Stabilization of Fly Ash Slope using Plastic Recycled Polymer

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***Abstract* -The model tests were conducted in laboratory without and with Plastic Recycled Polymer (PRP) in fly ash steep slopes on soft foundation soil (fly ash) to check the stability of slope. In this experiment fly ash was used as a slope filling material and also Plastic Recycled Polymers (diameter=3mm and length=4mm) made from waste plastic products (lower grade plastic products). The properties of fly ash and Plastic recycled polymers were determined. From the experimental investigation, load and settlement were measured. From these data, load –settlement curves have been reported. It has been observed from test results that load carrying capacity of fly ash mixture with plastic recycled polymers slope is more than that of fly ash slope. The deformation of Plastic Recycled Polymers slope is slightly more than that of fly ash slope. The experimental results were validated with a Finite Element Software Package (PLAXIS 2D AE version). The failure pattern, deformations and factor of safety are reported based on analytical program (Bishop's simplified method) and Finite Element Method (FEM). The results from experimental data and analytical programme are compared and reported.**

Keywords* - Fly ash, Plastic recycled polymer, Factor of safety, Finite element metho (FEM), Bishop's simplified method, Plaxis 2D AE.

I. INTRODUCTION

In view of the extensive use of plastic in our day to day life colossal amount of non biodegradable waste is generated causing severe environmental contamination. Recycling is one of the solutions to limit this contamination. Higher grade plastic can be recycled into a lower grade product, but once this lower grade product is converted to scrap it cannot be recycled which is a cause for further concern. Also fly ash is a man made resource generated in abundance from thermal power plants which has its own problem of disposal. Many authors such as Edgar [1], Krishnaswamy et al. [2], Mhaiskar and Mandal [3], Rowe and Mylleville [4], Salunkhe and Mandal [5] reported on behavior of fly ash at different mix ratios with plastic recycled polymers, Khedkar and Mandal [6,8] and Mandal and Bhardwaj [7] have used metallic and cellular reinforcement for reinforced soil walls and slopes. The objective of the present study is to check the feasibility of using Plastic recycled polymers with fly ash in construction of steep slopes so that a innovative methodology could be adopted for its utilization. The experimental analysis and validation using finite element method for the methodology adopted are as given below.

II. MATERIAL PROPERTIES AND MODEL SETUP

A. *Properties of Fly ash and Plastic recycled Polymers*

Laboratory experimental study was conducted on fly ash to determine the basic properties. Specific gravity = 2.18, D_{60}=0.045 mm, D_{30}=0.014 mm, D_{10}=0.003 mm, Coefficient of uniformity (C_u) = 15, Coefficient of curvature (C_c) = 1.45, Cohesion = 0.03 kN/m^2, angle of internal friction = 20^0, Optimum moisture content = 18.6% and Maximum dry unit weight = 12.21 kN/m^3 and corresponding mixture of fly ash with Plastic recycled polymer having dry unit weight = 13.30 kN/m^3 [5]. Some of the physical properties of Plastic recycled polymer were also determined: specific gravity = 2.154; density = 0.62 gm/cm^3

Direct shear tests were conducted on fly ash samples with a degree of compaction equal to 90% and maximum dry unit weight of fly ash with three different normal pressure 50, 100 and 150 kPa to evaluate the peak angle of internal friction ϕ.

TABLE 1: PROPERTIES USED IN THE FINITE ELEMENT SIMULATION

Material	Model Material Property		
	Property	***Unit***	***Value***
Fly ash	Dry unit Weight	kN/m^3	12.20
	Young's Modulus (E)	kN/m^2	4200
	Poisson's ratio (μ)	-	0.27
	Cohesion (C)	kN/m^2	0.04
	Angle of Internal friction (ø)	(^{0})	20
Fly ash with PRP	Dry unit Weight	kN/m^3	13.38
	Young's Modulus (E)	kN/m^2	5200
	Poisson's ratio (μ)	-	0.32
	Cohesion (C)	kN/m^2	0.17
	Angle of Internal friction (ø)	(^{0})	39

The dilation angle of fly ash was calculated from direct shear test data by measuring the maximum upward angle of the curve from relationship between vertical displacements to horizontal displacement. The Values of Young's Modulus and Poission's ratio are referred from Bowles, J. E. (1997) [11]. The properties used in the finite element simulation are given in Table 1.

