ANALYSIS OF SLOPE STABILITY OF FLY ASH STABILIZED SOIL SLOPE

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ABSTRACT: Fly ash is a waste product of thermal power plants, can be used as embankment material, stabilization of soft soils, road sub-base constructions and other geotechnical fields. In this study, fly ash is used as soil stabilizer for an embankment slope. This paper discusses the shear strength parameters of the soil stabilized with fly ash. The soil has been mixed with 10%, 20%, 30% and 40% fly ash by dry weight for conducting modified Proctor compaction test and direct shear test. The experimental results indicate that the dry density and cohesion value of soil decreases where as the angle of internal friction increases with increase in the percentage of fly ash. The analysis of slope stability of native soil and stabilized soil has been studied by Fast Lagrangian Analysis of Continua (FLAC) slope software. Parametric study has been done to calculate the factor of safety by considering different slope height at constant slope angle under summer and rainy season. The analysis revealed that the slope with native soil was stable up to 12.0 meter height under both summer and rainy season. With further increase in height, the slope becomes critically stable and failed under rainy season at 14.0 meter height. The addition of fly ash enhances the strength and provides resistance to slope instability under both the conditions up to 14.0 meter height. It has been found from the analysis that the factor of safety increases with increase in percentage of fly ash at a particular height. 30% fly ash is obtained as optimum amount as stabilizer for a slope of certain height.

Keywords: Fly ash, slope, stabilized soil.

1 INTRODUCTION

Most of the thermal power plants in India are facing difficulty for disposal and utilization of fly ash. Total generation of fly ash is about 184.14 million tons from 145 Nos. of thermal power plants of India (Report of central electricity authority, 2014-15). Only 55.69% of fly ash is utilized for the construction work i.e. brick, cement, concrete production etc. Remaining fly ash has to be suitably disposed off. Several researchers have worked for its effective utilization as embankment materials, stabilization of soft soils, road sub-base constructions and other geotechnical fields. Still, there is requirement to explore different fields for the utilization of fly ash and its safe disposal. Notification issued by Ministry of Environment and Forest (MoEF) made compulsory to utilize fly ash for construction of road and embankments, reclamation and compaction of low lying areas within the radius of 100 km from thermal power plants. Fly ash is a non-plastic material, having very negligible cohesion in dry condition, while it shows some cohesion under wet conditions due to its self-cementing properties (Porbaha et al. 2000). Fly ash has friction angle in the range of 29° to 37° (Pandian 2004). Fly ash consists of hollow spheres of silicon, aluminum, iron oxides and unoxidized carbon. Fly ash is pozzolanic in nature and contains some lime. Brooks et al. (2011) studied the stabilization of expansive soil with fly ash and suggested that mixing of fly ash improves the engineering properties of soil. Few researchers have worked on the stabilization of soil slope using fly ash. Construction of highway embankments with incorporation of fly ash has also been investigated by Martin et al. (1990). Pradhan et al. (2014) studied the optimization of dump slope geometry and dump slope stability with randomly mixed fly ash and suggested that mixing of fly ash in dump materials increases the slope stability.

In the present study, fly ash is used as soil stabilizer for embankment slope of north-east region soil (Agartala, Tripura, India) which is highly prone to landslide. The shear strength parameter of native soil and stabilized soil with different percentages of fly ash (10%, 20%, 30% and 40%) has been analyzed. An assessment of stability of fly ash stabilized soil slope under summer and rainy season were carried out using FLAC/Slope version 7.0. The parametric study has been done to calculate the factor of safety (FoS) by considering different slope height at constant slope angle under summer and rainy season. Further optimum percentage of fly ash has been suggested for stabilizing the soil slope of certain height.

2 MATERIALS AND EXPERIMENTAL PROGRAM

Bulk quantities of soil sample were collected from an embankment slope of north-east region i.e. Agartala, Tripura, India. Fly ash was collected from Kolaghat Thermal Power Station, Kolaghat, West Bengal, India. Particle size analysis of soil and fly ash were carried out in the laboratory as per IS 2720 (Part 4) -1985 and particle size distribution curve is shown in Figure 1. Geotechnical properties of the soil and fly ash were determined which are listed in Table 1. The sample has been prepared by mixing fly ash at 10%, 20%, 30% and 40% by dry weight of soil for stabilization as shown in Table 2. The modified Proctor compaction test and direct shear test were conducted as per IS: 2720 (Part 7) – 1980 and IS: 2720 (Part 13) – 1986 respectively for all the samples.

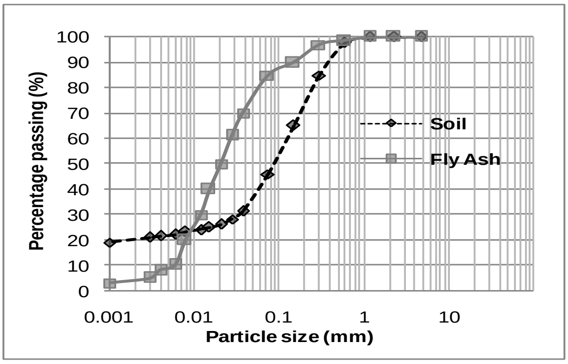

Fig. 1 Particle size distribution curve of soil and fly ash.

Table 1 Geotechnical properties of soil and fly ash

Properties	Experimental Results	
	Soil	Fly Ash
Specific Gravity	2.56	2.13
Plasticity	Low Plastic	Non Plastic
Maximum Dry Density (kN/m^3)	19.30	11.75
Optimum Moisture Content (%)	12.08	29.8

Table 2 List of sample prepared for analysis.

