DEEP EXCAVATION: AN OVERVIEW & CASE STUDIES

Koushik Datta
Sr. Engineer, Bridges, C.E.Testing Co.Pvt. Ltd.,
Email:bridges@cetestindia.com

Sudip Nath
Chief Engineer - Geotechnical, C.E.Testing Co.Pvt. Ltd.,
Email:snath@cetestindia.com

ABSTRACT: Now a days Deep Excavation is must for better utilization of space in commercial/residential buildings. A safe, economic & easily constructible deep excavation technique is very much required as this major activity takes place in an early stage of a building project. Deep excavation techniques may vary up to a wide range based on the functionality, geological and geotechnical information, availability of materials, construction time, budget etc. Three case studies of deep excavation technique, which are not only different by location [RPSG Office building at Alipore & Airport Hotel at Jessore Road, Kolkata, India & at Muscat (Al Wattaya), Sultanate of Oman], but also with geotechnical information and functionality of the building, have been discussed here. It not only illustrates the methodical and rational approach followed in selecting deep excavation techniques and support systems but also discusses the difficulties and remedial measures suggested. This also explains the suitability of using different components of deep excavation techniques used for difference in technical & functional requirement, financial support and serviceability criterion.

KEYWORDS: Deep Excavation, Basement, Soil Nailing, Sheet Pile.

1 INTRODUCTION

The number of deep excavation pits in urban area is increasing day by day to meet increasing space requirement. Execution of deep excavation has become very difficult due to adjacent structures, dense traffic in side by road, underground obstruction and utilities. So, analysis & design of deep excavation supporting system and supervised execution thereon is essential for complicated construction challenges in the urban area.

2 DEEP EXCAVATION TECHNIQUES

Generally, an excavation more than 4.5m is called **deep excavation**. A deep excavation with some retaining system, allowing vertical/near vertical excavation resulting increase in excavation area, is called **retained deep excavation.** Deep excavation technique is comprised of mainly three components – a) Excavation methods, b) Retaining Systems & c) Strutting System. Depending on the location, adjacent land-use, sub soil condition, ground water table, historical data, construction time, budget, availability of construction equipment & materials, a particular excavation scheme is chosen in combination with these components.

2.1 Excavation Methods

Some commonly used excavation methods are: **Open Cut Method (Sloped/Cantilever), Braced Excavation Method, Anchored Excavation Method, Island Excavation Method, Zoned Excavation Method & Top-Down Excavation Method.**
Depending on the site requirement any one of above method or in combination has been taken up.

2.2 Retaining System

Commonly used types of retaining wall are: Pile Retaining Walls (Soldier pile, Contiguous pile, Secant Pile), Sheet Piles, Diaphragm Wall & Tie Back System /Soil Nails.

2.3 Strutting System

The supplementary lateral supports, required for large excavation depth, are called as **Struts**. Selection of struts depends on the earth pressure, available material, construction period, functionality of the retaining system etc. Generally wooden, RC & steel struts are used out of which steel struts are the best choice for a sizable deep excavation

3 PLANNING & DESIGN OF DEEP EXCAVATION:

Stability check of retaining wall & structural design of the retaining wall, strut & wale beam are to be carried out. A simplified design approach is described below:

- An office & site study on adjacent building & UG facilities is must to explore possibility of interference with exiting walls, anchors & nails and utilities.

- Existing cracks /depression on adjacent buildings, streets are identified before excavations starts. Sub soil properties, GWT, dewatering arrangement, depth of excavation, availability of support types and construction details of main structure are altogether considered to select type of wall and support system.
- Support levels and horizontal spacing are so selected to keep the displacement within permissible limits.
- Solution for shears, moments, support reactions, displacements are obtained by structural analysis.
- External stability calculations are performed.
- Anchor or strut connections to waling or breasting beams are designed.
- Any excessive load, displacements or support reactions are recorded at any construction stage, diagnosis is made and required modifications are made in design and/or construction.

3.1 Design Loads

Loads required to be considered for design of deep excavation are: **Earth Pressure, Surcharge Pressure & Water Pressure.** Earth pressure distribution for braced excavation may be chosen from any standard literature.