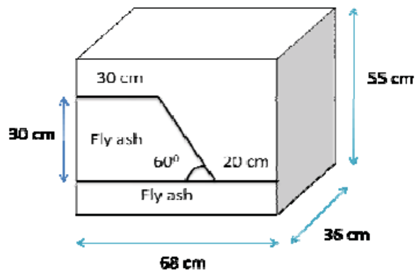
B. Model Test Setup

The model test set up used in this study was fabricated at Geosynthetics Research and Testing Laboratory at IIT Bombay and the dimensions of the test set up are as follows: length = 700 mm, width = 400 mm and height = 500 mm. The line sketch of model is shown in Figure-1. Test was performed in the laboratory without and with plastic recycled polymer. One side of the model setup was covered with Perspex sheet to observe the failure pattern.

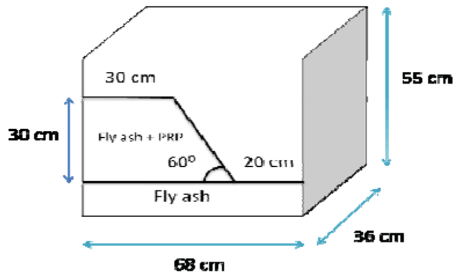
Figure 1 Test set up

To minimize the friction effect, oil was applied to the inner surface of the set up. Surcharge was applied to induce failure. The following procedures were adopted for testing.

- Fly ash foundation was prepared of length= 700 mm, width= 400 mm and depth= 100 mm.
- A height of slope 300 mm was prepared over the foundation at a slope angle of 60^0 as shown in Figure-2.
- The fly ash was compacted at 18.6% on dry side of optimum moisture content. The fly ash was compacted using modified proctor hammer in subsequent layer of 75 mm.
- After compaction, an incremental load was applied through a hydraulic jack on a plate of size 360 mm x 300 mm.
- For uniformly distributed loading condition steel plate of thickness 8 mm having its length 300 mm x width 360 mm was used.



Model – 1) Fly ash on fly ash



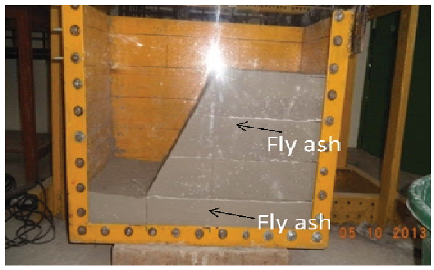
Model – 2) Fly ash with Plastic Recycled polymer on fly ash

Figure 2 Slope Models

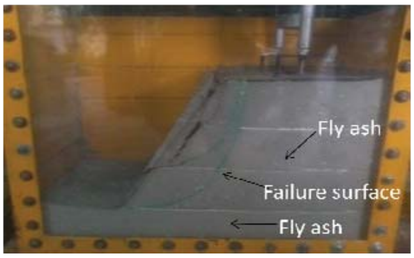
III. Slope Model under Uniformly Distributed Loading (UDL)

A. Model-1 Flyash Slope on Soft Foundation (Fly ash)

The fly ash slope was prepared at the wet of optimum moisture content and compacted by Standard proctor hammer to achieve the required density. Three trials were conducted to optimize the results. The factor of safety was calculated for the observed failure surface using Bishop's simplified method [9] analysis for uniformly distributed surcharge loading. This fly ash slope was observed to fail under a uniformly distributed load of 27.36 kN/m^2. Unreinforced fly ash slope before and after failures are as shown in Figure 3(a) and 3(b).



a) Fly ash slope model (Before failure)



b) Fly ash slope model (After failure)

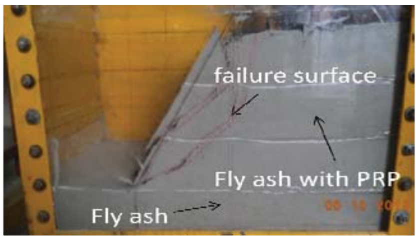
Figure 3 a) Fly ash slope model (Before failure) and **b)** Fly ash slope model (After failure)

Load at failure of slope (peak load) = 325kg
Total deformation = 6.85 mm
From Bishop's Simplified method analysis:
Factor of Safety = 0.975

B. Model-2 Fly ash with Plastic recycled polymers(PRP) Slope on Soft Foundation(Fly ash)

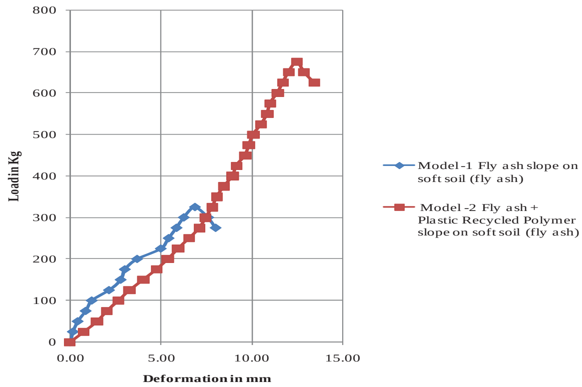
The recycled plastic polymers cylindrical in shape of length 4.0 mm and diameter 2.98 mm is made by scrap plastic material which is already recycled into a different plastic product. For this slope model test the optimum percentage (50%) plastic recycled polymer mix together with fly ash was used to conduct this model test. Three trials were conducted for optimization of results. This fly ash slope was observed to fail under a uniformly distributed load of 56.82 kN/m^2. Fly ash with plastic recycled polymer slope is shown in Figure 4 (a) and the observed failure pattern is shown in Figure 4(b) and Figure 4(c) shows deformation curve for soft foundation.

