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Stability Analysis of Geosynthetic Reinforced Embankment with Blast Furnace Slag as Fill Material

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ABSTRACT: The problems due to slope instability in embankments is a challenge for geotechnical engineers. The goal of this research is to evaluate the stability of a road embankment filled with blast furnace slag. Geogrids are installed to impart strength to the light weight embankment. based on the Finite Element Method, Plaxis-2D, is used to investigate slope stability. The geogrids are positioned at various layers in the embankment and the optimal arrangement is found out. The findings of this study demonstrate the applicability of construction of embankments using blast furnace slag as per the comparative analysis of deformations and factor of safety for an embankment with normal fill.

KEYWORDS: Slope stability, Finite element analysis, Plaxis, Geogrid, Normal fill, Blast furnace slag.

I. INTRODUCTION

The problems with slope instability are particularly common on road embankments and lead to failure in the embankments because of the movement of pavement and as a result of insufficient shear strength, leads to significant settling or sliding. Normal fill can consist of a mixture of several soils, such as silty sand, clayey sand, or silty clay, etc. that are widely used as embankment material throughout India. The soils frequently experience swelling, or shrinkage-related movements under the light to medium infrastructure, such as pavement, embankments, and crowded residential and commercial structures as a result of climatic variations. The soil movement in pavements causes settlements, surface cracking, which makes for challenging driving conditions, as well as expensive repairs and upkeep for the highways across the country.

Geotechnical engineers generally consider the factor of safety while evaluating the proximity of slope failure. The most popular analytical approaches are traditional limit-equilibrium procedures. Numerical modelling using commercial software utilizing finite element analysis techniques like PLAXIS, GEOSLOPE, GEO5, and others provide a strong and feasible substitute for the assistance of a geotechnical engineer. The purpose of this study is to do a slope stability analysis using the PLAXIS 2D platform to analyse the stability of a man-made slope

Blast furnace slag is a type of industrial waste that poses the biggest environmental contamination risk and necessitates a sizable amount of land for its safe disposal. Some potential uses for such wastes on a big scale include geotechnical structures, highway embankments, and structural fills. The polymeric materials like Geogrids made of Geosynthetics are used to prevent settlements under highway embankments. The use of blast furnace slag with geogrids has been found to be an innovative ground improvement measure for reducing stresses and settlements brought on by earthquakes.

The construction of embankments on soft soils like clay with high groundwater levels is very difficult and frequently requires preliminary research. The two most popular methods for analyzing and predicting the mechanical behavior of soil are finite element methods and conventional limit equilibrium methods for geotechnical stability. The ability to simulate the entire interaction of the embankment foundation without predetermining the mode of failure is the primary advantage of finite element analysis over conventional limit equilibrium methods

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II. OBJECTIVES

The primary goal of this research is to evaluate the effectiveness of blast furnace slag as fill material in combination with geogrids in embankments.

1. To analyse the stability of an embankment with blast furnace slag as fill material when compared to that of a normal fill embankment
2. To determine the optimal arrangement of geogrid layers in blast furnace slag embankment

III. METHODOLOGY

Themainpurposeofthisstudyistodeterminet hestabilityofblast furnace slagembank mentaccording to the factor of safety and deformation.The FiniteElementMethodbyPlaxis2Disusedfor stability analysis. The software was first validated and then samplecollection was carried out followed by testing theproperties of soil after which modelling and analysiswasdone.The Achenkovil River embankment in Pandalam, Pathanamthitta, was the location where the subsoil samples were taken.The normal fill samples were collected from Changanassery, Kottayam where the commonly used embankment material is a mixture of clay and sand.The engineering characteristics of blast furnace slag were discovered in the literature IRC: SP: 121- 2018 and other sources.

