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ABSTRACT

Jet grout columns are used widely in the last decade in Turkey especially in soil improvement projects. This study is intended to understand the behavior and stress distribution of jet grout columns installed in non-cohesive soils and are under vertical loads. Design capacity of jet grout column is examined by loading tests. Stress distribution was determined by strain gauges installed inside the jet grout columns. 35cm in diameter 8m long jet grout columns were constructed in silty sand. As measured by strain gages, the stress along the column extends deeper while load increases. According to the load test results, at the bottom of the column, 8% of the total test load was measured. Also the 60% of the total stress was observed at a depth of 3.5m to 4.5m below top of the jet grout columns. The loading test was modeled with a finite element program. 15m long jet grout columns was also modeled using a finite element program and it indicated about 60% of the total load occurred at a depth of 8.5m.

INTRODUCTION

Jet grout columns are used widely in the last decade in Turkey especially in soil improvement projects. Today usually jet grout columns are used as an improvement for foundation soil. Jet grout columns are used to carry vertical loads as to increase the bearing capacity and to prevent excessive displacements. This study is intended to understand the behavior and stress distribution of jet grout columns installed in non-cohesive soils and are under vertical loads. Design capacity of jet grout column is examined by loading tests. Stress distribution was determined by strain gauges installed inside the jet grout columns. 35cm in diameter 8m long jet grout columns were constructed in silty sand. The loading test was modeled with a finite element program.

INSTRUMENTED LOAD TESTING OF THE JET GROUT COLUMN

Investigation of stress distribution under vertical loadings in a jet grout column was done using strain gauges. Jet grout columns were constructed in Istanbul close to the seaside for the impermeability of the area, as a retaining structure and to increase the bearing capacity. Jet grout columns were constructed with a diameter of 35cm.

The site was logistically located in a difficult place and it was difficult to do jetgrouting with high pressure injection equipment as there were two buildings next to the site and also the road to the site was narrow for some equipment to pass and reach the site. Therefore using low flow and pressure jet grout pumps 35cm in diameter columns were formed.

Two boreholes each 15m long were bored during the site investigation. The soil consists of 3.5m thick fill followed by green red colored silty gravelly sand layer with clay bands. The ground water table was 3m below the ground surface (Erbay, 2009). The soil profile is shown in Fig. 1.

The aim of the loading tests was to investigate the stress distribution in the columns under applied loadings. In the columns, at different intervals strain gauges are placed. Two strain gauges are placed on the column at 0.4m, 2.30m, 4.10m, 5.80m and 7.70m below the ground surface. Figure 2 shows the places of strain gauges on the column. These strain gauges were connected to the data logger via cables.

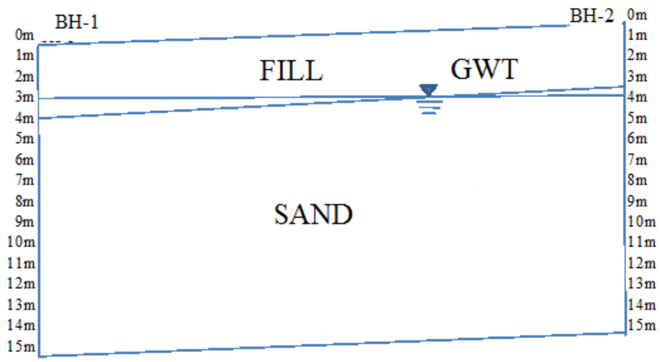

Fig. 1. Soil profile (Erbay, 2009).

