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Design of Support System for Excavation in Black Cotton Soils in Guntur, India

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ABSTRACT

Deep excavations are one of the venturesome tasks taken up by geotechnical engineers. Adept and secure design of deep excavations in especially clayey strata is a defying task per se it involves assumptions. Controlling the mobility of clayey soil is intricate. Deformations are consequential to stress release and redistribution in deep excavations and stability controls the design of the support systems. Usually, it is the supervision of deep excavations (Burland and Hancock 1977, O'Rourke 1981; Finno et al. 1989, Hansmire et al. 1989, Ulrich 1989; Whitman et al., 1991; Ikuta *et al*., 1994) at field that succor to attain economy and safety. It also aids in prediction of the ground settlement on adjacent structures. The objective of this paper is to discuss the design of sheet pile, supporting structures and challenges faced in the construction of a sump in clayey soil site. The case of study is located at Guntur district in the state of Andhra Pradesh, India. Standing on a bed of black cotton and plastic clays with water table as low as 0.5m, the site renders a geotechnical challenge.

Keywords: Deep excavation, Sheet pile, Finite Element Analysis, PLAXIS

[1] INTRODUCTION

Construction of deep basements, subways and service tunnels require deep excavations eventually making them contingent in the construction activities. Excavation is one of the most hazardous construction operations as the behavior is multifaceted and their failures are rapid. The effects are caused due to the decrease in vertical stress and loss in lateral support and hence requires the examination of field performance and monitoring [1]-[3]. Stability and deformation are the weightage factors in the performance of a deep foundation. If the factor of safety is small, strains are small and inturn the ground movements are small. The deformations damage the adjacent structures like buildings and utilities. Severity of this damage depends on the pattern and movements around the excavation.

Soil type dictates the design and performance of such excavations [4]-[6]. Including soil properties, depth of excavation and workmanship are intrinsic in controlling the earth movements [4].To verify the performance of a deep excavation, their analysis is required. Though stability is easy to analyse using equilibrium calculations, deformations are difficult to predict and require finite element analysis.

References [7]-[11] used 3D finite element analysis to study deep excavations. Study and analysis done by [10] and [11] have shown that a significant reduction in deformation in the corners was observed when corner restraints were used when compared with that for a plane strain condition. Fig 1 illustrates the effect of support system stiffness on the wall displacements.

In this paper the design of sheet piles as temporary support system for excavation in deep clay is dealt .The excavation has a 17m x 13.26 m plan area for construction of an underground sump with 6 m excavation depth at the Reliance cash and carry construction site in Guntur located in the state of Andhra Pradesh, India.

[2] SITE DETAILS

The site is blanketed with plastic silty clays up to 7.5m below the ground surface, underlain with about 5m of sandy clays (Fig). In order to excavate to the required depth of about 6 m total is a major challenge of controlling the soil collapse as well as the lateral support of the excavation.

In detail, the ground consists of 3 layers (Fig. 1). The upper most layer is 5.0 to 7.5 m thick silty clay (layer I). Beneath the fill is sandy clay (3.5 to 4.5 m) thick layer (layer II) and it is underlain by greenish white rock fragments / reddish clayey sand gravel (11m to 13.5m, layer III) .The recorded SPT ‘ N’ value ranges from 5-36 in the topmost layer ,19-61 for the sandy clay layer and 41-99 for the rock fragments in the third layer. The groundwater level was located at about 0.5m below the ground surface during the exploration in 2011(May) but is suspected to be seepage. The results of a number of field and laboratory soil tests are summarized in Fig. 2 and Fig. 3. The natural water content varies between 37 and 7% (including the pebbles) and shows a general decreasing trend with depth.

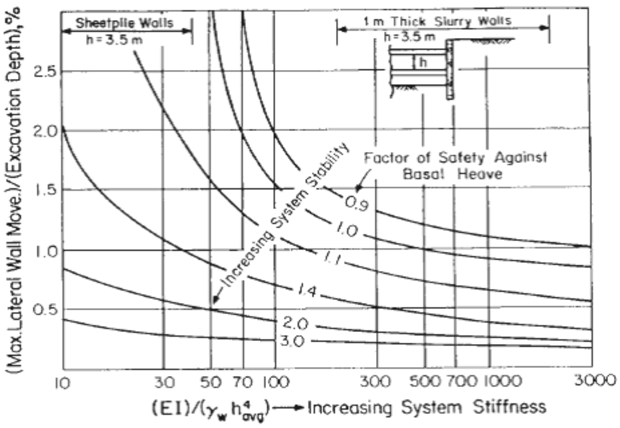

Figure 1 Chart for estimating maximum lateral wall movements and ground surface settlements for support system in clays [6].

