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VALIDATION OF A NUMERICAL MODEL FOR THE PREDICTION OF LOAD CARRYING CAPACITY OF RAMMED AGGREGATE PIER

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ABSTRACT

Foundation in soft ground suffers from excessive settlement and bearing failure problems. Rammed Aggregate Pier is used to improve the soft ground. Till to date, there is no mechanism based design procedure for such kind of foundation due to complexities in the failure mechanism created from the interactions of foundation, pier and surrounding soft soils. Finite Element Method can be an effective numerical tool to study such kind of complex problem. It was observed that the numerical result satisfactorily predicts the field load-deformation response of a footing rest on ground with reasonable degree of accuracy. Thus, this study proves that the FE model can be used to develop a design procedure for the prediction of the behavior of RAPs reinforced soft ground.

Keywords: *Soft ground, Footing load test, FEM, RAPs, Parametric study*

1. INTRODUCTION

The sub-soil in Khulna region mainly consists of soft fine-grained soil up to great depth with a layer of very compressible soil. Therefore, it is very essential to improve this soft soil to construct various types of civil infrastructures. In KUET campus, the RAPs in three different categories were constructed to improve the soil with locally fabricated equipment and construction materials. Load tests of full size isolated square footing were conducted on both the natural soil and improved ground to determine the load carrying capacity. The interaction between footings, RAPs and surrounding soil is a complex problem indeed. Finite Element Method (FEM) can be a good technique to simulate the situation and hence, for necessary predictions. So the PLAXIS, a FEM software, is used here as a numerical tool to predict the experimental results reported by Hossain (2007).

2. MATERIALS AND METHODS

2.2 Rammed Aggregate Pier

Rammed Aggregate Pier (RAP) has become a common ground improvement technique for improving the marginal sites. RAP methods have been used successfully in other countries for ground improvement projects (Alamgir 1996). The performance of this technique is required to investigate further in details in local condition. The RAP system is used to reinforce the soft or loose soils for the support of transportation structures including Mechanically Stabilized Earth retaining walls and large embankment fills. The installation of stiff RAP elements provides a significant increase in the composite stiffness of otherwise soft and compressible foundation soils. RAP Construction using open-graded stone affords radial drainage to the elements. The result of RAP installation is a significant decrease in both settlement magnitude and duration with the RAP-reinforced zone. The RAPs were installed successfully at KUET campus to investigate the improvement of a poor soil conditions having a significant layer of organic soils (Hossain 2007 and Hossain & Alamgir 2010).

2.2 Numerical Model and its Validation

PLAXIS Version 8 is a finite element package intended for the two-dimensional analysis of deformation and stability in geotechnical engineering. Geotechnical applications require advanced constitutive models for the simulation of the non-linear, time dependent and anisotropic behavior of soils and/or rock. In addition, since soil is a multi-phase material, special procedure are required to deal with hydrostatic and non-hydrostatic pore pressures in the soil. Although the modeling of the soil itself is an important issue, many tunnel projects involve the modeling of structures and the interaction between the structures and the soil. PLAXIS is equipped with the features to deal with various aspects of complex geotechnical structures.

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The Mohr-Coulomb failure criterion devised with the PLAXIS is due to its robustness and simplicity. It is based on soil parameters that are well-known in engineering practice. Not all non-linear features of soil behavior (hardening and softening) are included in this model. The Mohr-Coulomb model may be used to compute realistic support pressures for tunnel faces, ultimate loads for footings, etc. It may also be used to calculate a safety factor in slope stability determination using a 'φ-c reduction' approach. In this study, an elasto-perfectly plastic FE model with Mohr-Coulomb failure criteria has been used to predict the bearing capacity of the soft soil improved by RAPs. However, the geometry and finite element mesh of the problem are shown in the Figures 1and 2. The calibrated material parameters for the soil layers and the RAP materials used in the model are given in the Table 1. For the sake of the simplicity, the earth pressure coefficient was assumed constant throughout the different soil layers, though the effect of this value is observed in the parametric study in the ensuing section. Figure 3 shows that the numerical model closely predicts the experimental data points and the total displacement vectors from the analysis are shown in the Figure 4. It is observed that PLAXIS can be used with reasonable degree of accuracy to predict the capacity of RAP installed in a soft ground with layering property.

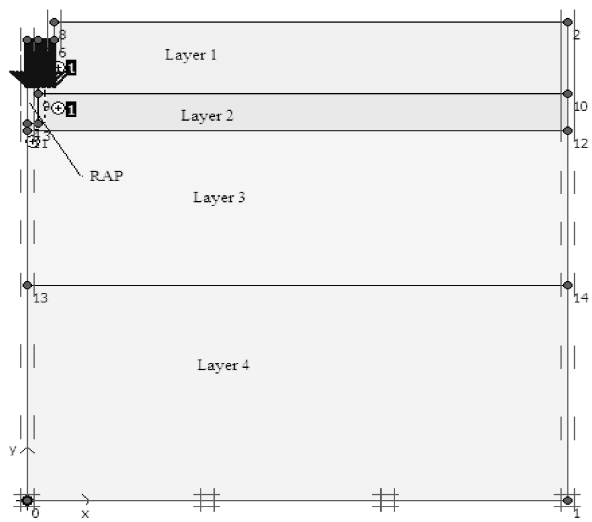

Figure 1 Geometry.