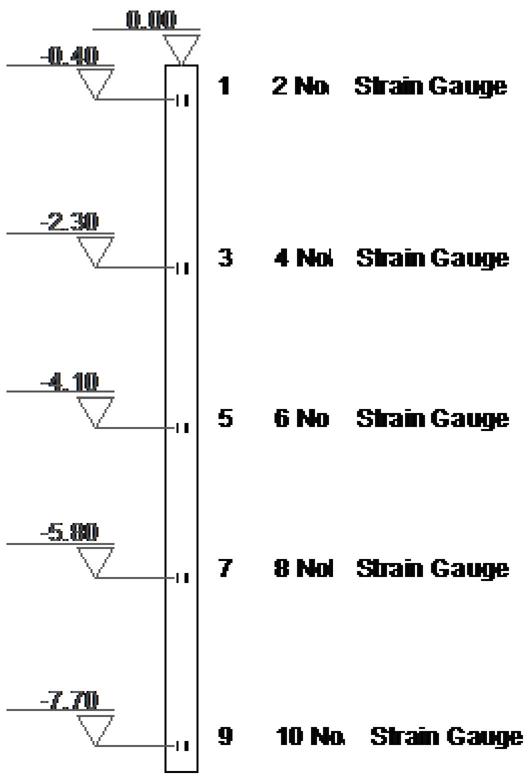

Fig. 2. Places of strain gauges on the column.

Strain gauges were glued to a 20mm x 20mm x 1.2mm aluminum brace. The ratio of axial rigidity (EA) of the brace to the jet grout column is 1/15. Two columns of 8m long were constructed as reference columns that have a distance of 4m between them. 15 tons of loads were used as service load and the capacity is calculated as 22.5tons. After 21 days, jet grout columns were loaded by 25% of service load increments every step and the displacements measured are recorded. Then it was unloaded. The results are shown in Fig. 3. The results for both the tests are quiet close. Under 15 tons of load, 2.5mm displacement was measured and under 22.5 tons of load 4 mm displacement was measured. In the unloading stage of the service load, permanent displacement has occurred. Unloading from the maximum load, 3.0mm permanent displacement was measured.

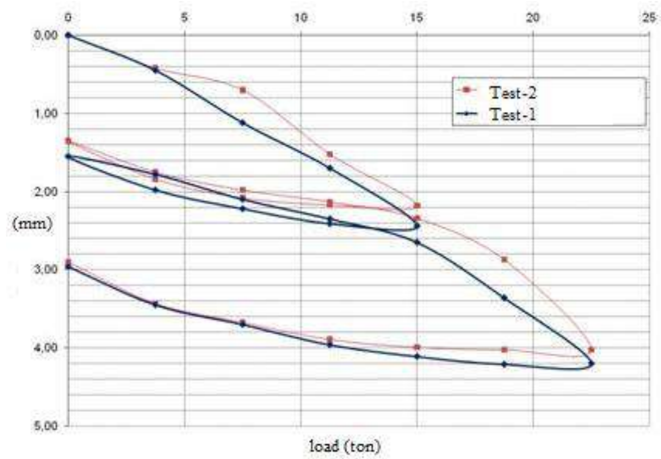

Fig. 3. Load displacement curves for the load tests.

During the loading tests, strain gauges placed in the columns were used to measure strains at different loading stages. From these, the change in the stress distribution in the columns can be determined. The measured values are normalized according to the maximum deformation measured 40cm from the top of the column. Figure 4 shows the deformations measured during the different loading stages.

As seen in the figure, with depth, the deformations measured decreases. As the load increase, unit deformations change and the deformations close to the surface increase. At 7.70m below the surface, compared to the strain measured at 0.40m below the surface under the maximum load 22.5 tons 8% of the deformation is measured. In the first 4m 60% of the load applied is transferred to the column.

