Comparative Study of Slag and Slag-Lime Columns in Kuttanad Clay

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Abstract – *Now a days, a major issue for proper development is the increasing cost and non-availability of land. An effective solution is to utilize the available land with weak strata which has low shear strength and high compressibility which are otherwise not utilized for construction. This demands the use of a proper ground improvement technique. Among various ground improvement techniques including dewatering, preloading, sand drains, prefabricated vertical drains, granular column etc., use of stone columns is a cost-effective and environment friendly method for improving the low bearing capacity and large-scale settlement of weak soils. In this study the analysis of ground improvement by stone columns will be carried out using finite element software PLAXIS 3D. The stone aggregates will be replaced by slag aggregates. Slag aggregates are the waste materials from the iron industry. Utilizing these aggregates in stabilization techniques helps in reducing its degrading effect on the environment. A comparison when slag aggregates are used with lime along with geotextile layer in between is also studied.*

Key Words: **Stone Column, Stone Aggregates, Slag Aggregates , Finite Element Analysis , PLAXIS 3D**

1. INTRODUCTION

Provision of granular piles or aggregate piers is one of the ground improvement techniques where weak soils are reinforced with compacted aggregate columns in a grid pattern. The purpose is to enhance load carrying capacity, accelerate consolidation to permit the application of higher imposed loads, and reduce settlement by densification and reinforcement of the subsoil. The load carrying capacity is obtained from the lateral confinement from the surrounding soils (Greenwood, 1970). The granular column behaviour can be further improved by encasing it with geosynthetics. In this numerical study, the aggregates are replaced by slag aggregates which are waste materials from the iron and steel industry.

1.1 Literature review

Jorge et.al (2017) performed review on the most recent advances and recommendations on modelling stone columns. He concluded that for numerical analyses of a problem, conditions such as an embankment, the simplified geometrical model of a three-dimensional slice of columns is recommended. For a more simplified model, the unit cell approach is recommended. The filler material in stone column was altered with that of shredded tyre chips (Ankitha et.al, 2017) and the load settlement behavior was obtained from the plate load test of both end bearing and floating stone columns with and without encasement. They found that in both end bearing and floating columns, mixture of 70% aggregates and 30% tyre chips showed better performance. Zukri et.al (2018) reviewed the stone column which enhances the weak soils by the partial replacement of compressible soil by more competent materials like sand, silica manganese slag, pulverized fuel ash, coal ash, quarry dust, highway ballast, stone dust shredded waste tyres, and flyash in terms of their consolidation behavior. Unit cell concept was used by Shahraki et.al (2018) on ABAQUS for 3 D modelling of stone columns in saturated soft grounds. 2D and 3D numerical analyses on PLAXIS were compared for a test embankment in Rio De Janerio, Brazil (2012) stabilized with basal geogrids and geosythetic encasement (Hosseinpour et.al, 2019). He concluded that 3D analyses were better since they can stimulate field conditions better. Ghorbani et.al (2020) did a parametric study of the factors affecting stone column properties and also the stability analysis of the embankment.

2. MATERIALS AND METHODOLOGY

The soil to be improved is taken from Kunnamkaery, Kuttanad. Both the stone and slag aggregates are of 20 mm size. Encasements using geogrids were provided. The soil and aggregate properties were tested in the laboratory and the input parameters to be used in the software were found.

The numerical analysis is done in a finite element software, PLAXIS 3D. The finite element analysis in PLAXIS 3D is utilized to analyse the settlement and total stress characteristics of various stone columns as in ordinary stone columns and encased stone columns both with stone aggregates and slag aggregates. Encasement is provided using geogrid element. Positive and negative interface elements were also provided.

Table -1: Material Properties

Kuttanad Clay	
Specific Gravity	2.49
Water content	93.9 %
Liquid Limit	103 %
Plastic Limit	42.8 %
Plasticity Index	60.14 %
Optimum moisture content	23.9 %
Max dry density	1409 kg/m^3
Bulk density	2730 kg/m^3
Cohesion (kPa)	6.5
Friction angle	2□
Youngs modulus (kPa)	89.96

Stone aggregates	
Bulk density	1480 kg/m^3
Specific gravity	3.35
Water absorption	1.38%
Cohesion (kPa)	0.2
Friction angle	57□
Youngs modulus (kPa)	35

Slag aggregates [9]	
Youngs modulus	41 kPa
Cohesion	4 kPa
Angle of internal friction	42□
Poisson's ratio	0.33
Unit weight	15.6 kN/m^3

3. VALIDATION STUDY:

The total stress characteristics from the journal [7] and numerical analysis on PLAXIS 3D are compared using their respective graphs and tables for the same model. The maximum variation of 1.36 % was found.

