

CONSTRUCTION OF DIAPHRAGM WALL FOR UNDERGROUND METRO STATION

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INTRODUCTION : PROJECT: "DESIGN AND CONSTRUCTION OF TUNNEL FROM START OF UNDERGROUND RAMP (NEAR CHARBAGH METRO STATION) TO END OF UNDERGROUND RAMP (NEAR K D SINGH BABU ST ADIUM) INCLUDING THREE UNDERGROUND METRO STATIONS (VIZ. HUSSAINGANJ, SACHIVALAYA AND HAZRATGANJ) INCLUDING ARCHITECTURAL FINISHES, E&M, TVS, ECS ETC. ON NORTH-SOUTH CORRIDOR OF LUCKNOW MRTS, PHASE IA PROJECT AT LUCKNOW, UP"

SCOPE & APPLICATION OF WORKS

Scope of works includes construction of guide walls, trench excavation using Polymer, placing of reinforcement and concreting of diaphragm wall panels. Approved Specialized sub-contractor will undertake this work.

The Scope of this work includes the following activities:-

- Utility Identification.
- Setting out Survey reference points for excavation of Guide wall.
- Construction of Guide wall.
- Excavation of D-wall by using polymer.
- Check the vertically of trench by using koden.
- Insert water stopper in stop-end groove.
- Lowering the stop-end by using Crane.
- Reinforcement cage fabrication.
- Insert/fix couplers as per levels.
- Lowering the reinforcement cage by using crane.
- Lowering the Tremie pipe for Concreting.
- Procedure of concreting.
- Stopend extraction by using Hydraulic jack and Crane.
- Excavated Muck disposal.

Water

Clean water will be used for concreting work. Water shall be free from solid suspensions and organic matters and will meet the requirements of IS: 456.

CONSTRUCTION PROCEDURE

General

Having completed all utility diversion, Guide wall trench excavation is executed by using JCB /Manual excavation for the pre-trench part up to 1.50 m.

Survey Works

Survey and setting out operations shall be carried out in accordance with Method Statement for survey. Sufficient reference datum and lines shall be available and visible on site for reference.

Survey and setting out will be done in the following manner:

- Control points will be fixed by Surveyor prior to start of the Guide walls.
- Each point of Guide wall location will be marked by minimum three triangulation survey stations.
- Temporary pillars for separate centerline and edge line will be made and centre points will be marked with the help of total station.
- The Guide walls will be constructed with respect to this center line. Then the reference lines will be marked again on the Guide walls itself for construction of Diaphragm wall.
- All panel numbers in accordance with the drawings will be identified on the guide wall.

Guide Wall

- Guide wall trench excavation will be excavated by manual/JCB excavation for the guide wall of 1.5m depth from the existing ground level. Before construction of Guide Wall it is necessary to compact the surrounding earth in case of loose or filled-up soil. The excavated area will be barricaded with safety ribbon all around the trench.
- Guide Wall will be constructed by inverted "L" shaped RCC walls forming a support to the earth and prevents it from collapse during the boring of Diaphragm wall. GW will be constructed prior to the excavation of the diaphragm wall and will be made with M-20 grade concrete as per the design mix.

The purpose of Guide Wall:

- To provide a permanent alignment for the grab.
- To protect the edge protection to the diaphragm wall.
- To prevent the collapsing of soil during the excavation/grabbing.

The following steps will be involved in construction of Guide Wall:

- Before excavation for guide wall a valid "Permit to Work" must be issued.
- The trench will be excavated as per set out and indicated alignment.
- Manual excavation/JCB Excavator for GW trench upto 1.5M depth from the existing ground level.
- Fixing of reinforcement will be done as per the Approved drawing.
- The minimum cover to reinforcement shall be 30 mm as per the drawings.

- Formwork will be fixed after proper cleaning the inner face and applying proper de-shuttering oil.
- The clear horizontal distance of guide wall i.e. Diaphragm wall plus 50mm will be maintained.
- Placing of M-20 grade of concrete with proper compaction.
- De-shuttering will be done after concrete gets set and the area will be backfilled for Safety purpose.
- After concrete gets hardened Curing shall be done with clean water.
- Variations of the alignment of guide wall shall not exceed +15mm in 3m and shall be without ridges or abrupt irregularities.

Construction of Diaphragm Wall Panel Sequence:

- The diaphragm wall panels basically comprise of:
 - a) Primary Panel
 - b) Secondary Panel
 - c) Closing Panel
- The Primary panel is the starting panel, which is cast with 2 stop-ends in place. These panels are logistically placed to suit construction schedule. The panel proceeds in both directions from the Primary panel using secondary panels, which are cast with a single stop-end in place. The closing panel is the final panel, which is cast after the removal of both stop-ends.
- The panel length is defined as the distance between the center lines of the two stop-ends (including the water stop). The orientation of the stop-end can therefore be changed without effect to the reinforcement cage position or size. The panel installation sequence and therefore panel types are in most cases interchangeable and thus the sequence of installation can be modified to adapt to the conditions experienced on site provided that the length of the panels being considered is the same.