a) Fly ash with Plastic Recycled Polymer slope (Before failure)



b) Fly ash with Plastic Recycled Polymer slope (After failure)

From Figure 4 :
Load at failure of slope (peak load) = 675kg
Total deformation = 12.02 mm
From Bishop's Simplified method analysis:
Factor of Safety = 1.937



c) Load vs Deformation for fly ash slope and fly ash with PRP Slope on soft soil

Figure 4 Fly ash with Plastic Recycled Polymer slope (Model -2)

The values of peak load at failure, Extreme total deformation and Factor of safety of fly ash slope and fly ash with plastic recycled polymer slope for Two cases are shown in Table 2.

TABLE 2 : SLOPE MODEL DEFORMATION AND LOAD

Model no.	*Slope material*	*Foundation soil*	*Experimental Deformation (mm)*	*Load (kg)*
1	Fly ash	Fly ash	5.2	325
2	Fly ash+ PRP	Fly ash	14.95	675

IV. FINITE ELEMENT ANALYSIS (PLAXIS 2D AE)

A. Model -1 Fly ash slope on soft soil (fly ash)

The mesh of fly ash slope before failure and deformed mesh of slope after failure are shown in Figure 5 and Figure 6 respectively. It can be observed from Table 3 and Table 4 that displacement of fly ash slope is 7.016 mm (Figure 7) and Factor of safety is 0.5731.

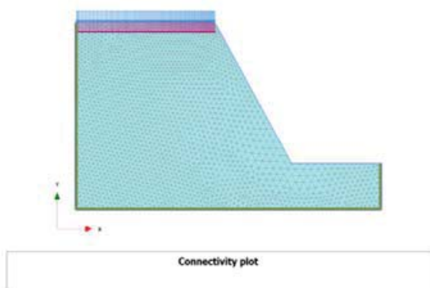


Figure 5 Fly ash slope mesh before failure (Model -1)

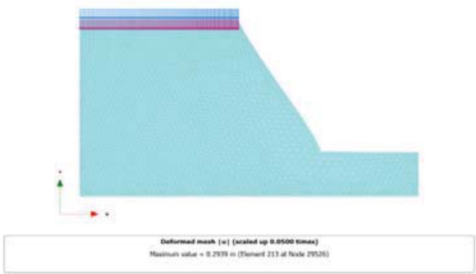


Figure 6 Fly ash slope mesh after failure (Model -1)

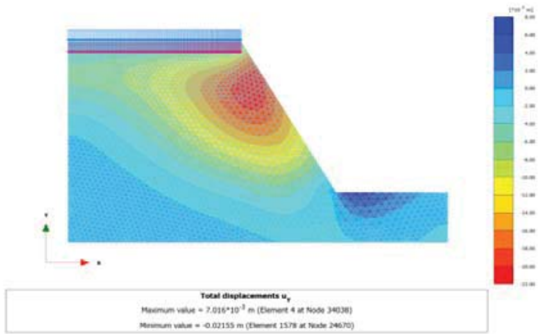


Figure 7 Displacement of Fly ash slope on soft soil (Model -1)

C. Model-2 Fly ash with plastic recycled polymer slope on soft Foundation (fly ash)

The mesh of fly ash slope before failure and deformed mesh of slope after failure are shown in Figure 8 and Figure 9 respectively. The Displacement of fly ash slope of 10.45 mm and Factor of safety is 2.071 as shown in Figure 10.

