FINITE ELEMENT ANALYSIS OF SHEET PILE WALL IN EXPANSIVE SOIL

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Abstract - *Sheet pile walls are long slender continuous structure provided with vertical interlocking system to hold the earth, water or both. The sheet pile wall built-in expansive soil may be subjected to damages, due to the volumetric expansion of the soil during wet seasons. Swell pressures are developed when the swelling of the soil is restrained by the structures. Swell pressure developed on the sheet pile wall may cause extra deformations. The effect of swell pressure on the sheet pile wall may cause early failure of the wall. To avoid the issue of swell pressure on the wall, a study is needed. Under the plane strain condition, the finite elemental study of sheet pile wall is conducted to study the effect of swell pressure on the wall. The swell pressure estimated from the experimental result for varying percentages of chemical is used for finite elemental study in Plaxis 2d. Experimental analysis of the black cotton soil was conducted to measure swell pressure generated on the soil. Influence of the chloride additive on the geotechnical properties of back cotton soil to investigated the use as a backfill in sheet pile wall.*

Key Words: **Finite elemental analysis, plane strain, swell pressure, lateral deformation, bending moment.**

1. INTRODUCTION

In India volume change behaviour of expansive soil is particularly troublesome when it is subjected to long dry periods and periodic rains. Heavy periodic rain causes the swelling of the black cotton soil. Soil swell vertically unless the superstructure provides sufficient load to suppress the swelling. Swelling of the soil causes heavy damages to the geostructures. The lateral swelling of the expansive soil is possible in the excavations, pits or on the retaining structures. The net forces acting on a unit soil mass in equilibrium is zero, i.e., there will be no motion and no rotation. But on the excavation to a depth, the one of the internal stresses acting on the unit soil mass get removed and results in imbalance of the forces causes the motion of soil towards the excavation. Retaining wall are rigid or flexible wall made to retain the soil mass firmly. Properly designed sheet pile wall can hold the earth at position. In case of expansive soil, the swell pressure get added to the earth pressure. Swell pressure is developed in the sheet pile wall when the swelling of the expansive soil is restrained by the sheet pile wall. The swell pressure in the sheet pile wall may cause excess lateral deformation.

The black cotton soil is the expansive soil, which swelling and shrinkage on the variation in the moisture content. This soil is considered to be most vulnerable soil and its deposits covers almost 20% of total land mass. The construction of the sheet pile wall in the expansive soil is vulnerable due to high swell potential. As a usual practice the construction of sheet pile wall is done with the replacement of expansive soil as the backfill. But the soil deposits is large in India, and is costly. So the modification of the expansive soil rather than the replacement is a most effective method. The chemical modification of the expansive soil with chloride additive is effective in reducing the swell potential. It is a cost effective method of mitigation of swell pressure.

Lassaad Hazzar et al [4] conducted vertical loads influence on the lateral performance of battered piles by 3d finite difference analysis in both sandy and clayey soils. Different batter angles and soil stiffness were considered to examine the salient features of this complex soil–structure interaction problem. The lateral response of the piles with positive inclination angles is independent of the batter angle and the soil stiffness. And its lateral capacity remains unaffected as the vertical load application is prior to the lateral load. Benzalkonium chloride contains a benzyl group, it is very effective in the reduction of swell potential **(M.V. Shah et al) [6].**

2. METHODOLOGY

Sheet pile wall designed here is to hold backfill on one side of the wall. Back fill used is expansive soil, which swells on the addition of water. Since the backfill is restrained by the sheet pile, the earth pressures get developed and acts on sheet pie wall. Along with the earth pressures, the swell pressure is also developed on the rainy seasons in black cotton soil. Swell pressure acts laterally to the wall only on the backfill portion of the wall. Beyond that depth swell pressure get cancelled each other.