Table1:Properties of Subsoil

Properties	**Value**
SpecificGravity	2.66
LiquidLimit	36.8%
PlasticLimit	22.93%
PlasticityIndex	13.87 %
Optimummoisturecontent	20%
Maxdrydensity	1.78 g/cm³
Cohesion	44kPa
Frictionangle	12°
Soil Classification	Clayey Silt

Table2:Properties of Normal Fill

Properties	**Value**
SpecificGravity	2.65
LiquidLimit	36%
PlasticLimit	24%
PlasticityIndex	12 %
Optimummoisturecontent	17%
Maxdrydensity	1.69 g/cm³
Cohesion	34kPa
Frictionangle	21°
Soil Classification	Clayey Sand

Table3:Properties of Blast Furnace Slag

Properties	**Value**
SpecificGravity	2.4 to 2.5
Gravel	0 to 10%
Sand	7 to 90%
Silt	8 to 85 %
Clay	1 to 10 %
Plasticity	NP
Optimummoisturecontent	8 to 12%
Maxdrydensity	2.05 to 2.15 g/cm³
Cohesion	Negligible
Frictionangle	40 to 45°

IV. VALIDATIONSTUDY

The factor of safety from the journal [13] and numerical analysis on PLAXIS2 Dare compared for the same model.The maximum variation of 5.43% was found.

Table4:Mesh Convergence Study

Tensile Strength (kN/m)	**Very Coarse mesh**	**Coarsemesh**	**Medium mesh**	**Finemesh**	**Very Finemesh**	**Journalvalues**
0	1.359	1.360	1.330	1.356	1.33	1.308
200	1.384	1.420	1.520	1.379	1.35	1.635
400	1.407	1.440	1.553	1.395	1.365	1.684
600	1.490	1.520	1.603	1.442	1.393	1.704
800	1.465	1.474	1.510	1.421	1.382	1.613
1000	1.471	1.501	1.523	1.464	1.397	1.614
TIME	1min	2min	4min	7min	10min	

V. NUMERICAL ANALYSIS

The geometry of embankment considered for the analysis is with height of 4 m,slope of 1 V : 1 H andcrest width of 9.5 m The geometry model used for analysis is only half of the actual embankment due to symmetry. There are 2 cases considering in the study (1) Case A is a normal fill embankment (2) Case B is an embankment made of blast furnace slag. The embankment is filled with 3 m high blast furnace slag. Soil cover of 1 m is provided on the top and side slopes. The slope is analyzed under plane strain condition with 15 noded elements. The displacements and strains in zdirection are assumed to be zero. Mohr- Columb model was selected as the material model. Drained conditions were assumed in the study. The material properties obtained from laboratory testing and literature were given as input parameters. The medium mesh setting was used to automatically create the finite element mesh. Triangular and quadrangular elements with a side length of 0.06 m are used to form the mesh, normal fill embankment generated 205 elements, 1743 nodes, embankment with blast furnace slag generated 223 elements, 1887 nodes. Staged construction feature allowed for fill placement. The analysis of each embankment case carried out under gravity loading when a traffic load of 11.97kN/m² is applied. Circular slip surface is assumed for models. The embankments ought to have a factor of safety at least 1.5. The maximum deformation of an embankment is 200 mm. The blast furnace slag embankment geogrid placement was optimized using factor of safety. For analysis, a geogrid with a stiffness of 50 kN/m [6] is used. The evaluation is completed with consideration of geogrid installed at various strata in the embankment, where the embankment consists of four levels.

VI. RESULTS AND DISCUSSIONS

The analysis of unreinforced embankment with normal fill and blast furnace slag was performed to determine the settlement and factor of safety. Some of the advantages of blast furnace slag include their low compacted density, which results in reduced dead weight load, reduces lateral pressure, high stability and friction angle. Because of its cementitious qualities, blast furnace slag can also contribute to some structural strength. The settlement of normal fill embankment is found to be 0.9109 mm while that of blast furnace slag embankment as 0.7401 mm. The settlement analysis indicates a decrease in settlement when blast furnace slag was used in place of normal fill. The factor of safety of an embankment with a conventional fill is determined to be 1.363, and the factor of safety of an embankment with blast furnace slag is found to be 1.470. The FOS improved when blast furnace slag was used as fill material. The embankment is reinforced with geogrid which is placed at different layers because the factor of safety is less than 1.5.For the blast furnace slag embankment, the FOS is higher for the geogrid layers positioned at the first and fourth levels.

