Construction of a Cross-Passage for a Twin Tunnel System for Delhi Metro’s CC-27 Project

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Abstract: In this paper, construction of cross-passage for a twin tunnel system has been discussed along with problem encountered and solution adopted, by using a case history of cross-passage in R.K Puram Station, being constructed by L&T-SUCG JV for CC27 of Delhi Metro. Work for the cross-passage commenced after the completion of the twin tunnel on account of ease and efficiency. Method employed for construction of the cross-passage and specifications of materials used have been reported in this paper. The paper also reports a solution adopted for mitigation of a major problem of water-logging encountered during the construction. Approach adopted to address the problem has also been reported in the paper. Efficacy of the procedure utilized and applicable conditions for same along with possible contributing factors have been also indicated.

Introduction

Cross-passages are reinforced concrete structures built in between either two tunnels (as in case of twin tunnel systems) or a tunnel and the ground surface. They are provided to serve two primary purposes namely, emergency escape and maintenance work. In this paper, design, construction methodology and problem encountered during construction of one such structure has been described by analyzing case of a cross-passage being constructed by L&T-SUCG JV for twin tunnels between R.K Puram and Munirka underground stations for project CC27 of ‘Delhi MRTS Project of Phase-III’.

Project Background

The project consists of five underground metro stations (Hauz Khas, Vasant Vihar, Munirka, IIT and RK Puram), underground ramp at Shankar Vihar metro station (part of CC-27) and tunnel from end of this underground ramp to Hauz Khas metro station connecting the five underground stations listed above. Total tunnel drive length is 4.49 Km. Keeping strata of the soil in mind and time constraints, five Tunnel Boring Machines (TBM’s) namely Okumura TBM, THI-1 TBM, Herrenknecht TBM, THI-2 TBM and Mitsubishi TBM were used for construction of the tunnels. Out of these, Okumura TBM is particularly suitable for tunneling in soft soil.

Of the total tunnel length under construction, part of the tunnel connecting R.K Puram station to Munirka station, is the subject of consideration in this paper. The tunnel extends 1.32km in length and has an internal diameter of 5.80m and external diameter of 6.35m.

As a standard practice, during construction of a tunnel system, depending upon length of the tunnel and soil characteristics, a pre-calculated number of cross-passages are planned. In the instant case, four cross passages numbered CP-12, CP-13, CP-14 and CP-15 are being constructed between the two stations with average gap of 400m between the cross passages. Soil type found in this region is called ‘Delhi Silt’ which contains silt and sand in varying proportions from 35% to 80%. It is lightly compacted, has only an insignificant proportion of clay and is largely non-plastic although its behavior is transitional. Absence of rocks and stones lends this soil easily to efficient utilization of Okumura TBM.

Construction of the cross-passages is taken up only after completion of the tunnels on account of ease of working and efficiency. Following steps were followed for construction of CP-15, the cross passage under study:-

(i) Marking up of the survey lines (for excavation purpose) with the help of total station.
(ii) Ring girder erection, which consisted of I-sections being fixed in the form of a polygon.
(iii) Packing of the ring girder with wooden wedges so as to fill the void spaces between the tunnel segment and the ring members thereby increasing the contact area and thus the overall strength of the system.
(iv) Core cutting with the help of a 150mm diameter core cutter.
(v) Excavation work is carried out after core cutting. In the course of excavation, structural steel member ISMB 125 or ISMB 150, as per the design considerations, is placed near the main tunnel segment to support the excavated soil strata, where in the load gets transferred by ‘arch effect’.

The excavation work is further divided into two parts

- Heading: The upper half of the excavation is known as Heading. Here it was kept at a height of 1.8m. After excavating for every heading, of 750mm in length, arch-shaped ribs are fixed followed by fixing of wire mesh between two consecutive ribs, as shown in figure 1. After this, shot-creting using M30 grade concrete mix was done to prevent collapsing of roof & side wall soil and strengthen these surfaces. 50mm thickness of shot-crete layer was maintained throughout the procedure. The shot-crete mix contained a chemical named ‘Master ROCS 540’ for the early setting of the mix (approximately 3-4 hours). Any further excavation was done only after checking the strength of the shot-crete mix, sprayed over the soil surface, which should be more than 10kN/mm² per 750mm mesh layer.
- Benching: The lower half of the excavation is known as Benching. It was kept at a depth of 2.2m below heading. Benching can be done up to a length short of heading i.e.
there should always be one extra heading than benching till the last part. Rib-fixing and shot-crating etc. follows benching as mentioned above.