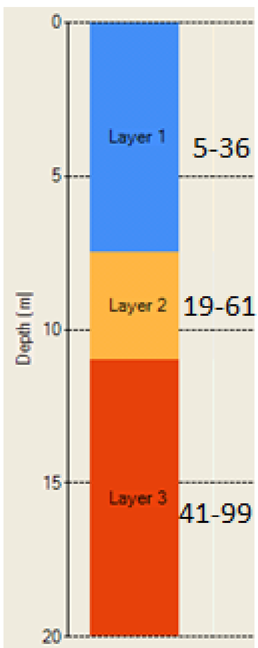

Figure 2 Predominant soil profile with SPT 'N' value

Table 1 Soil Properties

Depth (m)	Soil Type and IS Classification	SPT 'N'
0-2.5	Plastic silty clay [MH-CH]	8
2.5-4.5	Silty clay [MH-CH]	11
4.5-7.5	Plastic silty clay [MH-CH]	15-19
7.5-9.	Sandy clay +lime pebbles	30
9-12	Sandy clay +lime pebbles	32-38
12-15	Clayey sandy +pebbles [MI-CI]	46-47
15-20	Rock fragments [SC]	54-66-73

The liquid limit in the upper part is around 40 % which can be classified as plastic silty .Unconfined compressive strength and direct shear tests were conducted during the exploration phase.

[3] MODELING AND ANALYSIS

With the increase in the complexity of a geotechnical problem it is preferable to use a numerical model. Partial differential equations are employed with a combination of different variables and the calculations are used to mould the model. The variables maybe material parameters, stresses, and strains etc, and have a complex correlation. According to [12] the maximum horizontal wall displacement (δ *hm*) lies between 0.5% *H* and 1.0 % *H*, on average at 0.87% *H* (Fig.3).

The use of the sheet piles as temporary support system for the current problem of study satisfies the limits imposed by the design specifications and also addresses the constructability of the underground water tank. Finite element analysis is used, which is vital not only in the evaluation of the behavior and design of the support system for underground sump, but also in the evaluation of its impact on adjacent structures. The analysis is primarily based on the theory of earth pressure developed by Rankine, 1857. When designing sheet pile walls, the partial coefficient method is used, both in serviceability limit state and ultimate limit state.

The finite element software PLAXIS [13] has been used to model the staged excavation of the underground sump. Fig 4,5 show the excavation pit section details and plan with structural support system.

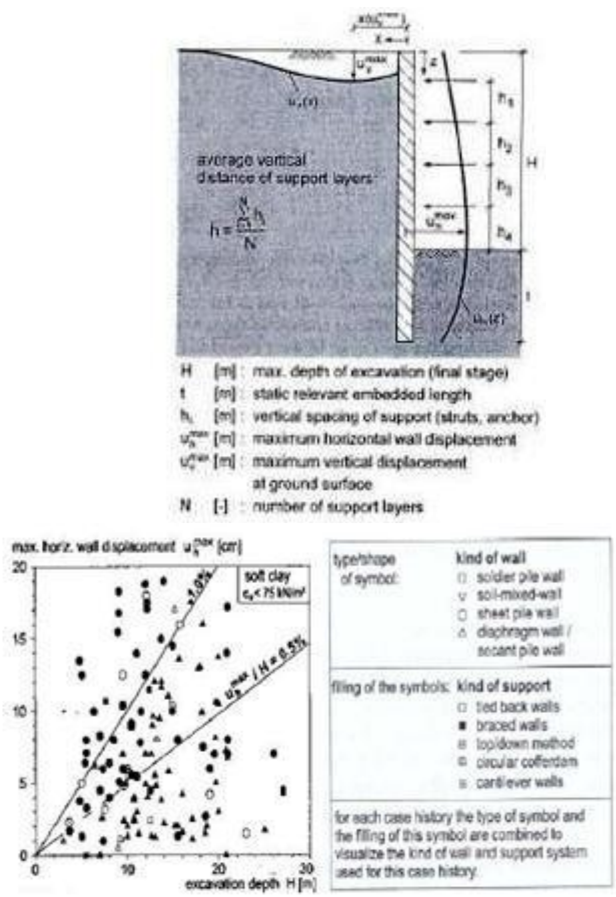

Figure 3 Variation of maximum horizontal displacements with excavation depth [12]

