Underground Metro Construction, Development in India

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Development of Metro System in the Country started with the construction of Kolkata Metro in mid 70's. Kolkata Metro 16.5 Km long North-South Line was predominately underground with only two terminal stations being at grade. The construction was carried out with limited local technical and engineering expertise, as was available.

The construction of Metro System in Delhi is partly underground and has been done very successfully, and many more cities of the Country like Bangalore, Chennai are constructing Underground Systems. I have been fortunate to have been involved in the construction of Kolkata Metro, Delhi Metro and also in planning of Metro Systems in other Cities like Chennai, Bangalore, Jaipur, Mumbai and Kolkata East-West Line. I can therefore, claim that I have witnessed the entire development of construction of Underground Metro Systems in the Country. The construction of Kolkata Metro was very remarkable, in view of the fact that we had very little Technical and Engineering experience and skill to execute such Projects, and also access to International Technology was limited. However, the Project had many Civil Engineering challenges and the execution of civil engineering works was not free from deficiencies. Since I was fully involved in execution of civil works in most difficult part of Kolkata Metro, i.e., section between Esplanade and Shyam Bazar, gained very valuable experience and was in a position to take care of these deficiencies in subsequent planning of Delhi Metro and other Metro Systems in the country.

Before we go into the deficiencies, let us understand the exact nature of civil works involved in an Underground Metro System. The Kolkata Metro Underground Section involved construction of stations approximately every km and tunnels connecting these stations. Both stations and tunnels were largely done by Cut & Cover Method except a small Section between Shyam Bazar and Belgachhia Stations which was done by Tunnel Boring Machine.

Cut & Cover Station

A typical Station involved constructions of 2 storey rectangular building below ground. Constructing this underground structures required excavation up to depth of about 17 to 18 meters and in order to support the soil temporarily, diaphragm walls were first constructed along with parameter of the Station and while excavating the soil between diaphragm walls, the diaphragm walls were strutted. Number of layers of strata were placed as excavation proceeded to the final level. The base slab of this rectangular station box was constructed first

and then side walls, concourse slab, and roof slab constructed progressively from bottom to top. The struts are also removed in sequence.

Cut & Cover Tunnel

The construction of Cut & Cover Tunnels connecting two stations involves similar operation as construction of station except that the structure is single story long box connecting two stations.

In addition to above main structures, number of ancillaries structures like entry, exit and ventilation shaft are required to be constructed normally in a same way as main station box.

Typical Kolkata soil is silty clay with poor bearing capacity and with high water table. Number of difficulties and deficiencies noticed in civil works construction and how these have been taken care in the subsequent Metro constructions:

1) The construction of Diaphragm wall was planned as a temporary structure and the Main Box was planned to be constructed inside these temporary diaphragm walls. The Diaphragm wall Panels went out of verticality and therefore, two adjacent panels were not in the same plain and sometimes forming a window/gap which was potentially risky for soil loss and heavy leakage during excavation. In fact, in some cases, the Diaphragm wall panel went out of plum to the extent that it infringed the permanent RCC box. This led to serious problem during excavation. Apart from the modification of the Box design and huge chipping and cutting involved in Diaphragm wall, it created big problem in casting the side walls while water was leaking from the Diaphragm walls' joints /gaps. This problem has been resolved as in subsequent planning the Diaphragm wall has been planned as a part of the permanent structure and the quality of the concrete as well as the geometry of the Diaphragm wall has been improved drastically. Verticality of the Diaphragm wall Panels has been ensured during construction by mapping the cut for the verticality before the concreting. In case of any deviation in the verticality, the trenching has been redone. With the advancement of the technology it is possible to introduce water seals between two panels of the diaphragm wall. With these provisions, the diaphragm wall joint has virtually being made water tight and also the two adjacent panels have been in perfect alignment to form the rectangular wall without leaving a gap between two panels.

2) Number of utilities crossing the Station Box or Cut & Cover Tunnel Box created special difficulties in casting Diaphragm wall Panel at the utility locations. The correct way is to complete the Diaphragm wall Panel in the adjacent stretch and divert the utilities on to the completed Panels and then take up the diaphragm wall Panel at original location of the utility. In Kolkata however, this could not be made possible at number of locations and therefore, the works were planned keeping the utilities in position and leaving a gap in Diaphragm wall at the utility location with the intention that this gap will be closed progressively with the help of steel plate lagging while doing the excavation. In

practice, however, this proved to be very risky affair because of the type of soil there was hardly any standing time and with the excavation even before placing the steel plate to cover the gap, there used to be soil movement causing settlement in the utilities. With this settlement, utilities start leaking particularly, storm water drain and high pressure water pipelines. This leakage water found easier way into the excavation area taking soil along with it causing further settlement and more leakage leading ultimately to collapse of the utility. In many cases, taking away huge amount of soil into the excavation area creating huge collapse, sometime very near to the buildings. Number of buildings have suffered serious damages on this account.

