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Deep Excavation for Contaminated Rainwater Storage Sump (CRWS) Using Raker-Supported Sheet Piling System – A Case Study

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Abstract - Deep excavations continue to present significant geotechnical challenges particularly under constrained site conditions. This paper presents a case study of a 13.25 m deep excavation for a Contaminated Rainwater Storage Sump (CRWS) at the Numaligarh Refinery Expansion Project, Assam. The excavation with a plan area of 40 m × 28 m in saturated alluvial deposits and a groundwater table at 3.5 m below EGL posed considerable stability concerns. Conventional stepped excavation with berms was not feasible due to severe space constraints and the proximity of adjacent pile-supported structures further restricted the use of ground anchors. Furthermore, conventional strut–waler systems were also not practical due to the large excavation plan area. Consequently, a braced sheet pile system supported by walers and inclined raker struts at two levels was adopted as the retention system. This case study focuses on a deep and large-scale shoring system in a highly constrained area highlighting the selection of raker struts over conventional horizontal struts and emphasizing the importance of sequential and staged construction for the deep sump.

Key Words: Deep Excavation, Sheet Pile, Raker Strut, Slope Stability, Construction Methodology

1. INTRODUCTION

Deep excavations in constrained industrial environments require solutions that balance geotechnical stability with practical constructability. As illustrated in **Figure 1-1**, for the present project limitations arising from limited space, adjacent roads, structures and subsurface conditions restrict the use of conventional retention systems necessitating alternative approaches for deep excavation support. This study presents a field-driven solution for a deep sump excavation highlighting the effectiveness of a raker-supported sheet pile system and the role of staged construction in ensuring stability and safe execution

1.1 Project Background

The Numaligarh Refinery Expansion Project in Assam involves the EPC of facilities associated with the Effluent Treatment Plant (ETP).

As part of the CRW Treatment Plant, contaminated rainwater storage (CRWS) sump has been constructed for intake purposes requiring a deep excavation of approximately 13.25 m.

Structure: Contaminated Rainwater Storage Sump

- Plan: 40 m × 28 m
- Excavation depth: 13.25 m
- Groundwater table: 3.5 m BGL

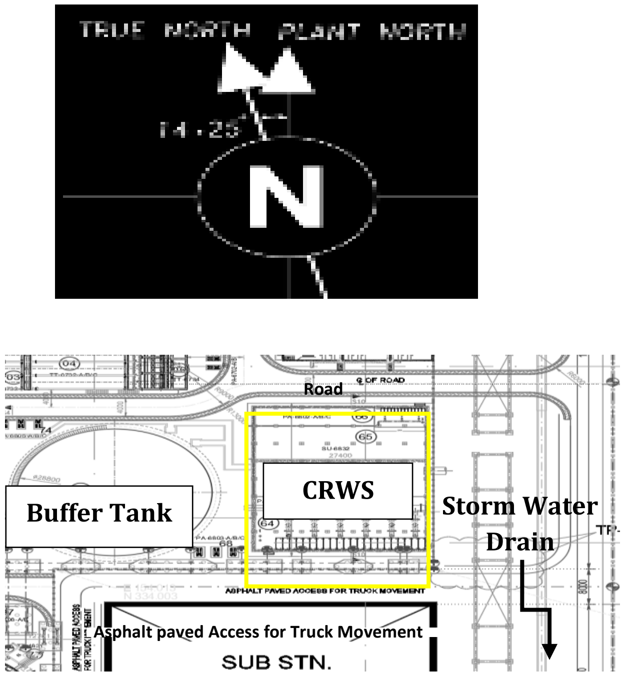


Figure 1-1 Layout plan of CRWS and nearby structure

1.2 Subsurface Conditions

Table -1: Soil Properties

Type of Soil	Depth (in m)	Unit Weight (γ) (in kN/m³)	Cohesion (C) (in kN/m²)	Angle of Internal Friction (φ)	Modulus of Elasticity (E) (in MPA)
Dense Sand-02	0.00-5.50	18.0	15	32	16.50
Dense Sand	5.50-11.0	18.0	15	34	32.50
Clayey Silt	11.0-15.0	19.50	60	0	16.50