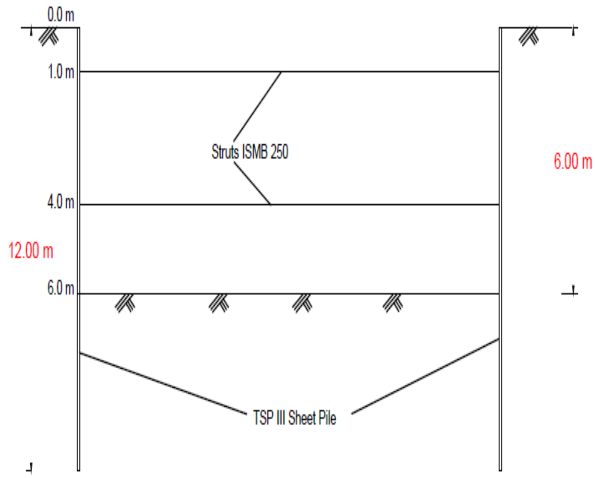

Figure 4 Excavation section with support details

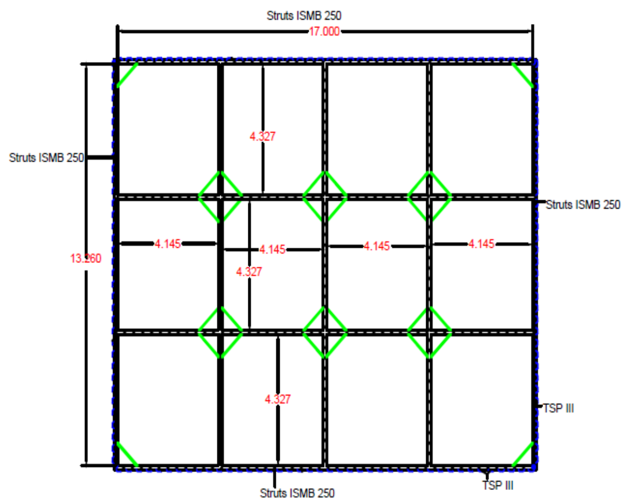

Figure 5 Excavation Plan details with support system

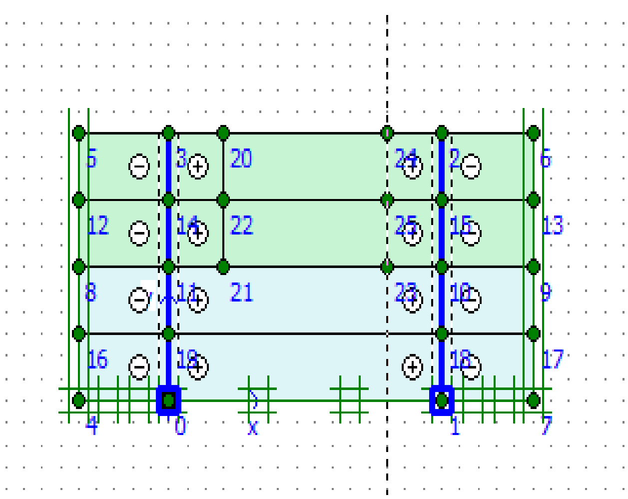

Figure 6 Geometry of the model with TSP III sheet pile for 12m

The geometry of the sheet pile used is TSP III with 400 x 125 x 13mm section piles (Fig. 6) with unit weight of 60kg/m from Hanwa Singapore is provided. In addition, soil properties from the geotechnical investigation reports were used. Struts or braces are modeled as bar elements which have only axial forces and no resistance to bending. The connection between the wall and the strut is consequently analogous to a pin connection. Pre-loads are specified as part of the strut definition. ISMB 250 is used at two preferable levels at 1.0 and 4.0m below the EGL.

[4] RESULTS AND CONCLUSIONS

Understanding of the load transfer mechanism around the construction site, superior workmanship, soil properties information is required for deep excavations. Prediction of accurate design before the construction is necessary, especially when clay soils are being dealt. Catastrophic failures of the excavation and structural failure can be avoided by detailed deformation analysis and site inspection during construction process.

In the current case, a temporary support system using sheet piles TSP III with 400 x 125 x 13mm has been adopted for adequacy of the lateral loads. Fig.7 details the deformed mesh of the sump after the analysis. The total displacements and vertical displacements at 14.6mm and horizontal displacements at 10.58mm are shown in Figs 8-10.