This has been taken care of as no gap is left in the Diaphragm wall and utility diversion if required, is must in Delhi. The responsibility of diversion of utility is also taken by Delhi Metro. This has ensured no collapse on this account during construction of underground Metro in Delhi.

3) **Problem of Severe leakage from the Base Slab** Since the soil has low permeability, it was not possible to lower the water table before casting the Base Slab and in most of the cases the water seepage from base could not be stopped. This seepage water under heavy head used to penetrate and form water channel in the Green concrete which ultimately lead to heavy leakage into the structure.

   This problem has been taken care in Delhi Metro that in case it is not possible to lower the water table below the base slab level to facilitate casting of the slab, a pervious filter is introduced below the base slab and over that the base slab is casted. The percolating water finding easier path in the filter did not penetrate the green concrete of the base slab ensuring setting of concrete without any risk of leakage.

4) Bottom upheaval was quite common in Kolkata Metro, particularly at final level of excavation because of very heavy earth pressure and surcharge outside the Diaphragm wall and bearing capacity of the soil being poor. This used to cause severe settlement outside the Diaphragm wall and number of building affected due to this differential settlement, being more near to Diaphragm wall and less beyond the Diaphragm wall. It appeared that the depth of Diaphragm wall below the final excavation level did not have much margin of safety. A typical embedment length in Kolkata Metro was about 4 meters beyond the final excavation level. This problem has been resolved in Delhi by providing adequate embedment length typically 8 meter or so. This has ensured no upheaval at Delhi & no major settlement to cause damage to buildings adjacent the work.

5) **Environmental Issues** Number of environmental issues like spilling the muck on the road, poor upkeep of the work sites , large scale movement of construction vehicles/ equipments and large scale activities at the site in congested area lead to great

inconvenience to the public. For Metro Line in Delhi, a strict regime detailing to take care of these problems was worked out and made part of the Contract conditions to ensure the compliance of the regime. This ensured that the Contractor was allowed to work in the designated area properly barricading and segregating the public area from the construction area and Contractor not allowed to encroach upon the public area. Similarly, Contractor to transport the excavated earth in good condition vehicles, cleaning the tyres and vehicle under frame before leaving the site to avoid defacing the roads. The construction vehicles movement restricted to allow in night hours mainly. The activities at sites were minimized by enforcing major activities like Fabrication, Concreting, Pre-casting, etc. done off the site. Not allowing the Contractor to use work site for labour camps. Using only good condition Machines and Equipment causing less noise, vibrations, etc.

6) **Speed of Construction** Speed of Construction at Kolkata Metro was extremely slow and a line of about 16.5 km took more than 22 years to complete. The whole city was put to inconvenience for long. It was therefore considered necessary to plan and execute the project in Delhi and subsequent other cities in more expeditious manner so that this inconvenience is reduced greatly. The best Construction Practices and Management Practices to execute such projects, available internationally, are adopted. With the result in Delhi we were able to develop network of about 190 km (Phase I and Phase II) in about 10 to 12 years time. Further in Phase III, about 140 km is under implementation which will be completed by December 2016. The development of network at such a rapid pace has on one hand reduced the inconvenience to the public during construction and also has provided great relief to the city traffic.

7) **Traffic Management** During construction very heavy traffic congestion was encountered due to reduced road width available for traffic and addition of construction related traffic of heavy vehicles and equipment etc. In Delhi, this problem was taken care of by suitably diverting the traffic after detailed Traffic Study and also making improvements to the adjacent roads for diversions. The movement of construction vehicles was restricted mainly during night times only and avoiding completely during peak hours. Deployment of trained Traffic Marshals to guide the Traffic has also helped greatly.

8) **Conclusion** The experienced gained at Kolkata Metro proved to be very useful and difficulties faced during construction of underground Metro in Kolkata has been duly taken care of by deploying suitable technology and Project Management Practices in subsequent Metros. With this, not only construction of Underground Metro Systems but also the Construction Industry, in general, has improved drastically in India.