The sheet pile to hold an expansive earth of 4m was designed as per IS code. The design obtained is shown in figure 1. Analysis of sheet pile wall is considered to do under plane strain condition, so it was done in Plaxis 2d. For the analysis of the sheet pile wall, the experimentally estimated swell pressure is provided up to 4m depth. Sheet pile wall of 8m depth and infinite length was driven to the black cotton soil. The swell pressures estimated for varying percentages of chemical was chosen for each analysis. The table shows the values of the swell pressure with different percentage of additive. Total of five analysis were done with increasing swell pressures.

A 12m x 9m of soil model was provided and meshed to medium fine. The 8m sheet pile wall was driven to a depth of 8m. The figure shows the geometry of the sheet pile wall embedded in the black cotton soil. The soil is excavated from one side of the wall up to 4 m to create the condition of backfill. The swell pressure is provided on the wall in the portion of the backfill as the distributed load.

Percentage of Chemical	Swell pressure (kPa)
0	176
0.5	90
1	58
1.5	30
2	26

Table 1: swell pressure for different percentage of additive

2.1 Design parameters of sheet pile wall

The sheet pile wall was designed as per IS code. Table 5.1 shows the design parameters of sheet pile wall without considering the swell pressure.

Properties	Values
Cohesion, c	18.26 kN/m^2
Angle of internal friction, Φ	12 degrees
Density of soil	12.5 kN/m^3
Height of sheet pie wall	8 m
Depth of embedment	2.4 m
Depth of point of fixity from top	1.6 m

Table 2 : Design specification for the sheet pile

2.2 Properties of sheet pile wall

Sheet pile wall is provided as a plane wall without any joints in it. The property of the sheet pile wall is stimulated with the stiffness and thickness instead of providing the u shaped sections for the sheet pile wall.

2.3 Modelling and staged construction

The soil bore hole of 12m x 9m was created and meshed. For the Input Parameters the density choose was the density for maximum swell pressure, ie., 12.5 kN/m^3. Swell pressure value was chose by conducting oedometer test with variation in the percentages of chemical. In staged construction, the sheet pile wall is initially driven and the after that soil is excavated. Excavation of the sample to 1m depth was done on each phase. Excavation should not done for too much depth because it causes collapse of soil bed.

3. RESULTS AND DISCUSSIONS

3.1 Lateral deformations

Small lateral deformations may occur in the sheet pile wall driven in sand due to surcharge and earth pressures. But the sheet pile wall driven in the expansive soil causes large lateral deformations due to development of excess swell pressure.

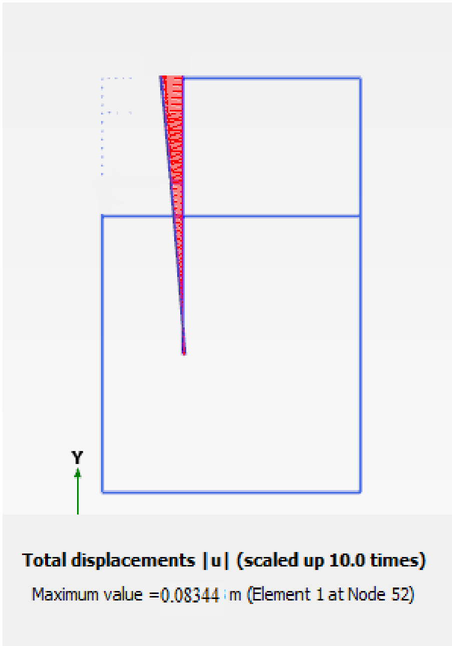

Figure 1 Deformed mesh for 176 kPa

Lateral deformation of the sheet pile wall in the untreated black cotton soil sample is shown in the figure 1. The maximum deformation is at node 52, ie., the topmost portion of the sheet pile wall and. For the black cotton soil treated with 0.5% of chemical the maximum deformation is at node 52, ie., the topmost portion of the sheet pile wall. 75 mm deformation was observed. For the black cotton soil treated with 1.0% of chemical, the maximum deformation is at node 52, ie., the topmost portion of the sheet pile wall and 74mm deformation was observed.