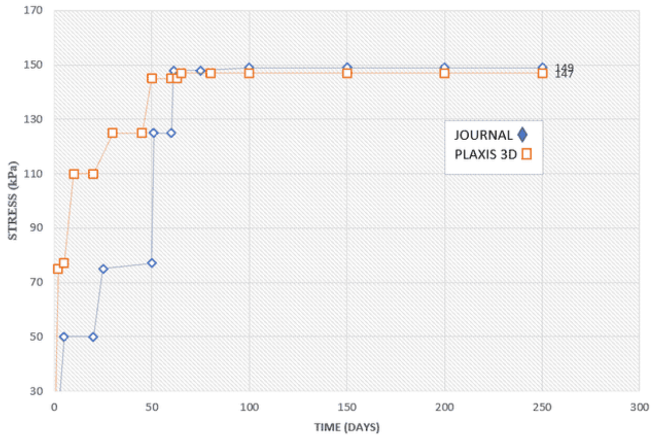

Fig -1: Name of the figure

Chart -1: Comparison of stresses with validation journal

4. NUMERICAL INVESTIGATION USING PLAXIS 3D:

18 m length soil bed of Kuttanad clay with 6m width is stabilized with columns 6 x 3 with 2m spacing between them is considered. Due to symmetry, half of the soil bed is modelled. The embankment has a height of 5.3 m, width 6m, and breadth 18m. The slag and lime columns modelled are of 11m length, 0.8m diameter, and 2m center to center spacing. Encasement using geogrids are provided around the columns. Here, Mohr Coulomb model is provided to the soil layers, embankment, and stone columns. The geosynthetic encasements are provided as geogrid elements specifying their axial stiffness equal to 2250 kN/m. The boundary conditions are provided such that the bottom is restricted for motion on all directions. Both the vertical end sides are restricted in motion in x and y directions only, that is, it is free to move in vertical direction.

5. RESULTS AND DISCUSSIONS:

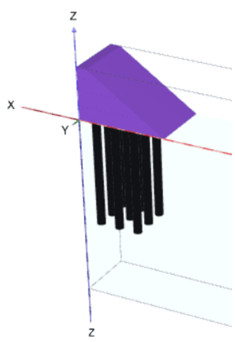

Fig -1: Type 1 column (100% slag aggregates) model in PLAXIS 3D

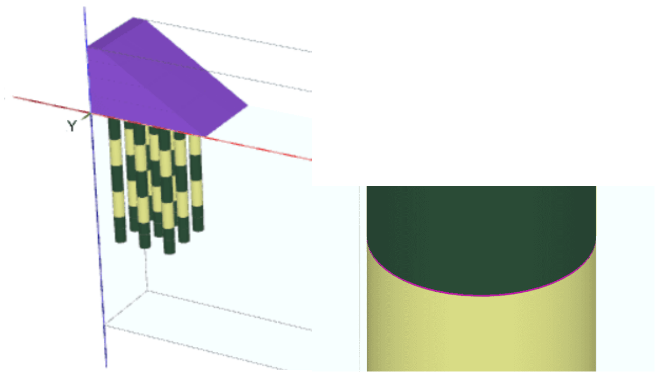

Fig -2: Type 2 column (slag aggregates + lime with geotextile separator) model in PLAXIS 3D

