tr>
</tbody>
</table>

The Total Area Required for the Construction in the Three Sites of UAA-04 Package is
The segment lining will provide the required architectural finish for the tunnel. Dimples have been provided in the segments at the time of casting for drilling and cable laying. The rail will be placed over a base support with adequate drainage.

Walkways

Walkway will be provided for service personnel and emergency rescue. It is also known as Escape Walkways which provides continuous access from the train to the cross passages and station platforms and having a width of 966 mm at train floor level.

Quality initiatives

The Metro work has to be executed with full quality control and guaranting the overall life of the project as 120 years following all the codes and specification laid. Many varieties of test are conducted for ascertaining the quality of activities in hand like Sonic logging test for D-Wall integrity, Pull out test for couplers, adiabatic test for temperature control, Proctor test for compaction. The quality team work towards ensuring proper quality standards of the raw materials such as cement, sand, aggregates, admixture, as well as concrete of M20, M35 & M50 and fabricated steel. The quality laboratory is well equipped with scientific instruments calibrated to conform to Indian Standards and to test the materials at the required testing frequencies.

Safety Health & Environment

- Ensuring cleanliness of the road. Deployment of separate housekeeping workers

Provision for environmental impacts of this Metro corridor has been made to cover various protection works, additional compensatory measures, and compensation for loss of trees, compensatory afforestation and fencing, monitoring of water quality, air/noise pollution during construction is done. For every one tree cut 12 trees are planted and maintained.

The safety department conducts regular pep talks and training sessions for workers and engineers. Regular audits are conducted on site and the safety issues are addressed immediately. The project is certified by BSI-ISO and OSHAS and recently was conferred with the RoSPA award.

Past Metro Project executed by L&T

L&T’s association with Metro Business started a decade back when it bagged the first elevated package of Delhi Metro followed by 6.6 km of underground metro corridor including construction of six underground stations. Subsequently for DMRC Phase2, L&T has completed 4.65km twin
tunnel and 3 stations by cut & cover method on standalone basis and with joint venture companies have completed 10.72km twin tunnel by TBM & two number of stations.

10. The Chennai metro is very conscious of the needs of disabled people and will make all efforts so that they do not face any difficulties. All our stations will have ramps from the streets so that wheelchair-bound persons can directly roll up to the lifts. The lifts will move to the concourse level where the ticketing counters are located. From the concourse level, other lifts will take them to the platform level. Signs have also been put up outside all lifts that these are exclusively for the use of disabled persons.

The control panels inside all the lifts are placed at a low level so that persons on wheelchairs can access these without having to strain themselves. Disabled commuters can also expect accessible seating on the trains, as well as Braille instruction signs and audio announcements.

Benefits of Metro to commuters

1. Time saving for commuters
2. Reliable and safe journey
3. Reduction in atmospheric pollution
4. Reduction in accident
5. Reduced fuel consumption
6. Reduced vehicle operating costs
7. Increase in the average speed of road vehicles
8. Improvement in the quality of life
9. More attractive city for economic investment and growth

The above facilities will be available to the commuters by 2015.

Researchers from the University of Arkansas have come up with using a special mixture of concrete which is cheaper, effective and safer to store heat produced at concentrating solar power plants. The researchers say that a thermocline system that is hot on top and cold down below using parallel plates made of their proprietary concrete in a single storage tank in particular packed rock can conduct heat with an efficiency of 93.9 percent. The most efficient, conventional method of storing energy from solar collectors satisfies the U.S. Department of Energy's goal for system efficiency, Panneer Selvam, professor of civil engineering said. Filler material used in the conventional method could lead to catastrophic rupture of a tank. The researchers said their tests confirmed that the concrete layers conducted heat without damaging the materials used for storage. And, they said, the cost of energy storage using this method is a mere 78 cents per kilowatt-hour. The Arkansas system employs plates that were developed by Micah Hale, an associate professor of civil engineering that has survived temperatures of up to 600 degrees Celsius, or 1,112 degrees Fahrenheit, the university said. The packed-bed thermocline system has the unique ability to conduct and store heat without damaging tanks and costs less. This will increase production and decrease operating expenses for concentrated solar power plants. The work at Arkansas was done with the help of a $770,000 U.S. Department of Energy grant, the university said.