International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 3 Mar. 2021, pp: 1339-1343 www.ijaem.net ISSN: 2395-5252

Numerical Analysis of Lime and Geogrid Reinforced Embankments

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Submitted: 30-03-2021 Revised: 06-04-2021 Accepted: 09-04-2021

ABSTRACT: The objective of this work is to enhance the stability of the high embankment with lime stabilized soil and geogrid by using PLAXIS 3D. Embankment is made of hardening soil model and the foundation soil is made of Mohr-coulomb model. It is found that the lime stabilized soil sandwiched between geogrid layers with increased stiffness has made a significant impact in reducing the total displacement of the high embankment. The embankment is susceptible to toe failure when it is reinforced with only geogrid layers. It is observed that increase in the no of geogrid layers to stabilize the high embankment although reduced the total displacement, the concentration of total displacement on toe region has not reduced. Thus, introducing lime stabilized soil between geogrid reduces the potential of failure in the toe and increases the stability of the high embankment.

I. INTRODUCTION

In order to stabilize the expansive subgrade soil, naturally available materials had been in use from ancient days like Natural Pozzolana, Lime, etc. [1,2,3] Later abundant wastes from several industries had a series concern on disposing them properly. Thereby, innovative ideas came up to mix these wastes with constructional materials especially in road constructional activities had been used by several investigators. Hence, Fly Ash, Lime Sludge composites, Silica fume, Gypsum and many chemical additives are found to improve one or many physio-chemical properties of the problematic black cotton soil thus making it suitable to be used as subgrade soil. [4,5,6,7].

Soil reinforcement has been evolving in geotechnical engineering with many advanced materials like geosynthetics since the last century. Reinforcing the soil has economically proven to be the best method by eliminating the cost and materials involved in the construction of large retaining structures, embankments and slopes. It is a common practice to use well graded coarse-grained soils as a fill material for embankments since they provide unrestrained drainage, stability and are not much influenced by change in temperature. For all the soil reinforced structure, perfect deformation assessment can be done through finite element analysis. The behaviour of the complex structures can be easily predicted in more economical way by Numerical simulation. There are different types of geosynthetic basal reinforcements which include geocell mattress, bonded geogrid, Extruded geogrid, woven geogrid, woven geotextile and knitted geogrids. Knitted polyester geogrid especially biaxial geogrids provide better stability to the reinforced soil structures due to finest interlocking mechanism with the aggregate particles.

From the past it is known that lime is a promising material for stabilizing the expansive soil.Lime when mixed with the clayey soil and laid between the embankment and subgrade, it becomes a buffer layer to resist the swelling displacement and volume changes that otherwise take place in the subgrade soil.

Sandwich construction was introduced where thick layers of quicklime about 0.5 m thick have been confined by filter fabric and alternated with 0.7 m to 1.2 m lifts of compacted cohesive soil [8]. In soft soil, vertical lime columns were found to improve the strength of the surrounding soil thus load is transferred to a firm stratum below.

In this paper an attempt has been made to stabilise the high embankment using lime and Geogrid. From the bottom of the embankment, geogrid is laid first, above which lime stabilised soil extends to 0.5 m height. Geogrid layer is placed above this lime stabilised soil. Earth materials are later staged above this layer to make total height of the embankment about 9m. Geogrid layer are also introduced at 3m and 6m height of the high Embankment. The lime stabilised soil sandwiched between the geogrid is intended to increase the stiffness of the embankment thereby controlling the total displacement and improving the stability of the high embankment. Phreatic surface is kept at the ground level in order to achieve worst condition. As a common practice, Mohr – Coulomb and Hardening Soil Model wereused for simulating the foundation soil and embankment respectively.

II. GEOMETRY OF THE MODEL

The embankment which is 9m high with 45˚ slope is presented in figure 1. The embankment is reinforced by 4 layers of geogrid along with a lime stabilised soil sandwiched between geogrid which is situated at the bottom of the embankment. Lime stabilised soil extends to a depth of about 50cm above which earth fill materials are laid in layers following the standard procedures of the compaction. The vertical spacing of geogrid is 3m.