3.2 Analysis

The analysis maybe carried out as soil-structure interactive model by any standard structural analysis software. Generally, the critical sections of a excavation pit are chosen and modeled. The retaining wall is assigned as column whereas the subsoil criterion is simulated by appropriate compression spring. Struts are represented as beams come into the model in a sequential manner with input loads. Support due to soil below the dredge line is simulated by dummy struts/spring with high stiffness.

3.3 Results

The deformations obtained from analysis are checked with the permissible value. Corresponding reactions of various members are obtained for structural design.

4 CASE STUDIES

Some deep excavation case studies are discussed below:

4.1 Case Study-1: RPSG Office building at Alipore, Kolkata

The CESC Limited has proposed to construct a corporate office at 2, Alipore Road, Kolkata, with 9.0m deep basement. Pile foundation was suggested. The project site was almost “T” shaped having almost equal width in all three arms, which has restricted the possibility of island/open excavation. Presence of building at close vicinity of the site also restricted the option of anchored excavation and the permissible deflection at top of retaining wall was limited to 25-40mm only. Braced excavation has been proposed with steel sheet pile and three level struts. Vertical H post at few locations has been used to reduce the strut section.

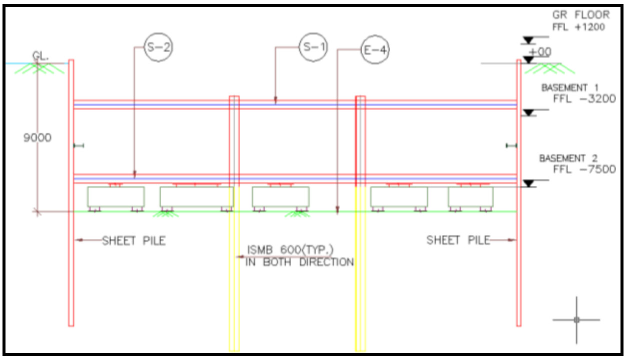

Fig- 1: Final profile of Braced Excavation

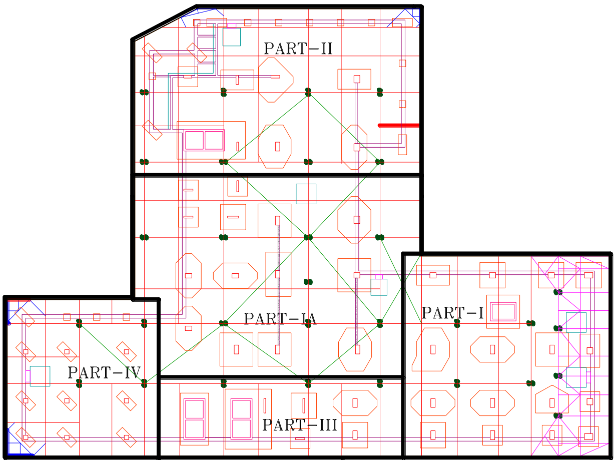

Fig- 2: Stage wise construction zones and corner trusses

- The site consists of poor top soil with almost no sand content and high water content thereby.
- Sheet pile of sufficient section to withstand 3.0m cantilever cut has been proposed. Strut of suitable size has been installed to brace the sheet pile wall..
- Three confirmatory bore holes were sunk up to a depth of 22m to get the present subsoil parameters.
- **Design:**
  - Selected design parameters are
    0-14m- soft to medium clayey silt: C = 0.3 kg/cm^2 = 3 t/m^2, $\Phi = 0$; **14m-19m-** stiff clay:
    C = 0.8 kg/cm^2 = 8 t/ m^2, $\Phi = 0$.
  - Inter locking type Sheet Pile viz. OT22 with Z_{xx} =2200 cm^3/m has been used.
  - This braced excavation has been modeled & analyzed to obtain deflection at the top of sheet pile at each excavation stage. The soil beyond excavation line has been represented as equivalent spring while soil below dredge line is represented by a dummy member.

- o Final deflection at sheet pile obtained as 21mm.

➢ **Difficulties & Remedies:** The location, size & shape of the site do not allow both sides bracing completely. The end wall of each side of "T" also required sufficient support for bracing. Hence, the braced excavation proposal has been combined with zoned excavation (Ref. Fig-1 & 2) to have sufficient support from existing soil mass. Two level truss girders, corner trusses & some diagonal strut members are introduced to transmit the pressure from end wall and corners of wall. Instrumentation & monitoring system is installed to record the in-situ sheet pile deflection so that prompt action can be taken, if the deflection reaches threshold imit.