5.1 Settlement studies:

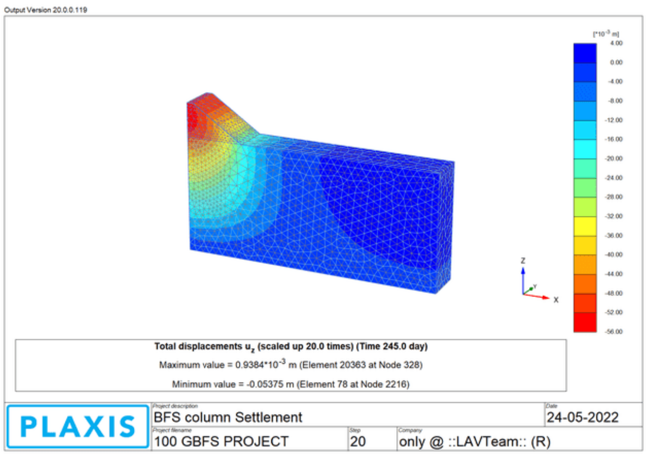

Fig -3: Total displacement distribution in Type 1(100% slag aggregates) column

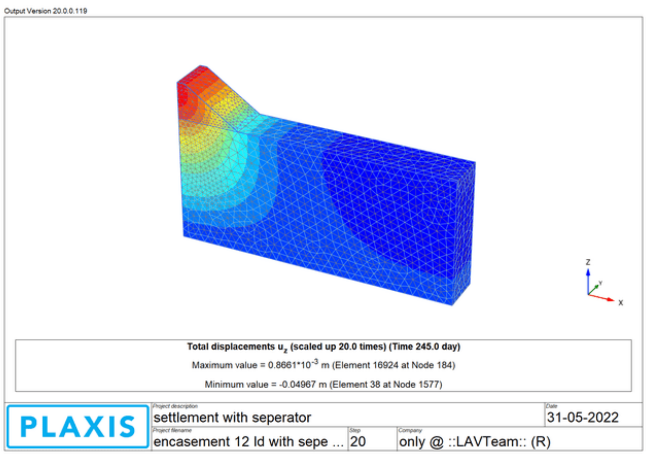

Fig -4: Total displacement distribution in Type 2(slag aggregates + lime with geotextile separator) column

5.2 Stress studies

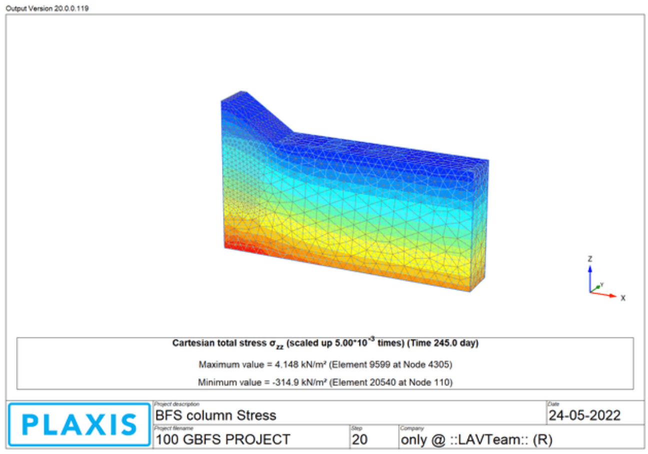

Fig -5: Total stress distribution in Type 1(100% slag aggregates) column

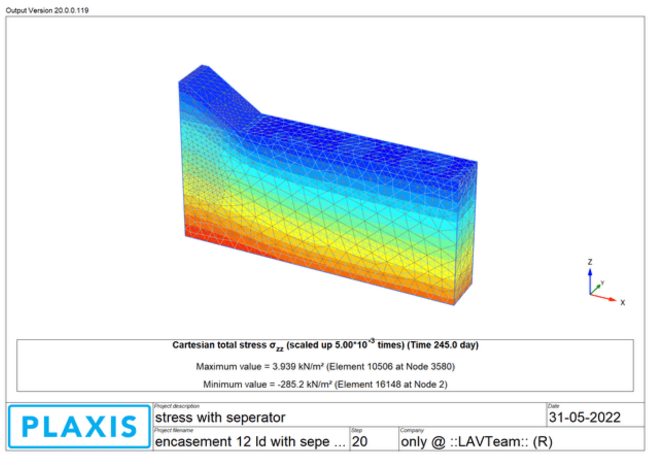

Fig -6: Total stress distribution in Type 2(slag aggregates + lime with geotextile separator) column

The models of granular columns with 100 % slag aggregates and slag aggregates with lime in addition to geotextile separator were studied for settlement distribution and it was found that on using composite column with slag and lime, a decrease in settlement by about 8.34% is found. But, in case of stress studies there is a decrease of 5 % for the lime slag composite columns. Further when settlement criteria is given importance it can be said that composite columns with separator performs better than slag columns.

Table -2: Results showing variation of settlement and stress

Column Type	Maximum Settlement(m)	Maximum Stress(kPa)
100 %Slag aggregates	0.9384	4.148
Slag -lime column with separator	0.8661	3.939
Variation	8.34% decrease	5.03% decrease

6. CONCLUSIONS

Numerical studies were conducted using plaxis3D on encased granular columns by replacing the filler material with slag aggregates. The various conclusions that were made includes:

1. Slag - lime columns with geotextile separator is a potential alternative for improvement of Kuttanad clay.
2. There is a decrease in 5 % in the maximum stress that can be taken by the composite slag-lime columns when compared to 100% slag columns.
3. There is a decrease in settlement of 8.34 when slag - lime columns with separator are used instead of 100 slag columns. Hence it is better to use when soil is subjected to considerable stress.

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