Poly Mud Slurry (Polymer)

- Polymer should be test as per specifications.
- The DW excavation will be done by soil support polymer slurry to prevent collapsing / caving in soil inside the panel.
- An impermeable bund shall be provided around the Polymer mud plant.
- Polymer shall be stored in a designated area, under waterproof covers during the wet season.
- Generally the suspension will be prepared with a composition ranging within the limits below mentioned, depending on the soil and groundwater condition:
- The Polymer slurry will be mixed, in the predetermined ratio, with water in the high turbulence colloidal mixer thus ensuring the complete dispersion of the Polymer particles. Site test will be performed at site prior to start of the DW as per IS 9556-1980 test procedures.
- While in storage mixed Polymer slurry shall be continuously agitated.
- To assure that the Polymer slurry is in accordance SOP of Poly Mud Slurry System, the quality of the Slurry used for the excavation will be verified during preparation and excavation, prior to concreting.
 - ❖ Density
 - ❖ Marsh viscosity
 - ❖ Sand content
- pH The site laboratory to be established shall be equipped with the following instruments

- ❖ Fluid sampler
- ❖ Marsh funnel + Stopwatch
- ❖ Graduated cylinders
- ❖ Mud balance
- ❖ Sand-screen set
- ❖ Litmus papers
- If a panel were to remain open for 24 Hours, each shift the above mentioned tests will be performed (top, middle and bottom excavation level) and the panel trench topped up with fresh mud: if necessary the slurry will be replaced or regenerated. Quality of Slurry will be verified twice per panel.
- The Poly Mud shall be disposed in accordance to the SOP of Manufacturer recommendation.

Slurry specifications of Polymer slurry as per SOP are tabulated

Parameter	Fresh Mix	Reused slurry	Before Pour	Concrete
Viscosity (Seconds)	55-140	55-140	50-140	
Density (kg/m3)	1.00-1.04	≤1.08	≤1.04	
Sand Content (%)	-	≤2%	≤2%	
pH	11-12	11-12	9-12	

Diaphragm Wall Excavation

- The diaphragm wall will be located between the guide walls. The guide wall will be marked with the panel reference number and center line of stop-end position. The guide wall will have been strutted and backfilled prior to excavation to prevent movement or settlement.
- The trenching will be carried out by the grab attached to the telescopic Kelleys which are mounted on Hydraulic Rigs. The hydraulic rigs support and operate Kelley bars and the grabs through hydraulic power of the Rig. The swing, levelling, hoisting, closing and lowering of grab is controlled by the Rig.
- Once the grab is set up over the designated location (checked visually against colour marker pegs and the number on top of guide wall), the operator shall lower the grab onto the ground and commence trenching.
- Prior to commencing actual excavation, the grab rig will be set up vertically, either on one side of the diaphragm wall axis.
- Excavation by grabbing will be done in presence of the Poly Mud solution. The density of fresh Poly Mud system Polymer solution for circulation will be kept more than the normal density to ensure the stability of the trench.
- The standard panel will be excavated in three main "bites". The first "bite" will be excavated to the design toe level. The second "bite" will be a repeat of the first and finally the third "bite" will be the center portion.

- Grabbing will start in presence of Poly Mud system Polymer solution from one bites of the panel and will excavate up-to the founding level i.e. up-to the required depth of excavation as per the cross section details of approved drawings.
- The rig is then shifted to the Second bite of the panel and excavates up-to the founding level. Then the rig is shifted to the middle bite of the panel and excavates up-to the required depth. This gives us a full length excavated trench of the panel. The panel bottom is then cleaned by final grabbing.
- Excavated muck mixed with Polymer slurry will be kept aside, and the same will be disposed in the dumping yard at appropriate designated dumping yard.
- When the grab reaches guide wall level upon exit, a momentary suspension is recommended to allow the excess mud to drain from the spoil through the drainage holes of the grab. The operator then rotates the rig via crane swing and discharges the spoil either into skips or onto the ground.
- As excavation proceeds, Poly mud is pumped into the excavated trench to ensure that it shall kept full and the level of Polymer slurry must always be 300mm below top of the GW. During the course of the excavation, and upon reaching final depth, the panel depth is verified using a sounding chain and 30m tape. Logging of the slurry will be carried out during the excavation to check the slurry losses.
- Checking for the verticality of the trench will be carried out by KODEN instrument.
- Verticality shall be checked by KODEN for every D-wall panel.
- During excavation of each panel verticality by panel shall be checked two times (After 50% excavation and 100% excavation of d-wall panel for initial five panels subsequently it shall be checked after 100%/0 excavation for each panel.)
- The plane of the D-Wall face to be exposed shall be vertical to within a tolerance of 1:200, relative to a vertical line projected from the base of the guide wall.
- The ends of panel shall be vertical to within a tolerance of 1:200.
- The stop end with water stop attached will be lowered into position.
- Disposal of polymer slurry is not required as it can be cleaned in the Trench using polymud. Excavated soil shall be disposed during night shift at the designated dumping yard.

Procedure for Rock Chiselling in D-Wall panel.