2 ENGINEERING CONSTRAINTS

- **Large Layout Area:** Large plan dimensions made a conventional multi-level internal strutting system impractical and uneconomical, particularly when effective support could be provided only along limited sides.
- **Adjacent Pile-Supported Substation**: Ground anchors were not feasible due to potential interference with the existing pile foundations of the nearby substation building on the south side
- **Nearby road/structures:** Open cut excavation with stable side slopes was not possible due to the presence of adjacent roadways on three sides.
- **Deep cut in sand below GWT:** Excavation in sandy strata below the groundwater level posed a significant risk of basal instability and lateral wall

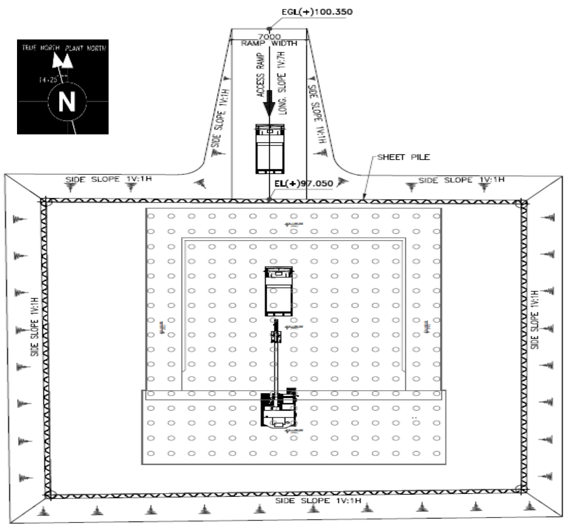
2.1 Adopted Geotechnical Solution

A sheet pile shoring system supported by walers and inclined raker struts was adopted to provide lateral stability for the excavation. The system transfers earth pressure and hydrostatic pressures from the sheet piles through walers to the raker struts and ultimately to the base.

3 CONSTRUCTION METHODOLOGY

Excavation was carried out in stages to ensure slope stability at each phase.

Stage 1: Initial excavation up to a depth of 3.3 m was completed followed by ramp construction and subsequent sheet pile installation.

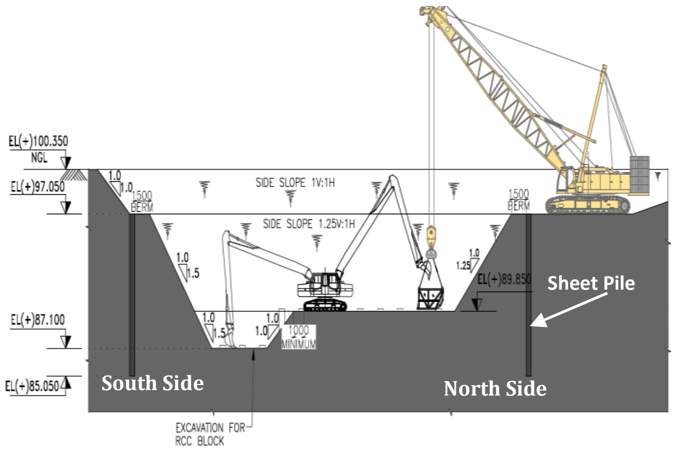


Stage 2: Layered excavation

Stage 2a:

1. Excavation in the north side was completed up to EL +89.850m from EGL at an EL +100.350 as shown.

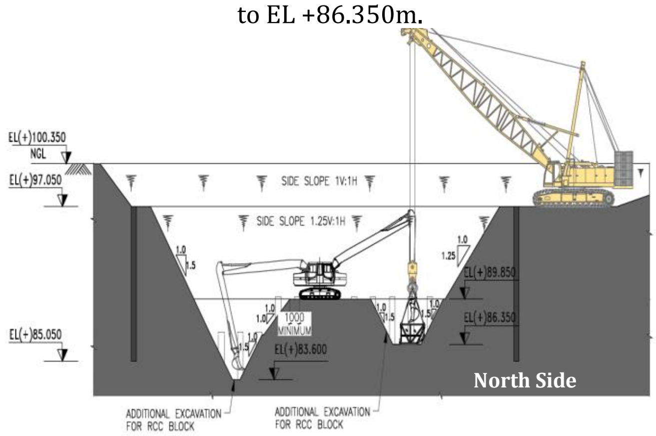
2. Excavation in south portion for RCC block was done up to El+87.100m.



Stage 2b:

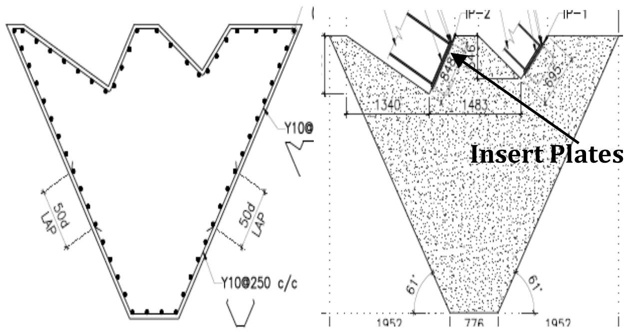
1. Additional excavation for RCC block in south portion was done up to EL +83.600m.

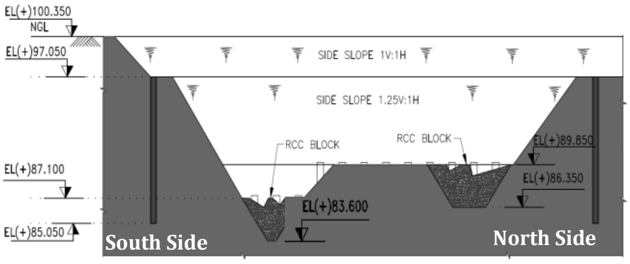
2. Additional excavation for RCC block in north portion up to EL +86.350m.



Stage 3: Construction of RCC Block

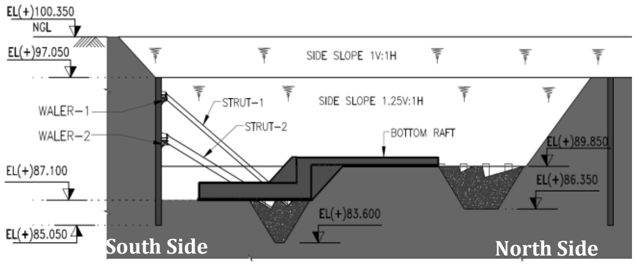
1. Placing reinforcement in the additional excavation
2. Concreting for the RCC Blocks as shown in the diagram.
3. Finishing the RCC Blocks work for strut fixing
4. Installation of the Insert Plates for fixing the inclined rakers





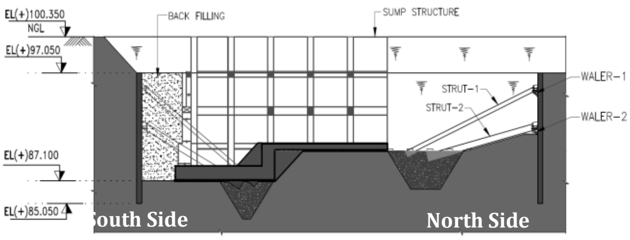
Stage 4: Installation of Waler and Raker on South Side

1. Waler and strut were fixed on the first level and then excavation was done up to second level waler
2. Second level waler and raker were installed and remaining excavation was completed
3. Construction of the bottom raft on south portion



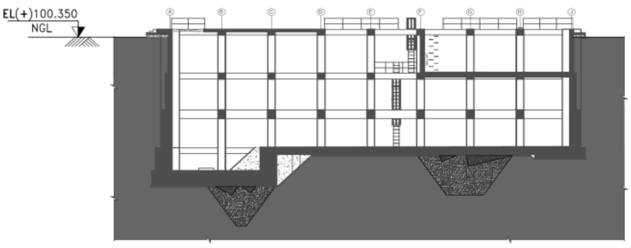
Stage 5: Construction of CWRS Structure

1. CWRS Structure was constructed on the south side
2. Backfilling of soil between sump wall and sheet pile
3. Removal of the strut and waler fixed to sheet pile and trimming of the struts if required
4. Repetition of the above steps to fix the walers and struts on the north face sheet pile.