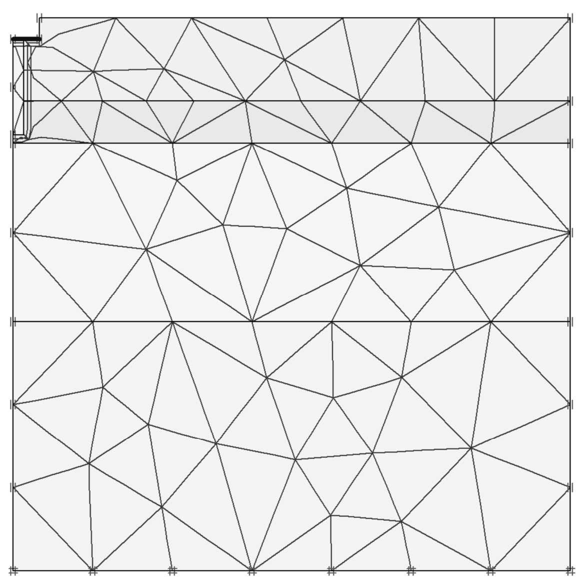

Figure 2 FEM mesh.

Table 1 Material parameters.

Layer	Soil type	Ko	λ_{unsat} kN/m^3	λ_{sat} kN/m^3	E kN/m^2	ν	C kN/m^2	Φ degree	ψ degree
Layer 1	Silty Sand	1.00	17.00	20.00	10,000	0.30	15.00	30	10
Layer 2	Clay	1.00	16.90	18.90	2,000	0.30	30.00	0	0
Layer 3	Organic clay	1.00	12.63	15.00	2,000	0.30	31.00	0	0
Layer 4	Silty clay	1.00	16.69	18.69	5,000	0.30	13.00	0	0
Sand Column	RAP	1.00	17.00	20.00	20,000	0.30	10.00	45	15

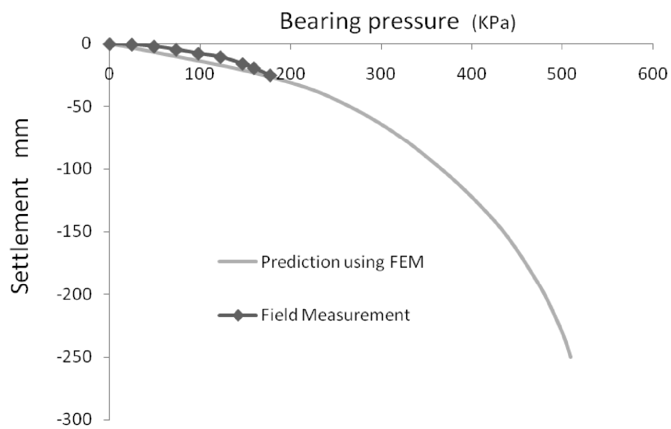

Figure 3 Load-settlement curve.

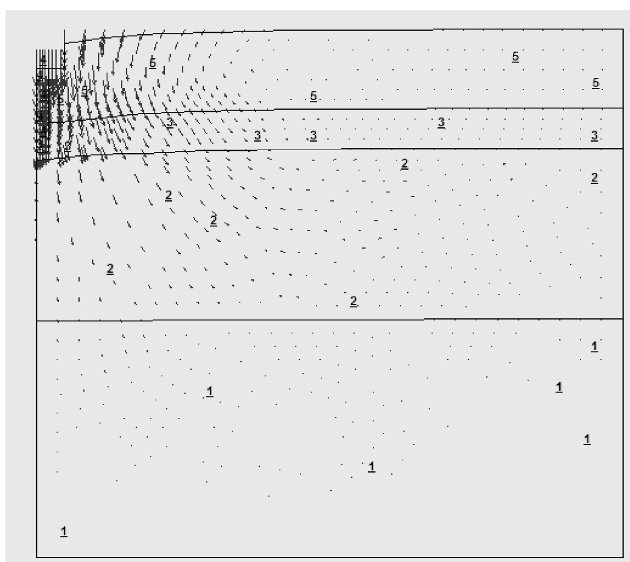

Figure 4 Total displacement vector from FE analysis.

