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Anchored Steel Sheet Pile Wall vs. Cross-Lot Bracing System for Deep Excavation- A Case Study for a Multi-Storeyed Building in Guwahati, Assam

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ABSTRACT

The commercial complex in Guwahati, Assam is a 13 story building with a stilt car parking having 2 levels of basement which required an excavation of 8.0m below ground level. The lift pit required an excavation of 9.5m below the existing ground level. Minimization of impact of excavation-induced ground movements on the adjacent structures was one of the major considerations in the design and construction of the excavation and its temporary retaining system. The temporary retaining system initially consisted of anchored steel sheet pile walls along the entire building perimeter. After excessive vibration was detected in the adjacent buildings during sheet pile driving by vibratory hammer, the matter went to the court and as a replacement, cross-lot steel bracing was installed. This paper discusses the geotechnical aspects of the design and construction of the excavation and its retaining system, the analysis approaches employed to evaluate the efficacy of both the temporary support systems, namely anchored steel sheet pile wall and the cross-lot steel bracing system.

Keywords- Deep excavation, sheet pile, cross-lot bracing

1. INTRODUCTION

The commercial complex in Guwahati, Assam is a 13 story building with a stilt car parking with a footprint area of approximately 2400 m^2. It consists of a 2 level basement, the maximum excavation depth was about 8.0m along the building perimeter. The lift pits, which also existed along the building perimeter, required an excavation of 9.5m from the existing ground level. Eastern side of the site runs an important road, has a setback of only 7.5m. Northern side of the site has a high rise structure and the set back of the proposed structure in that side is only 7.5m. Minimization of impacts of excavation- induced ground movements on the adjacent road as well as on the adjacent high rise structure was one of the major issues needed to be considered in the design and execution of the excavation and its temporary retaining system.

The temporary retaining system initially consisted of anchored U- section steel sheet piles 12.0m long. During driving of these sheet piles, vibratory hammers were used, which created some vibrations in the nearby tall structures. After about 40.0m of steel sheet piles were driven, fearing damage to the nearby structure, the matter was reported to the court, and for a smooth progress of the work, an alternative support system was immediately required to be designed. Least disturbance to the nearby structures and the ease of execution were the primary considerations in designing the new retaining system. Cross-lot steel bracing system was thought to be a very good alternative, and as such designed and executed at the site.

This paper discusses the geotechnical aspects of the design and construction of the excavation and its retaining system, the analysis approaches employed. A comparison between the two retaining systems, namely anchored steel sheet pile wall and cross-lot steel bracing systems with respect to deep excavation in thickly populated urban centres is also provided.

2. GROUND AND GROUNDWATER CONDITIONS

A comprehensive ground investigation program comprising of 10 numbers of exploratory drill holes extending up to 20.0m depth was carried out on the site, including, various in-situ and laboratory tests. The ground conditions were assessed based on the investigation results and are discussed in this section. The boreholes carried out for the site showed that there are general similarities and

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continuities of the subsurface materials which consist of greyish loose silty clay up to a depth of not less than 15.0m with occasional lenses of fine sand of thickness varying from 0.5m to 1.9m within this depth. Though during monsoon period, water is likely to pose an excavation problem, during winter the true ground water table occurs at much below the proposed maximum depth of excavation and as the entire excavation operation is proposed during the winter period, water thrust was not taken into consideration while designing the support systems. The geotechnical parameters adopted in the design of the retaining system are presented in Table 1.

Table 1. Adopted Geotechnical Parameters

Depth (m)	Soil Type	Cohesion, C (kN/m^2)	Angle of Internal friction 'Ø' (degrees)	Unit weight of soil (kN/m^3)
0-2.5	Filled up soil	Neglected	Neglected	16
2.5-8.5	Silty clay	28	2	19.5
8.5-12.0	Silty clay	37	2	19.6
12-13	Sand	0	33	20.0
13-17	Silty clay	49	2	19.8
17-20	Silty clay	45	2	19.7
20-22.5	Silty clay	53	3	19.9
22.5-26.5	Sand	0	38	21.5
26.5-30	Silty clay	64	2	20

3. DESIGN OF RETAINING SYSTEM

The design of retaining system comprising of anchored steel sheet piles and the cross-lot steel bracing system is discussed in the following sections. This study adopted the "apparent earth pressure" concept outlined by Terzaghi and Peck (1967) and later described by Peck (1969). The reduction of design earth pressures for shoring walls has been advocated for sheet-pile bulkheads by Rowe (1952, 1957), and for excavations with multiple levels of support by Peck et al. (1973) and others. Reduction factors as low as 0.67 (Peck et al. 1973) to 0.8 (Goldberg et al. 1976) are used depending on the particular situation. Reducing the load assumes that the wall between the supports will deform sufficiently to allow "arching" to occur, thereby shedding the load to the struts. Depending on the soil conditions, the degree of arching and load sharing between the wall and struts is assumed to achieve equilibrium at some undefined level of deformation. In this case, a reduction factor of 0.8 has been considered in calculating the earth pressure. Earth pressure diagram considered for both anchored sheet pile wall and cross-lot bracing system is shown in Fig. 1a. and Fig. 1b. respectively.