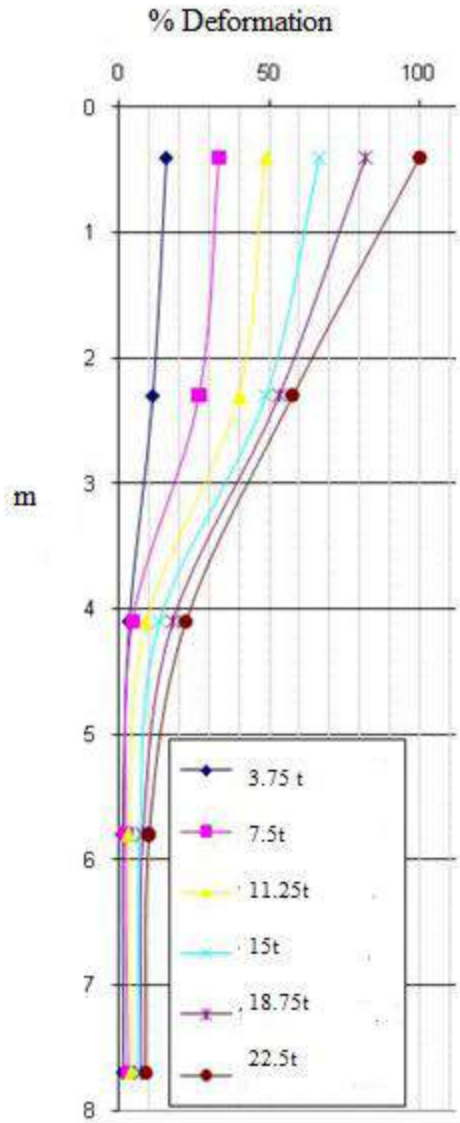

Fig. 4. Deformation change with depth for the first column.

NUMERICAL ANALYSIS OF THE LOAD TESTS

Figure 5 shows the mesh for the numerical model. Numerical analysis of the load tests was done using Plaxis 2D software. In the program Mohr-Coulomb model was used. Table 1 shows the parameters used in the model for the soil and the jet grout column. Drained analysis was done and the internal friction angle (ϕ) was chosen as 32°. Cohesion value of the jet grout column was determined as 40% of the unconfined compression value of it. Unconfined compression strength of the samples taken from the column is 3.69MPa.

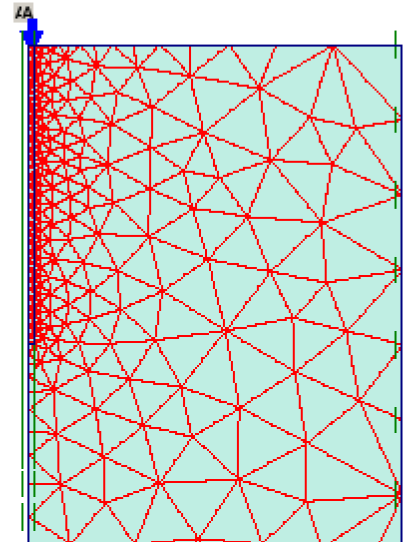

Fig. 5. Mesh system.

Table 1. Soil Parameters used in the analysis

	γ_n (kN/m^3)	γ_{sat} (kN/m^3)	v	E_{50} (MN/m^2)	c (kN/m^2)
Gravelly Sand	18.8	20	0.29	30	5
Jet grouting	23	23	0.20	2750	1500

Figure 6 shows the comparison of numerical analysis and load test results. The results are close to each other.

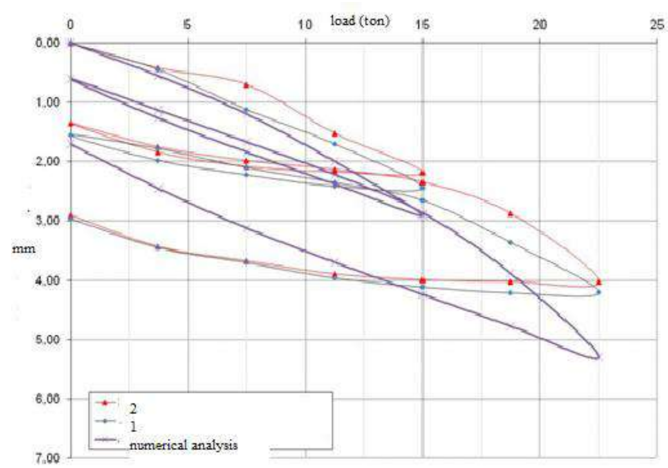

Fig. 6. Comparison of numerical analysis and load test results.