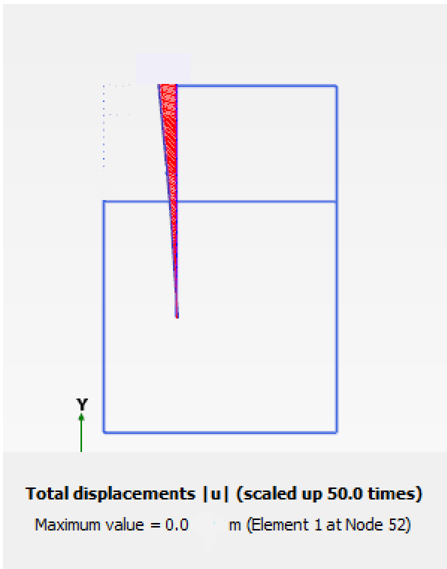

Figure 2 Deformed mesh for 0 kPa

The 1.5% of chemical treated black cotton soil shows a deformation of 17 mm due to 30 kPa swell pressure. For 2% chemical additive, the swell pressure obtained is 26 kPa. The maximum deformation for the swell pressure 26 kPa is at the topmost portion of the wall and it is 14 mm. The Figure 2 shows the deformation of the sheet pile wall in lateral direction for the black cotton soil in ideal conditions with zero swell pressure. The maximum deformation is at node 52, ie., the topmost portion of the sheet pile wall and the deformation observed to be negligible.

The Chart 3.1 shows the variation of lateral deflection with depth in meters for varying swell pressures. The lateral deflection of the sheet pile wall in the non-expansive backfill shows negligible deformations, while the lateral deflections are higher for the soil with high swell pressures. The construction of sheet pile wall is unsuitable in the soil with swell pressure is beyond the 30 kPa.

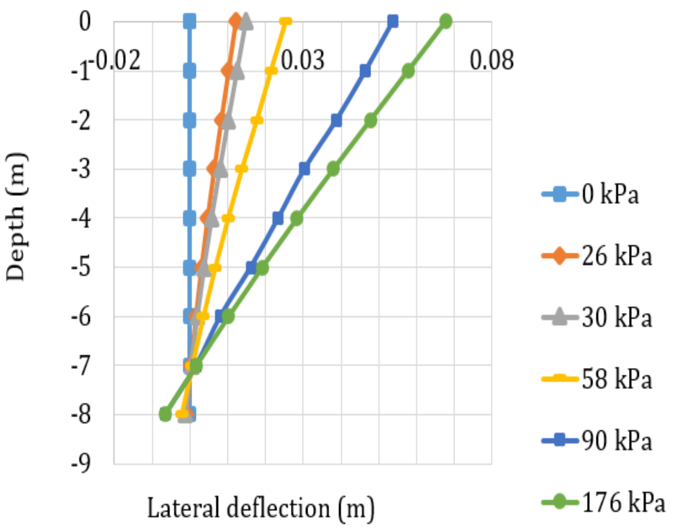

Chart 1 Variation of lateral deflection with depth

3.2 Bending moment

The bending moment obtained for different swell pressure value was plotted in the figure below. From the figure it is clear that the increasing of the swell pressure causes the increasing of the bending moment value. Also the soil with swell pressure of 0kPa, 26 kPa and 30 kPa are suitable to use as a backfill for the construction of sheet pile wall. Figure 3 and figure 4 shows the bending moment diagram for swell pressure of 176 kPa and bending moment diagram for 0 kPa respectively.