3. PARAMETRIC STUDIES

Using this validated FE model, an extensive parametric study was carried out to find the effect of (i) earth pressure coefficient (Figure 5: ultimate bearing capacity of the footing is increasing with the increase of earth pressure coefficient of the surrounding ground), (ii) frictional angle of RAPs material (Figure 6: : ultimate bearing capacity of the footing is increasing with the increase of frictional angle of RAPs), (iii) plate area ratio (Figure 7: : ultimate bearing capacity of the footing is decreasing with the increase of plate area ratio), (iv) dilatation angle of RAP material (Figure 8: : ultimate bearing capacity of the footing is increasing with the increase of dilatation angle), on the bearing capacity.

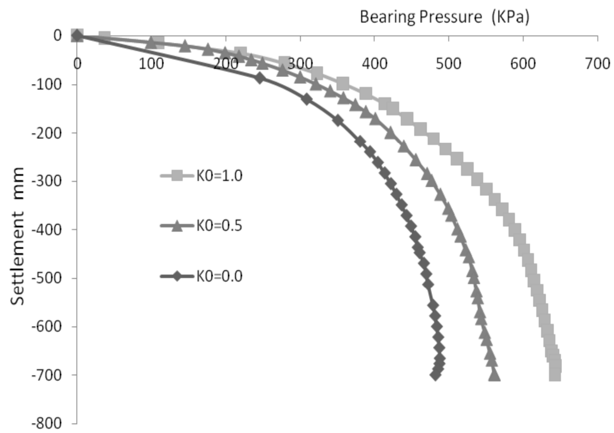

Figure 5 Effect of earth pressure coefficient of the ground.

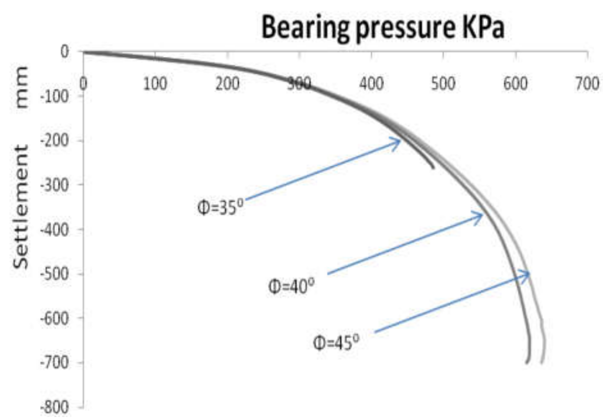

Figure 6 Effect of internal frictional angle of RAP material.

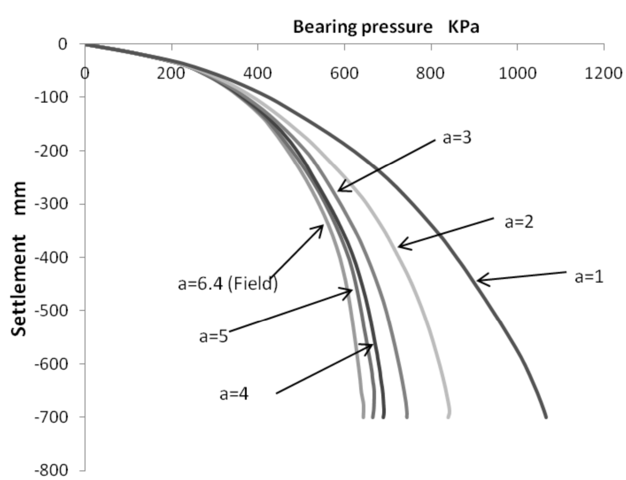

Figure 7 Effect of plate area ratio

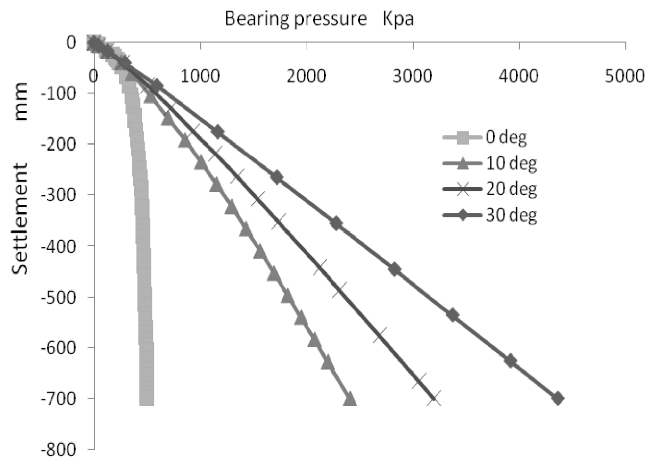

Figure 8 Effect of dilatation angle of RAP material.

4. CONCLUSIONS

Based on this study the following conclusions can be made:

- The RAP is a proven technique to improve poor soil conditions.
- The RAP improved ground can be analyzed and hence predicted with reasonable degree of accuracy using the Finite Element method.
- The ultimate bearing capacity of the footing increases with the increase of earth pressure coefficient of the surrounding ground, frictional angle and dilatation angle of RAPs, but decreases with plate area ratio of the footing.

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