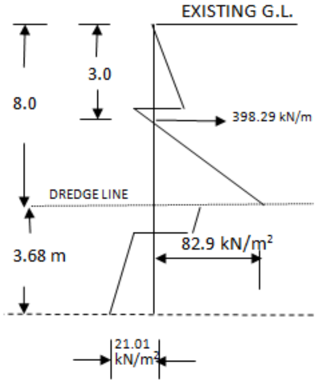

Figure. 1a. Earth Pressure Diagram for Anchored Sheet Pile Wall

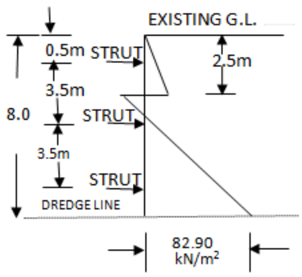

Figure. 1b. Earth Pressure Diagram for Cross-Lot Steel Bracing System

Maximum lateral movement of wall with anchor support has been calculated as per Long (2001) and Clough and O'Rourke (1990), whichever is larger. Plate 1a. and 1b. shows the various elements of the Cross-Lot steel bracing system. Cross-lot or internal bracing transfers the lateral earth (and water pressures) between opposing walls through compressive struts. In this project cross-lot steel bracing system has been designed as rows of vertical joists to be driven at a spacing of 0.6m. Steel sheets of appropriate thickness are driven in between the joists and held in position by angles in such a way that the joist-sheet combination forms one side of the support wall. One other similar wall runs parallelly to the first wall at 6.0m distance. Struts are installed at appropriate spacing of 3.5m c/c both in horizontal and vertical direction.

Plate 1a. Top-down excavation with cross-lot bracing

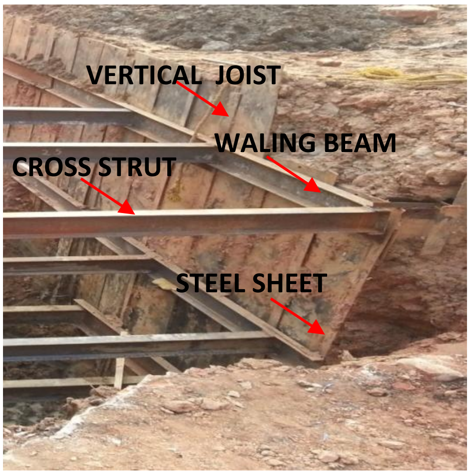

Plate 1b. Various elements of cross-lot bracing system

Waling beams are also provided and bolted to the vertical joists so that the struts do not slip on the joists. The struts rest on a series of wale beams that distribute the strut load to the diaphragm wall.

The calculated maximum critical loads such as bending moment, shear force and strut loads (whichever is applicable) as well as deflections for the elements of both the retaining systems are shown in Table 2. These forces were used for the structural design of the members of the two retaining system under consideration, namely, anchored steel sheet pile and cross-lot bracing system.

Table 2. Critical Member Loads, Deflections and Design Sections of the Elements of Anchored Sheet Pile and Cross-Lot Bracing Retaining System.

Retaining System	Member	Bending Moment (kN-m/m)	Shear Force (kN/m)	Axial Force (kN/m)	Deflection (mm)	Design Section
Anchored Sheet Pile	1. Sheet Pile	837.36	284.88	--	72.8	ISPS 2770 U (Grade 58-ST conforming to IS:961-1975
Cross-Lot Bracing System	1.Vertical I-sections	9.82	92.16	---	---	ISLB250@27.9kg/m
	2.Struts	---	---	122.38	---	ISHB250@57.0kg/m
	3. Vertical steel sheets	4.48	---	---	---	15.9mm thickness
	4. Waling Beams	---	---	---	---	ISLC300@33.1kg/m

4. PERFORMANCE ASSESSMENT OF ANCHORED SHEET PILE WALL VS. CROSS-LOT STEEL BRACING RETAINING SYSTEM

1. Ease of Execution: Steel sheet piles are robust and require heavy machineries like high lift drop hammer, vibratory hammers etc. The driving operation creates substantial amount of vibration in nearby structures and is a serious issue in the urban environment.
   On the other hand the cross lot steel bracing system is simple, does not require heavy driving equipments, and does not create vibration and noise.
2. Material and equipment availability: Steel Sheet piles are still not very common in many small cities. Transportation of steel sheet piles from other metros involves a huge cost.
   Elements of Cross-lot bracing system, which comprises of steel joists, steel sheets, channels and angles only, on the other hand, are readily available and can be easily installed, even without any heavy machinery.
3. Reusability: Both steel sheet piles and cross-lot braces are reusable. However, due to huge skin friction mobilised in steel sheet pile walls, special equipments are required for pulling them out too.
   In case of the cross-lot bracing system, skin friction in the vertical joists and in the steel sheets are not significant and thus can be pulled out easily with ordinary hoisting equipments..
4. Load transfer mechanism: Anchored steel sheet pile walls are to be anchored properly. Inappropriate mobilization of anchoring force may lead to excessive wall movement and also may lead to collapse of the retaining system. In most of the cases, limited set back and non-availability of hard strata at shallow depth give rise to problem in proper anchorage.
   Cross-lot steel bracing system on the other hand works by the principle of earth pressure balance. Therefore, soil condition and/or set back availability does not matter for the stability of such system.
5. Economic consideration: For the case discussed in this paper, an economic evaluation led to the fact that per metre of anchored sheet pile costing comes to Rs. 2,37,571.20.
   Whereas, for the same soil condition and same depth of dredging, costing per metre run for cross-lot bracing system is Rs.1,24,466.00. That is an economy of 47.6% is achieved in cross-lot bracing compared to anchored sheet pile walls.

5. CONCLUDING REMARKS

Vibration during installation of sheet piles is a very serious issue, and therefore, is possible to be installed only in less densely built-up urban areas. The temporary retaining system consisting of cross-lot steel bracing is found to be more environmentally friendly, easy to install, effective in arresting wall movements and significantly economical compared to anchored steel sheet pile wall.

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