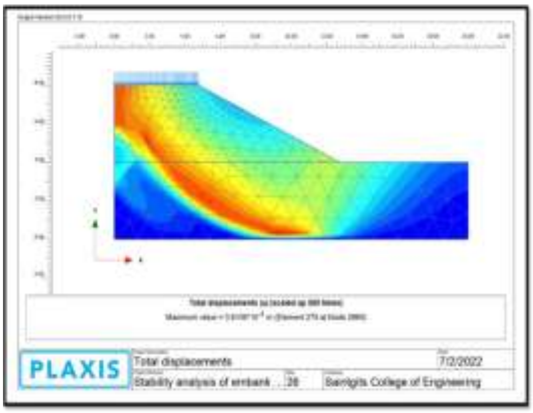

Fig 1: Total displacement of normal fill embankment

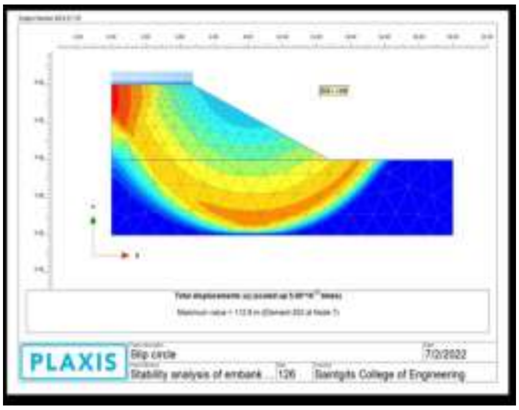

Fig 2 : Slip circle of normal fill embankment

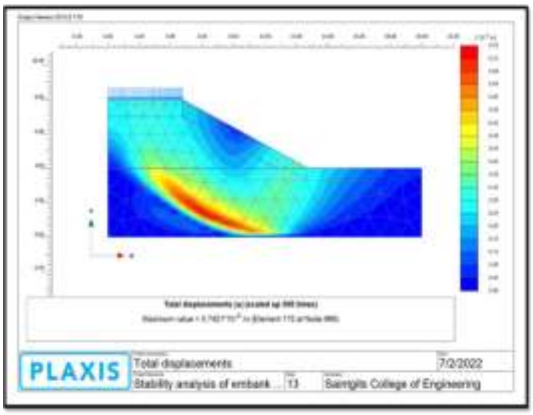

Fig 3 : Total displacement of blast furnace slag embankment

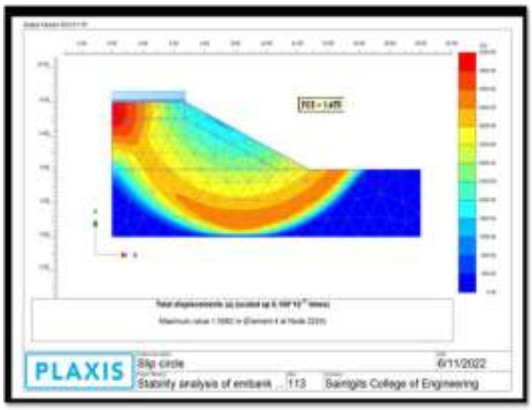

Fig 4 : Slip circle of blast furnace slag embankment

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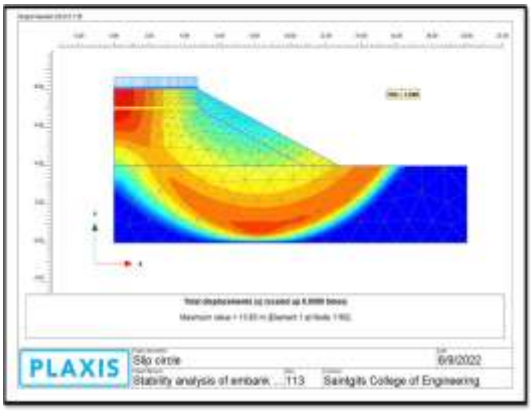