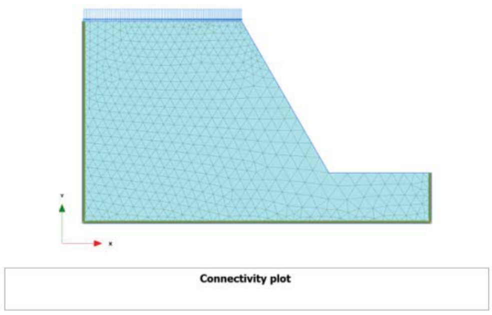


Figure 8 Fly ash + Plastic Recycled Polymer slope on soft soil mesh before failure (Model -2)

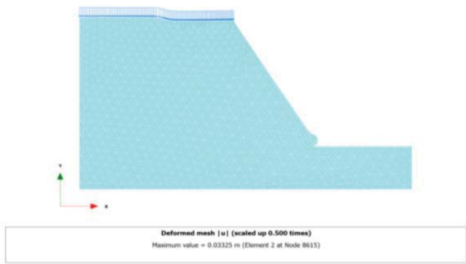


Figure 9 Fly ash + Plastic Recycled Polymer slope on soft soil mesh after failure (Model -2)

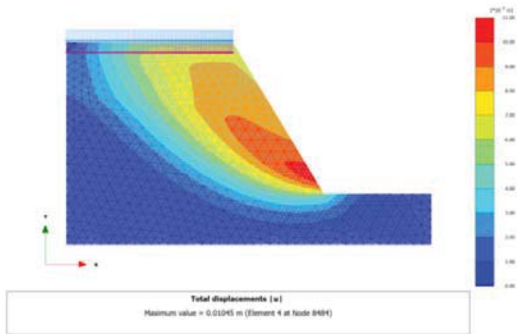


Figure 10 Fly ash + Plastic Recycled Polymer slope on soft soil (Model -2)

V. RESULTS AND DISCUSSIONS

A. Experimental Investigation

Several tests were carried out on fly ash slope and fly ash with mixture of plastic recycled polymer (50%) on soft foundation. It can be observed from Table 3 that the slope on soft soil foundation fails at lower load. It was further observed that the fly ash mixed with Plastic recycled polymer could sustain more load than a fly ash slope. This is due to inclusion of plastic recycled polymer in fly ash. Similarly form the Fig. 4(c), it is clear that deformation is more for the case of fly ash with PRP compared to fly ash alone for the same load. For the determination of factor of safety a theoretical method "Bishop's Simplified method" was used to find out factor of safety using computer program "Microsoft Excel".

TABLE 3:COMPARISON OF SLOPE DEFORMATION EXPERIMENTAL

Model No.	***Slope Material***	***Foundation Soil***	***Experimental Deformation in mm***	***FEM Method Deformation in mm***
1	Flyash	Fly ash	6.20	7.016
2	Flyash+ PRP	Fly ash	12.35	10.45

TABLE 4: COMPARISON OF SLOPE FACTOR OF SAFETY

Model no.	***Slope material***	***Foundation soil***	***Experimental Factor of Safety***	***FEM Factor of Safety***
1	Flyash	Fly ash	0.975	0.5731
2	Flyash+ PRP	Fly ash	1.937	2.071

B. *Finite Element Analysis*

The variation of deformation, factor of safety for fly ash slope and fly ash with plastic recycled polymer (50%) slope are analyzed using Plaxis 2D AE [10] to find out a scatter variation as shown in Table 3. The variation of experimental values for factor of safety and deformation of slope are lower as compared to Plaxis 2D AE software results.

VI. CONCLUSIONS

Reinforced slopes are widely used now-a-days because it represents the most economical solution and also provides flexibility. Model test set-up was developed for carrying out tests on fly ash slope and fly ash mixed with Plastic recycled Polymer (50%) slope under uniformly distributed load. Properties of fly ash and fly ash with inclusion of Plastic Recycled polymer (50%) two types of slope are ascertained.

Fly ash is a hazardous waste material and difficult to dump, so it can also be used as a filling material in geotechnical application such as embankments, pavements etc. Plastic Recycled Polymer made up of lower grade recycled Polymer product can be used as a construction material as it will solve the problem of its disposal leading to a better utilization of the product which does not decompose with time.

- In case of fly ash slope on soft foundation that is on fly ash as a foundation soil the load taken by fly ash slope is 325 kg and as the inclusion of Plastic Recycled Polymer in fly ash the load carrying capacity increases to 675 kg.

- From experimental investigation it can be concluded that the fly ash slope on soft foundation i.e. on fly ash as a foundation soil the factor of safety by fly ash slope is 0.975 and as the inclusion of Plastic Recycled Polymer in fly ash the factor of safety increases about 1.937.

- From Finite element method that is PLAXIS 2D AE software we conclude that the fly ash slope on soft foundation i.e. on fly ash as a foundation soil the factor of safety by fly ash slope is 0.5731 and as the inclusion of Plastic Recycled Polymer in fly ash the factor of safety increases about 2.071.

Finally, Plastic recycled polymer can be used as a viable alternative to stabilize fly ash slope to make it steeper and stable. Due to its confinement and inclusion property it can take larger loads and results in lower deformations.

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