- The soil grabbing is done with the help of trenching machine upto the rock level.
- During the excavation of DW if hard strata encounter the following arrangements will arranged.
- After the completion of soil grabbing the rock chiselling arrangement will be attached to the grabber with the help of crane (P & H crane 335/440) and chisel of weight 3.5 MT with successive bytes.
- The chiselling operation is continued upto to a depth of 200 to 300mm for entire length of panel, and trenching machine is used for cleaning the trench.
- Once the cleaning of trench is completed rock chiselling is again continued with the crane and chisel. And the same procedure is continued till the required depth is attained upto the required founding level.
- After attaining the required depth the trench will be cleaned finally and stop end will be lowered.

Mud cleaning and disposal

Mud cleaning and disposal will be in accordance with specifications.

- Cleaning of diaphragm walls by sedimentation of the suspended particles to the bottom of the excavation, ensuring the stability.
- Spoil Slurry mixed with the excavated soil will be kept aside / loaded on trucks with excavator the safely transported and disposed at approved dumping yard.
- There will be a provision of cleaning arrangement to ensure proper cleaning of the entire sub-frame of dumpers before it fly on public road.
- During the transportation special care will be taken to avoid spillage of mud from the trucks.
- Since it is an environmentally friendly so it can be used for any land filling without any further treatment.

Installation of Stop-end & Water Stop

- After completion of excavation and trench, the stop-end along with the Water stoppers will be installed.
- After completion of grabbing upto a required depth, the trench will be cleaned. The Stopend will be Cleaned, greased and the water stopper shall be fixed in the stop end groove and to be ensured that while lifting the stop end the water stoppers do not slip from the groove. Before lowering the cage, verticality will be checked by using KODEN, then the stop-ends attached with the water stoppers are lowered in the trench, which mark the boundary of panel so that fresh concrete does not come in direct contact with the soil in the next panel. In case of primary panel 2 nos. of stop ends have to be introduced at both sides, for follower panels 1 no. of stop end shall be fixed whereas in case of Closing panel no stop end is required to be introduced.
- The stop end will be lowered straight and shall be kept vertical with the help of Concrete block. After fixing the stop end, the panel dimensions will be checked and ensured that it should be within tolerance limits. Verticality will be checked and monitored with the help of plumb-bob and spirit level keeping parallel and perpendicularly to the stop-ends. The Tolerance of stop end shall be in 1:80 ratio.

Concrete

It will be in conformance of Special Specification of Contract and Approved mix design of M-40 grade will be used for DW.

Placing of Concrete

- Concreting of D-wall shall be done continuously without interruption to ensure no mixing of Polymer with concrete.
- All concrete shall be supplied and tested in accordance with Method Statement for Production of Concrete.
- Before start of concrete works a steel grill will be provided over the Guide wall to prevent the falling of persons in the excavated trench.
- Before concreting the following parameters of Concrete shall be tested at site.

Parameter	Value
Slump	150-200 mm
Temperature	>5° C & <32 ° C

Frequency of cube sampling A set of 3 cubes will be casted for every 25 cum of concrete.

- Concrete will be checked for its workability using slump cones to ensure the required parameters during the concreting.
- With the steel reinforcement in place the tremie pipe of 200/250 mm diameter along with the hopper attachment is lowered at the centre of the point to have uniform fill of compacting concrete in panels. The tremie pipe is set at 300mm from the bottom of the excavation and suspended by a self-locking working platform. All joints in the tremie pipe must be made watertight and inspected at every make-up. Any pinched O-rings or damaged threads must be discarded and replaced.
- This will be done by skilled supervision on daily basis to ensure the correct procedures to carry out all measurements and recording. In fact, upon completion of assembly, the tremie pipe will be lowered to contact the bottom of the panel in order to check that the length is sufficient and cross-check the recorded length.
- At the start of concrete placement, a plug is placed at the bottom of the funnel, protected by a shovel until the hopper is full of concrete. The shovel is then removed and the concrete gushes down the tremie, thus keeping the concrete away from mixing with the polymer slurry.
- Concrete will be poured continuously till the panel is filled up above the theoretical cut-off level.

Conclusions

- As we know the complexity of the interaction between the ground and the retaining diaphragm wall structure that make it difficult to predict the behavior of a retaining diaphragm wall structure in detail and accurately before the actual execution of the works.
- The long term effect of a retaining diaphragm wall structure on the sub soil has a large role in the analysis and design of the diaphragm wall.
- The success of the design and construction of a diaphragm wall begin from well planed and closely supervised subsurface investigation works including field and laboratory testing.
- The design of retaining diaphragm wall structure should follow the appropriate standards, specifications, guide lines and good practices.
- The design step doesn't stop by accomplishment of the diaphragm wall design but it still continuous during construction to review the performance of the diaphragm wall, compare the design requirements and prediction and take necessary action to prevent the occurrence of the critical limit state.
- The construction should also follows the approved method statement and have a check list on supervision to prevent mistakes or carelessness in the execution of the works especially those highlighted in this research.
- Major consideration during construction as follows:
 - Survey of adjacent structures.
 - Instrumentation and monitoring program.
 - Supervision and construction control.

Quality assurance system should be implemented to ensure design and construction is carried out systematically.