Fig 5 : Slip circlewhen geogrid is provided 1 m below crest level

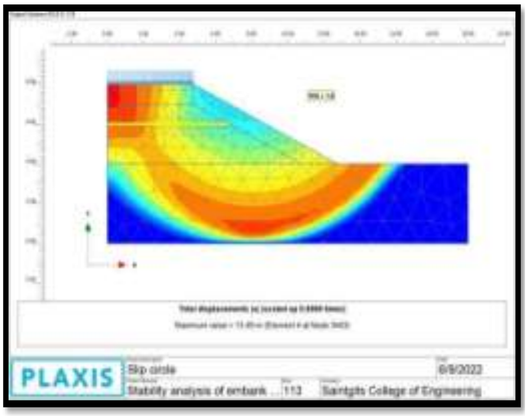

Fig 6 : Slip circlewhen geogrid is provided 2 m below crest level

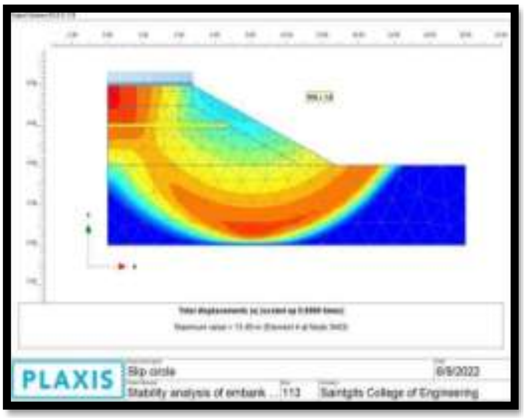

Fig 7 : Slip circlewhen geogrid is provided 3 m below crest level

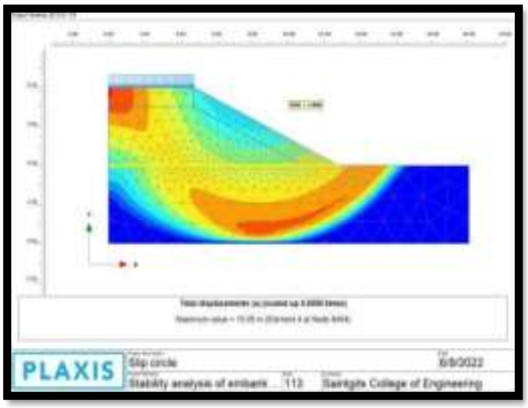

Fig 8 : Slip circlewhen geogrid is provided 3 m below crest level

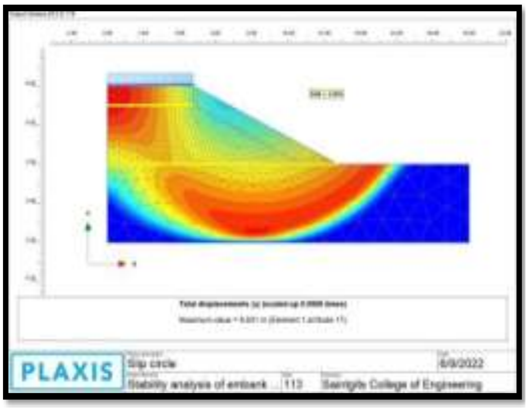

Fig 9 : Slip circlewhen geogrid is provided 1 m and 4 m below crest level

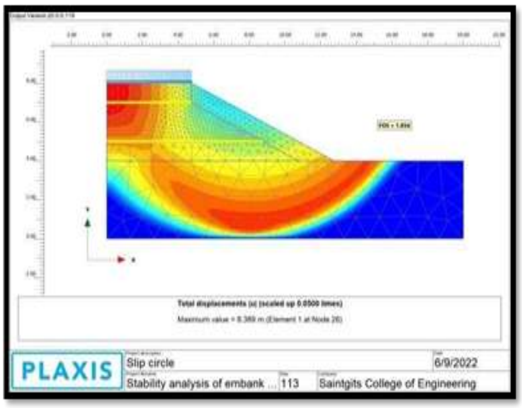

Fig 10 : Slip circlewhen geogrid is provided 1 m and 3 m below crest level

VII. CONCLUSIONS

1. Thesettlement decreases by 23.08 % when blast furnace slag is used instead of normal fill due to their low compacted density which result in reduced dead load
2. Blast furnace slag has a higher angle of internal friction than normal fill due to which the factor of safety increases by 7.85 % owing to greater stability.
3. The use of geogrid reinforcement results in higher factor of safety when compared to when it is not employed since it gives tensile strength to the soil.
4. The impact of the load will have a lesser influence as the depth increases, increasing the distance of the geogrid layers from the crest level which has increased factor of safety.
5. The factor of safety is higher when geogrids are positioned at the first and fourth layer because the first layer of geogrid serves as a load distribution layer and the top reinforcement, and the fourth layer serves as a basal reinforcement.

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