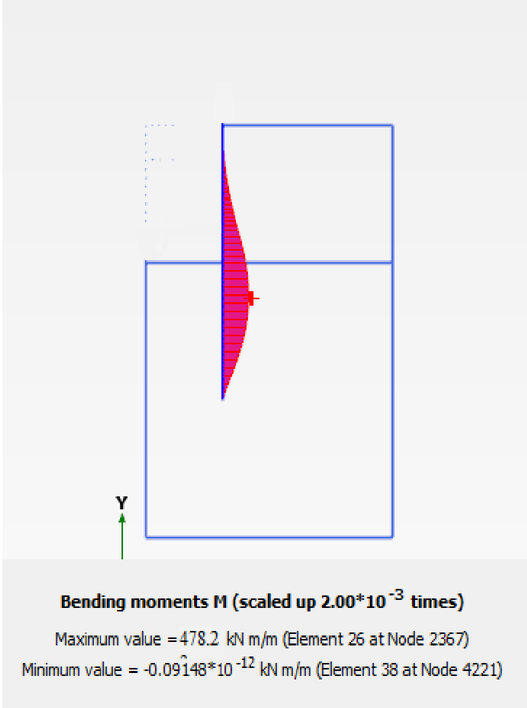

Figure 3 : Bending moment diagram for 176 kPa

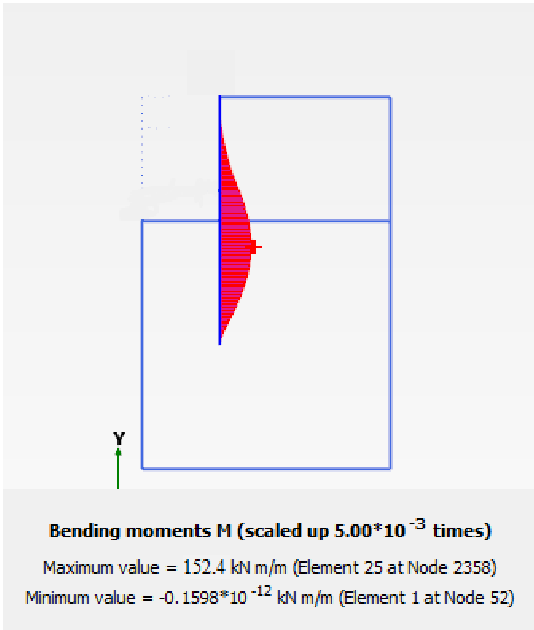

Figure 4: Bending moment diagram for 0 kPa

3.3 Pile head deformation

The deformation in the top of the pile causes due to the swell pressures. Pile head deformation is higher for large swell pressure. The figure 3.3.1 shows the lateral deformation of pile head decreases with the increase in the additive content or the reduction in swell pressure.

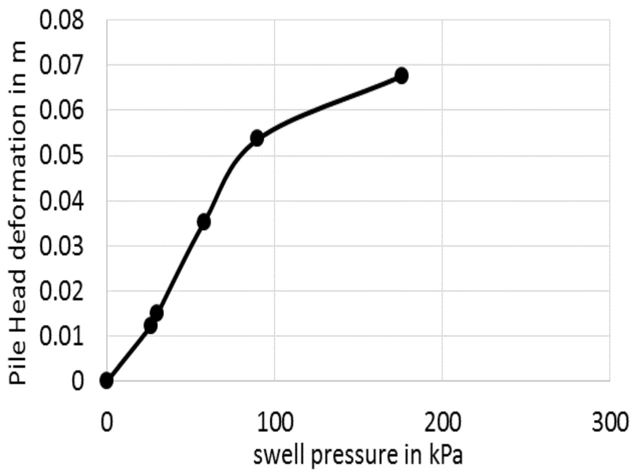

Chart 2: Pile head deformation with swell pressure.

4. CONCLUSIONS

The swell behaviour study of the black cotton soil with the varying percentages of additive was included in this work. Also the works includes the effect of sheet pile wall design and analysis of lateral deformations and bending moment in the expansive soil. Following are the conclusions drawn from my work:

- Lateral deflection of the sheet pile wall is very higher for the expansive soil. It is about 84mm deflection is observed, which is not permissible.
- Lateral deflection seems to be decreased with decrease in the swell pressure from the backfill.
- Pile head deformation decreases with decreasing in the swell pressure in backfill.
- The bending moment of the sheet pile wall is higher for the expansive backfill. The additional swell pressure from the backfill tends to cause the higher bending moment. The bending moment value decreases with decreasing swell pressure.
- From the analysis, it is advisable to construct the sheet pile wall in the non-expansive soil or the soil treated with chemical to ensure the stability of the sheet pile wall.

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