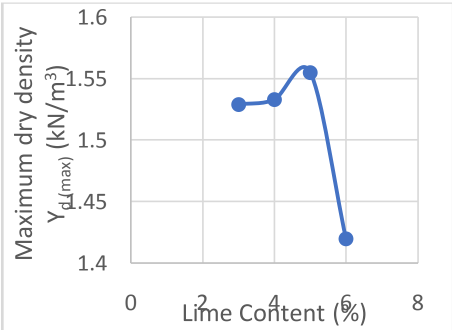

Fig.2. Optimum content of Lime

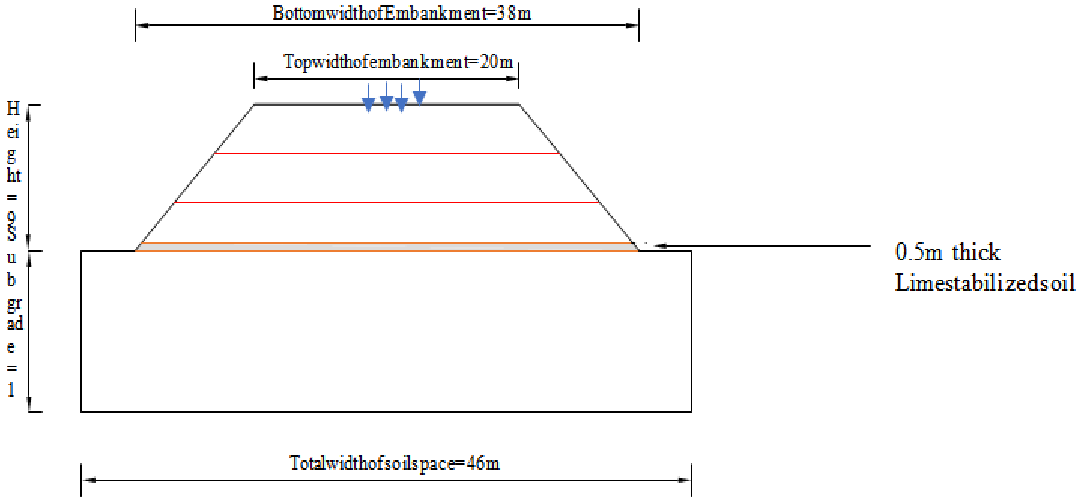

Fig.1. Geometry of the Model

III. PROPERTIES OF THE SOIL:

The optimum content of lime to be mixed with the soil was found out to be 5% by Standard Proctor Compaction test and the results are given in fig.2. Lime stabilised soil is made by mixing 5% Lime with the foundation soil. Foundation soil of the material model is done with the Mohr – Coulomb and the Embankment is done with Hardening Soil Model. The properties of soil model are presented in Table 1.

BOUNDARY CONDITIONS:

The deformation boundary conditions of the simulated model are given below:

X_{min}, X_{max}, Y_{max}, Y_{min} are all normally fixed while Z_{min} is normally fixed. Z_{max} is allowed to deform freely.

The boundary conditions for groundwater flow is modelled to be open on all boundaries except Z_{min} was closed.

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Soil	γ_{unsat}(kN/m^3)	Γ_{sat}(kN/m^3)	C(kN/m^2)	Φ
Embankment Earth Material	18	23	5.5	28
Lime Stabilised Soil	15.4	19.52	258.4	7
Foundation Soil	19	23	37	3

Table 1. Properties of the Soil Model

IV. RESULTS AND DISCUSSION FROM NUMERICAL MODELLING:

The unstabilised embankment is found to collapse resulting in face failure of the embankment. Also, total displacements of the embankment were found to be 0.93m (Fig.3) which exceeds the permissible settlement of high Embankment.

Effect of two layered geogrids:

When the high embankment is stabilised with 2 layers of geogrid, there was a decrease in total displacement and the magnitude of displacement is found to be within permissible limit. But the results indicate that the displacements are concentrated in the toe region which implies that the toe region is more susceptible to collapse resulting in the toe failure of the embankment (Fig. 4). Multiple layers of geogrid are introduced to stabilize the embankment which resulted in similar behaviour.

Effect of four layered geogrid with lime sandwiched between two geogrid:

Here the embankment construction is started with lime stabilized soil sandwichedbetween two layers of geogrid whose depth extends to 0.5m, thereby this layer is intended to arrest the displacement taking place in the toe region. Above the stabilised layer conventional procedure is adopted to compact the subsequent layers of the embankment with the given earth material. Geogrid layers where also introduced at 3m and 6m to provide stability to the embankment. The lime stabilised soil layer sandwiched between two layers of geogrid was acting as a cushion which provides adequate stiffness to the embankment. In addition, the total displacement of the embankment was found to be 17.14cm (Fig. 5) well below the permissible limit.