Figure 7 shows the stress distribution from the load tests and the numerical analysis results. According to the analysis results stress distribution changes with depth and decreases with depth. However decrease in the site measurements are quicker than the one given by the analysis. The analysis shows that the stress decreases linearly with depth. At 7.7m the stress is 10% less than the value at 0.40m below the top of the jet grout column. Load test results are close to the numerical results.

CONCLUSIONS

Jet grout columns are used widely in the last decade in Turkey especially in soil improvement projects. This study is intended to understand the behavior and stress distribution of jet grout columns installed in non-cohesive soils and are under vertical loads. Design capacity of jet grout column is examined by loading tests. Stress distribution was determined by strain gauges installed inside the jet grout columns. 35cm in diameter 8m long jet grout columns were constructed in silty sand. As measured by strain gages, the stress along the column extends deeper while load increases. According to the load test results, at the bottom of the column, 8% of the total test load was measured. Also the 60% of the total stress was observed at a depth of 3.5m to 4.5m below top of the jet grout columns. The loading test was modeled with a finite element program. 15m long jet grout column was also modeled using a finite element program and it indicated about 60% of the total load occurred at a depth of 8.5m. At a depth of 12 to 15m below the top of the jet grout column, stress increases were damped.

In the design of jet grout columns, length of the columns can be optimized with the settlement and bearing capacity checks for the site. However the quality control of the columns constructed need to be checked and necessary tests done on site.

ACKNOWLEDGEMENTS

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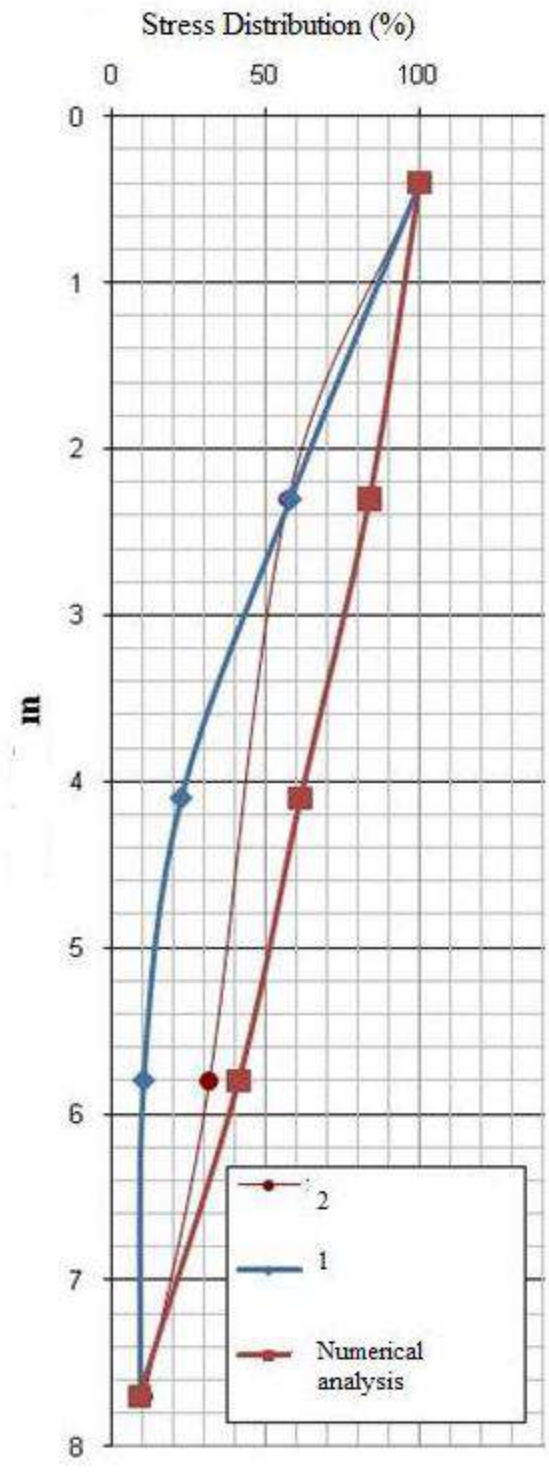

Fig. 7. Comparison of stress distribution of load test and numerical analysis.