4.2 Case Study-2: Al Wattaya, Muscut, Sultanate of Oman

A residential structure was proposed on a highly undulated terrain. A 30-40m high slope is to be stabilized having a cut angle of almost 45° with 6.0m wide road beyond toe line and 8.0m high retaining wall thereafter. So, basically this is a slope stabilization work, but deep excavation technique (top-down construction with ground anchor) has been proposed to cut and stabilize the slope (Ref. - Fig-3).

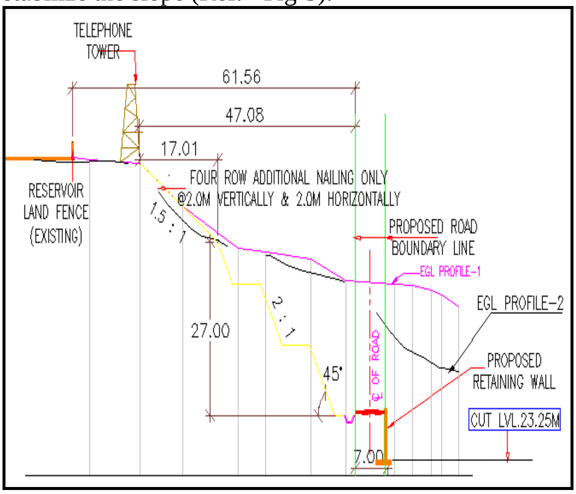

Fig- 3: Slope stabilization work

- ➢ Benching was done at two levels so that equipment can rest on it.
- ➢ Expected Φ value is taken as 33° depending on the past data.
- ➢ The nailing profile (Fig-4) has been finalized and modeled & analyzed by GEO5 software. Total design of slope stability with anchors forces are obtained after all necessary checking.
- ➢ Nailing number has been optimized by changing the vertical & horizontal spacing within the permissible FOS against stability. Nails & bearing plates are designed accordingly.

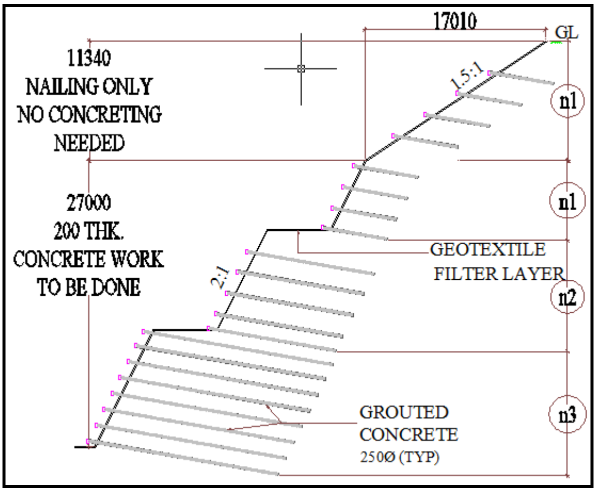

Fig- 4: Nailing Profile

4.3 Case Study-3: Airport Hotel, Kolkata

A hotel building having three level basements with 10.0m depth and 500m perimeter was proposed to be constructed by SPCL at 28, Jessore Road at Kolkata. The site has been situated at a corner of a T-junction of very busy Jessore Road and a local road. The geometry of the site was not regular, as two almost equal longer sides had little offsets and those came closer with larger offsets near the junction side. The large area and wide shape of the site allowed us to go for island excavation and optimize the strut length. Fig-5 illustrates the same.

- ➢ The retaining wall has been constructed by driving sheet pile wall, while wale beam and struts have been used to transmit the loads from retaining system to the u/c structure. Excavation & supporting arrangement were planned in a sequential manner.
- ➢ The island excavation has been proposed to be taken up in two/three separate phases to optimize the cost by reusing the supporting arrangement.
- ➢ 3.0m free cutting followed by island excavation has been taken up to the 1st phase construction.
- ➢ Two level struts has been proposed taking support from the u/c structure. Connection of struts with concrete has been done by MS insert plate & gusset plate arrangement. Bracket & steel packing

has been introduced to integrate the behavior of wale beam & sheet pile.