After this stage, permanent lining is constructed by using M40 grade Water Proofing Course concrete. Method of construction is similar to any RCC structure. Rebars are fixed first, as shown in Figure 2, followed by shuttering form-work before pouring of the concrete mix. Note that the main reinforcement has to be provided as per the design, considering the overburden and lateral earth pressures of the location being considered.

As per the drawing shown in figure 3, the cross-passage contains a hydrophilic strip at the entry and exit, so as to prevent seepage from entering in the construction joint formed between the tunnels and the doors of the cross-passage. The cross-passage was 10.5m in length, 1.31m in width and 2.493m in height. The total number of ribs used was 14.

During the construction of the cross-passage, a major problem was encountered due to leakage of a water supply pipeline located above the cross passage resulting in extensive seepage of water from top strata of the soil into the cross passage itself. Same delayed the work being undertaken in the cross passage as it affected the shot-crating which was not setting in the given time frame and lumps started forming on the surface. Although the leaking pipeline was fixed post haste, but in order to prevent further leakage and possible failure of the shot-creted soil surface, pressure grouting using a...
The grout-mix having a composition as 3:3:2; cement (OPC 53), sand, water, was done using grouting packers, along with pumping out of excess water. This filled up the voids and prevented any further seepage into the cross passage.

The final settlement value as measured with the help of a Total Station came out to be 7mm. Since this value is much lesser than the danger-level value (13.5mm), specified by L&T and Delhi Metro Rail Corporation, the construction and design were deemed safe. Reduction in the level of vertical deformation was achieved due to high rigidity caused by the arching action of the ribs-mesh arrangement. Also, the depth of excavation which was nearly 11m, offered well compacted soil.

The entire construction process was done following the necessary safety measures. The measures taken were as follows:

- All the workers were cladded with proper safety equipment.
- Regular checking of gaseous release from the soil. As the soil contained minor portions of lime, daily checks for ‘carbon mono-oxide’ were carried out so as to prevent any mishap.
- Lighting was provided in the tunnels, with illumination at the work area (in cross-passage) being 100 lux and elsewhere 50 lux. Emergency lighting units were also provided so as facilitate safe egress in the event of power failure.
- The processes of heading and benching were carried out alternately, with one benching after one heading. If more than one heading or benching were to be done, there was a chance that the soil may have settled due to lack of binding force.
- While shot-crating, gas masks, rubber gloves and boots, eye-gear and ear-protecting gear were used so as to prevent any fatalities due to inhaling of pressured fumes coming out with concrete and damage to eyes and ears and body parts in contact with the shot-crating equipment.

Conclusions

- This project is being undertaken in silty-clay type soil, which is a type of soft soil, which limits the construction procedure to the one applicable only for soft soils. The construction method utilized in this case wouldn’t have been suitable for undertaking similar work in hard soil since the overburden pressure due to above strata would have been extremely large exceeding the retaining limits of the ribs-mesh arrangement. However, in this project, the soil characteristics lent itself to the ribs-mesh method of construction.
- The method used to prevent failures due to seepage as encountered in this case can only be applied to situations where the water discharge is in limited quantity and can be easily pumped out in short duration of time. If quantity of water is large (say) due to a nearby water body, excessive weight of the water may cause excessive settlements and, in worst case scenario, may lead to collapsing of the cross-passage, resulting in fatalities.

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References

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Checking tunnels for defects is an important process for railroad operators as cracks and corrosion can lead to the structures collapsing. Zapping train tunnels with superfast laser beams could replace the slow, manual use of hammers in detecting dangerous structural defects that could cause cave-ins. The newly tested laser technology would allow flaws in concrete tunnels and buildings to be detected 50 times quicker than with the current laser system, a team of scientists announced at the Laser Society of Japan conference in Nagoya recently. The method using a “vibrational excitation laser” to cause vibrations on a surface and also a “measuring laser” to detect the varying vibration patterns allows inspectors to search for structural defects in concrete. However, the devices currently in use cannot reach high speeds as heat distorts the beam when the number of times the laser is shot is increased. The team of researchers from the Japan Atomic Energy Agency, Institute for Laser Technology and other bodies said it fixed that problem by developing a new cooling system. The team also tested a device that transports the laser at higher speed and with greater accuracy. After conducting a test on a concrete structure located approximately 7 meters from the laser, the team found that the new system could conduct 25 inspections in one second—about 50 times faster than the current system. The researchers anticipate making the new package more compact and installing it on an inspection vehicle in an experiment to detect defects in tunnels within the next two years.