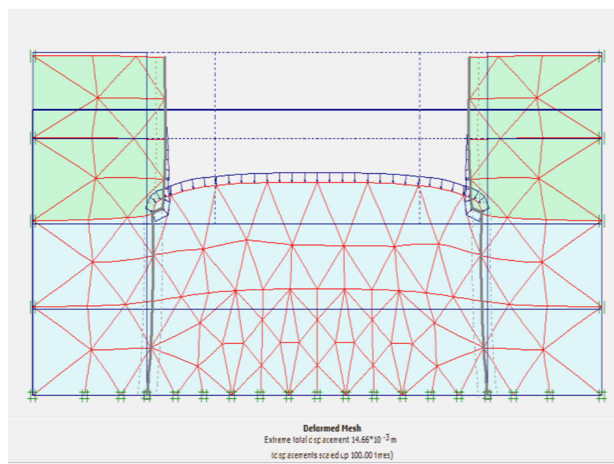

Figure 7 Deformed mesh of sump

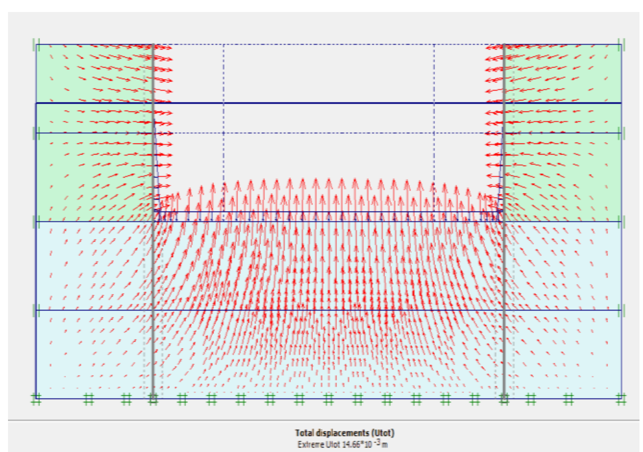

Figure 8 Total displacement (14.66 mm)

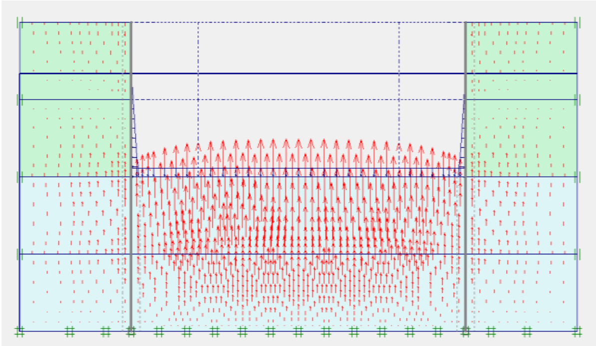

Figure 9 Vertical displacements (14.66 mm)

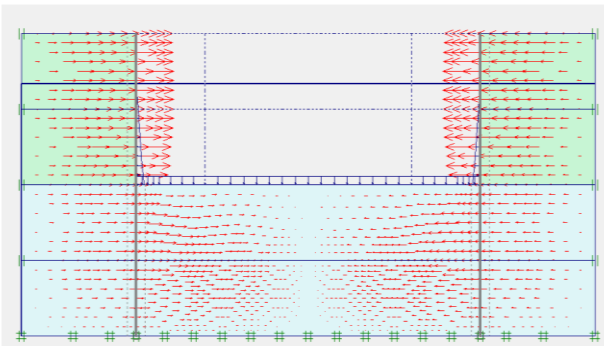

Figure 10 Horizontal displacements (10.58 mm)

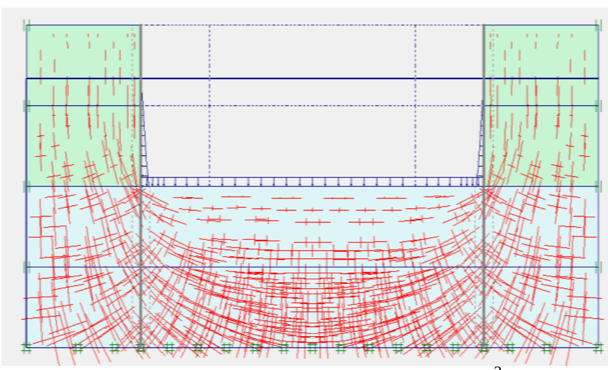

Figure 11 Effective stress (145.50 kN/m^2)

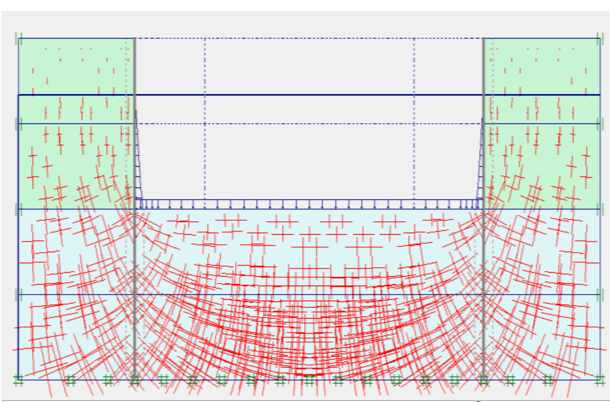

Figure 12 Total stress (208.66 kN/m^2)

The values of total and effective stress are derived to be 145.5kN/m^2 and 208.6 kN/m^2 (Fig.11, 12)

Finally, sheet piling has been designed to facilitate the excavation in the site blanketed with clay as sheet piling also does not require much expertise and time. However, skill is necessary to safely install walers and toms which support the piling.

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