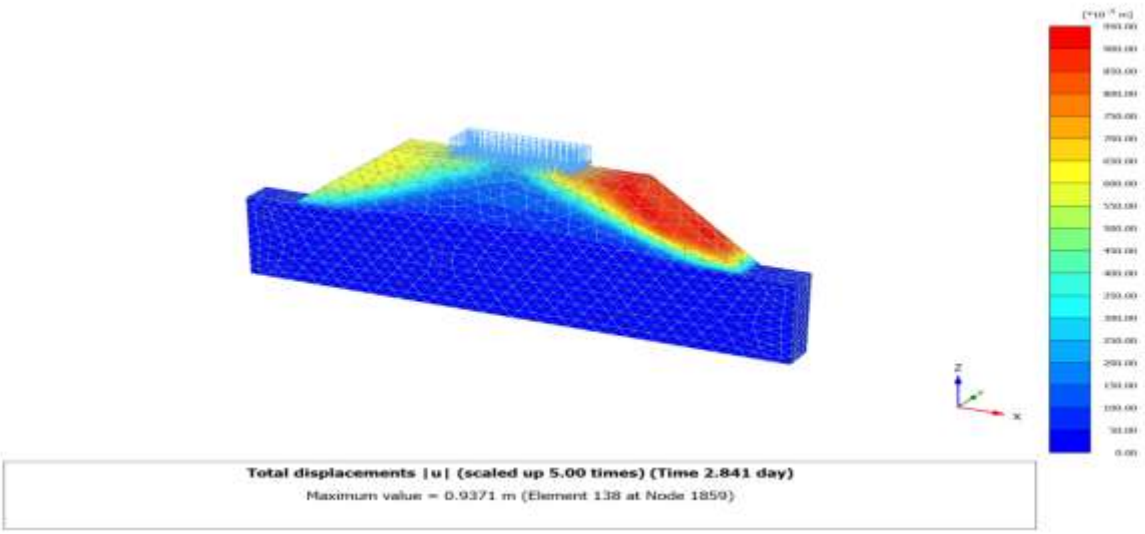

Fig.3. Unstabilised Embankment

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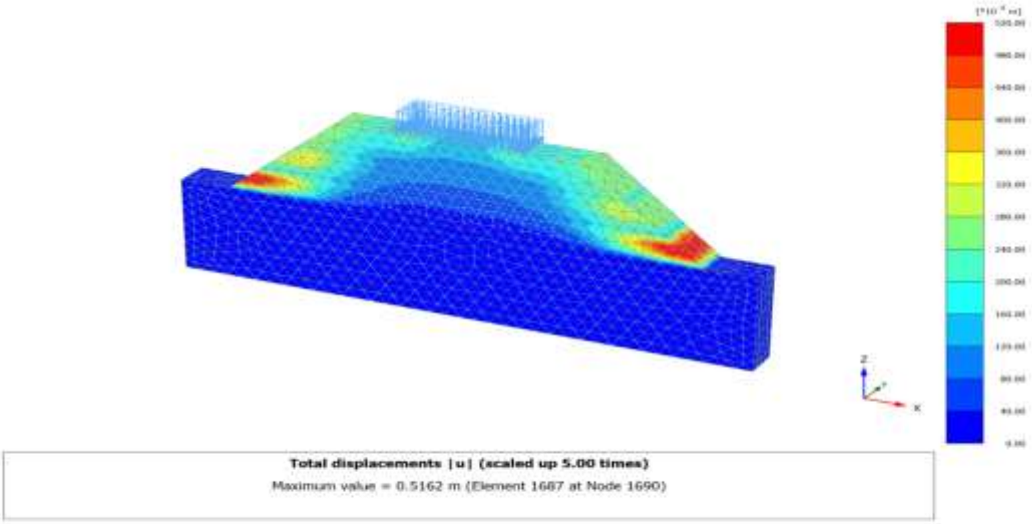