Stage 6: Final Stage

1. CWRS Structure was constructed on the north side.
2. Backfilling of soil between sump wall and sheet pile.
3. Removal of struts and walers from both the faces.
4. Removal of sheet pile using vibro hammer and crane.



4 DESIGN AND ANALYSIS

For the design and analysis of the shoring system, Geo5 software was used to evaluate the performance of the sheet pile system and to determine the forces acting on the walers and raker struts. These calculated forces were subsequently used as input for the structural design of the walers and raker struts in STAAD.Pro.

4.1 Input Parameters

4.1.1 Soil Stratification

The subsurface soil parameters as described in **Section 1.2** were adopted as input for the analysis.

4.1.2 Sheet Pile: GU 20N

Table -1: Geo-05 Input Parameters for Sheet Pile

Area of cross-section	A	1.72E-02	m^2/m
Moment of inertia	I	4.13E-04	m^4/m
Elastic modulus	E	210000	MPa
Shear modulus	G	81000	MPa
Sectional modulus	W	1.92E-03	m^3/m
Plastic sectional modulus	W_{pl}	2.28E-03	m^3/m
Structure Length	L	12	m

4.1.3 Structural Steel

The steel sections (NPB) correspond to European parallel flange I-sections with dimensions conforming to EN 10365.

1st Level Lateral Support System @4.8m below EGL

- Waler 01 - 2NPB 400x180x66.3
- Strut 01 - 2NPB 400x180x66.3

2nd Level Lateral Support System @8.3m below EGL

- Waler 02 - 2NPB 500x200x90.68
- Strut 02 - 2NPB 600x220x107.56

Analysis using Geo5 and STAAD.Pro confirmed that the selected sheet pile section along with the designed lateral support system comprising walers and raker struts is adequate and performs satisfactorily.

5 FIELD PERFORMANCE OBSERVATIONS

The on-site construction is illustrated in the figure below:

Figure 5-1 Sheet Pile Installation and 1st Level Excavation

Figure 5-2 First Level Raker Support

Figure 5-3 First lift wall casting -CRWS

Figure 5-4 Final wall and slab - CRWS

5.1 OBSERVATIONS

1. No visible deformation of sheet piles was observed at final excavation depth.
2. No sloughing or collapse of the soil occurred during excavation.
3. Stable base conditions were maintained, with no signs of basal heave.
4. No distress was observed in adjacent structures during staged construction.
5. The raker system provided high lateral stiffness, resulting in negligible deflections.

6 CONCLUSIONS

The field performance of the shoring system indicated a notable difference between anticipated and observed behavior. While significant seepage, wall deformation and potential instability were expected due to excavation below the groundwater table in sandy to stiff clayey silt strata, actual conditions exhibited minimal seepage, negligible deformation and stable base performance. This can be attributed to the presence of an overlying dense sand stratum, controlled excavation sequencing and the high stiffness provided by the raker-supported sheet pile system. The absence of adverse effects such as heaving, excessive deflection, collapse or distress to adjacent structures demonstrates that constraint-driven engineering solutions can effectively outperform conventional approaches when tailored to site conditions.

The study highlights that raker-supported sheet piling systems are particularly suitable for deep excavations in confined environments where anchors or open cuts are not feasible.

Overall, the case highlights the critical role of a well-planned and strategically executed construction approach in ensuring the success of deep excavation works.

7 REFERENCES

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BIOGRAPHIES

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