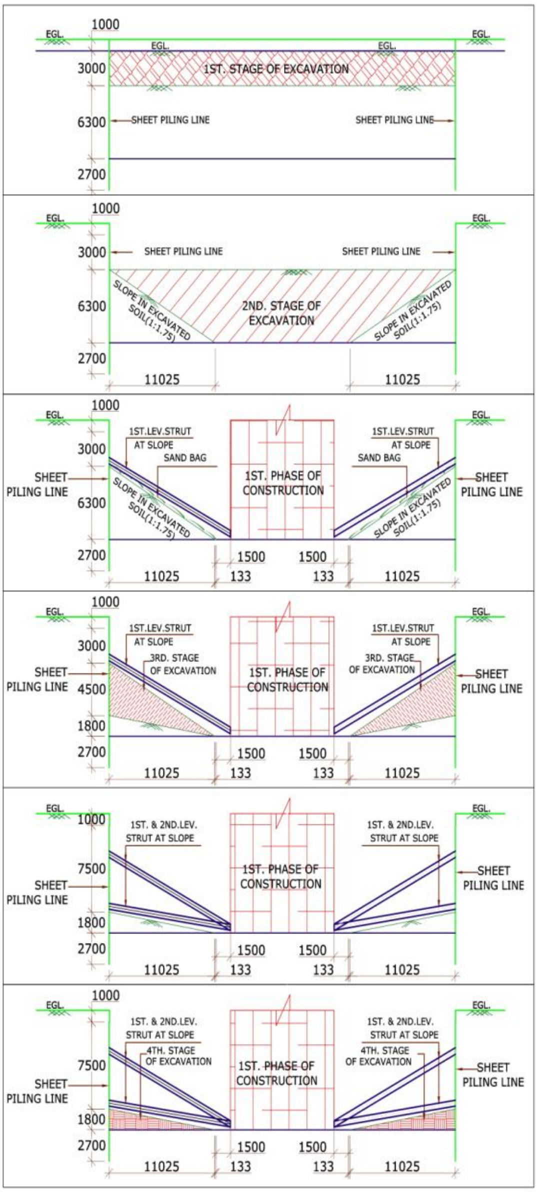

Fig- 5: Stage wise excavation

- **Design:**
  - The sub-soil characteristic was stratified in nature. The design parameters selected are:
    0-2m: C = 0.18 kg/cm^2 = 1.8 t/sqm, Φ = 30°
    2-5m: C = 0.58 kg/cm^2 = 5.8 t/sqm, Φ = 0°
    5m-10m: C = 0.30 kg/cm^2 = 3.0 t/sqm, Φ = 0°
- The earth pressure distribution has been obtained after Tschebotarioff and combined with water pressure & surcharge pressure.
- The sheet pile deformation has been obtained and kept within the permissible limit. Strut, wale beam and connections have been designed based on the forces/moments obtained from the analysis.
- **Difficulties & Remedies:** The excavation continued through almost 2years in one stretch due to fund crisis which converted the temporary stresses in the members to permanent nature. This scenario has become worse during the second rainy season as GWT rose leading to increase in water pressure and caused additional deformation in sheet pile top, tilting of boundary wall and tension cracks thereby in the heel side deposit near road side area. Immediate measure was taken by driving two rows of balli pile beyond the line of sheet pile which not only densified the soil mass, but also increased the stiffness of the retaining wall and thus deformation was restricted. Some additional struts were also installed. It was also advised to speed up the construction to avoid such instances in future.

5 CONCLUSION

To cope up with the increasing population, development of residential/commercial buildings has to be vertical and lead to deep vertical excavations, which requires a safe & economic supporting system which is easy to construct. A successful deep excavation requires proper planning, in depth desk study to correlate the field data with soil-structure interaction model, efficient execution and its monitoring and quick remedial action, if required.

REFERENCES

CE Testing Co. Pvt. Ltd.., ‘Reports of various jobs related to Deep Excavation’.

Ergum M. Ufuk., ‘Deep Excavations’, *Dept. of Civil engineering, Middle East Technical University, Ankara, Turkey.*

Godavarthi V.R., Mallavalli D., Peddi R., Katragadda N. and Mulpuru P., ‘Contiguous Pile Wall as a Deep excavation Supporting System’, *Dept. of Civil Engineering, SRK Institute of Technology, Andhra Pradesh*

Mushtaq Fahad, ‘Presentation on Deep Excavation Technique’,