Fig 4. Embankment with two layered Geogrid

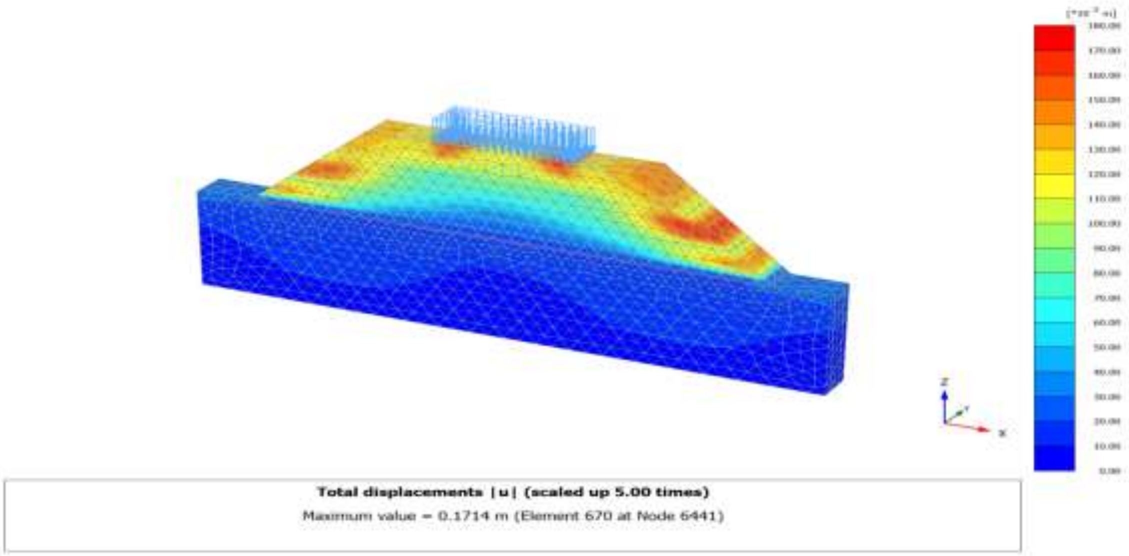

Fig 4. Embankment with four layered Geogrid and lime stabilised soil

Shear stress variation between various Models:

It is observed that the embankment model collapses for a given surface load of 50 kN/m^2 with a shear stress of 12 kN/m^2 for one, two and three-layered Geogrid. The maximum shear stress of the high embankment increases 80% when a small strip of lime stabilised soil is introduced at the bottom. Hence, it is observed that the lime stabilised soil sandwiched between the geogrid layers is enhancing the stability of the high embankment by improving the shear capacity of the compacted earthfill material.

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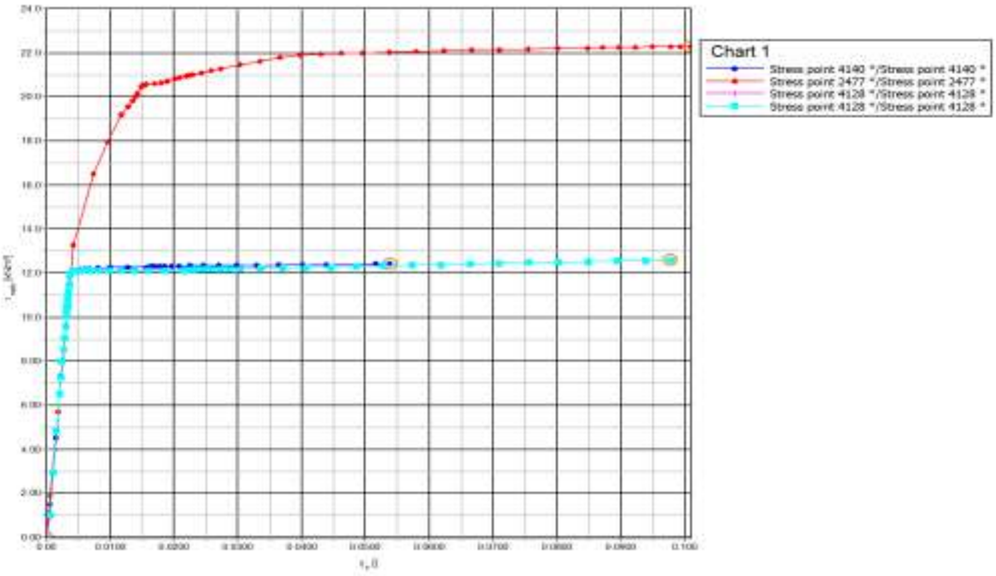

Fig 6. Shear stress variation

V. CONCLUSION:

It is observed that the finite element analysis carried out using PLAXIS 3D that; the total displacement in the high embankment is reducing to about 81.2% when it is reinforced with the lime and Geogrid. Also, it is found that the Shear capacity of the high embankment increases to 22 kN/m^2 from 12 kN/m^2 which means the stability of the high Embankment had a significant impact when lime stabilised soil layer sandwiched between Geogrid is introduced in the bottom of the embankment. Therefore, it can be concluded that introducing a lime stabilised soil sandwiched between geogrid decreases the total displacement taking place in the high embankment

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International Journal of Advances in Engineering and Management
ISSN: 2395-5252

IJAEM

Volume: 03 Issue: 03 DOI: 10.35629/5252

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