Name of Sample	Proportion
100S	100% Soil
90S+10F	90% Soil + 10% Fly ash
80S+20F	80% Soil + 20% Fly ash
70S+30F	70% Soil + 30% Fly ash
60S+40F	60% Soil + 40% Fly ash

3 ANALYSIS OF SLOPE STABILITY USING NUMERICAL MODELLING

The analysis of slope stability of embankment soil and stabilized soil has been done by Fast Lagrangian Analysis of Continua (FLAC) slope software version 7.0. FLAC/Slope. It is a mini version of FLAC which is specially designed to analyze slope stability using FoS. It is an alternative approach to limit equilibrium analysis for FoS calculation. FLAC/Slope provides full solution of coupled stress/displacement, equilibrium and constitutive equations. FoS were calculated for all the samples under different geometric conditions.

4 GEOMETRY OF SOIL SLOPE

The slope stability analysis of embankment with native soil and fly ash stabilized soil were carried out with different slope height and constant slope angle (37°). The slope heights were varied from 8.0 meter to 14.0 meter at every 2.0 meter interval under both summer and rainy season. Under rainy season the water table were simulated at toe level i.e. 1.0 meter and 2.0 meter from the toe of the slope. The geometry of embankment slope with native soil of 8.0 meter slope height and 37° slope angle at summer season is shown in Figure 2.

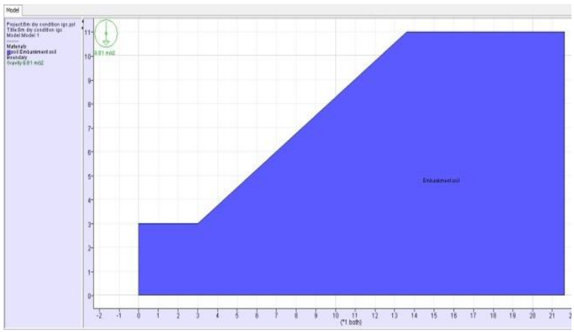

Fig. 2 Geometric model of embankment slope with native soil during summer season.

5 RESULTS AND DISCUSSIONS

5.1 Soil Stabilization

5.1.1 *Compaction characteristics*

Modified Proctor test were conducted on all five samples as presented in Table 2. The values of Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) were evaluated in the laboratory and compaction curve of all five proportion are shown in Figure 3. MDD and OMC value of these proportions are tabulated in Table 3. As the percentage of fly ash increases from 0% to 40%, the MDD decreases and OMC increases. This could be due to the lower unit weight and lesser content of sand size particle in the fly ash as compared to the soil sample which causes reduction in dry density (Deb and Pal 2015). Similar trend was also reported by Brooks (2009).

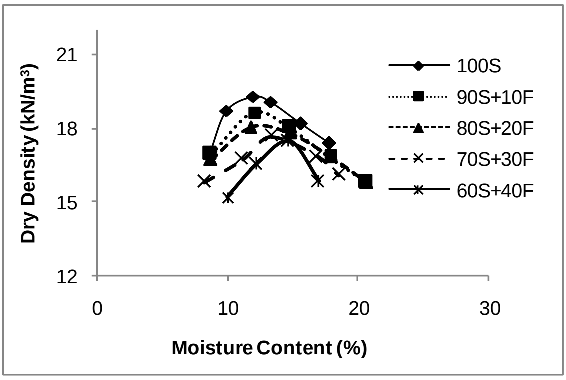

Fig. 3 Compaction Curve for all samples.

5.1.2 *Shear Strength Characteristics*

Direct shear tests were conducted on all the samples. Based on normal stress versus shear stress curve the cohesion (c) and angle of internal friction (ϕ) were obtained as presented in Table 3. From Table 3, it can be revealed that, with increase in percentage of fly ash the angle of internal friction increases and cohesion decreases. The increase in angle of internal friction may be due to the increase in silt size particle of the stabilized sample. Similar trend was reported by Sezer et al. (2004).

Table 3 Compaction and Shear Strength characteristics

Sample	MDD (kN/m^3)	OMC (%)	c (kN/m^2)	Φ (degree)
100S	19.30	12.08	38.25	29
90S+10F	18.70	12.50	32.28	32
80S+20F	18.10	13.05	29.08	35
70S+30F	17.68	14.25	20.10	37
60S+40F	17.50	14.70	10.18	39

5.2 Analysis of slope stability

The analysis of slope stability of native soil and stabilized soil has been studied by FLAC/Slope software. Parametric study has been done to evaluate the FoS by considering different slope height at constant slope angle (37°) under summer and rainy season. The slope heights were varied from 8.0 meters to 14.0 meters at every 2.0 meters interval. The shear strain rate contour for slope of 14.0 meter height at 2.0 m water level with native soil and stabilized soil with 30% fly ash are shown in Figure 4 and Figure 5 respectively.

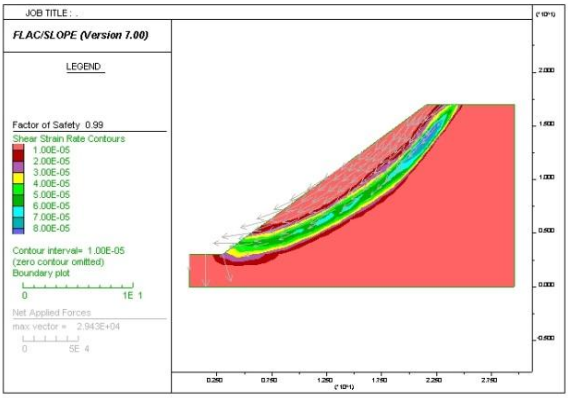

Fig. 4 Shear strain rate contour for native soil slope of 14.0 m height and 2.0 m water level (FoS=0.99).

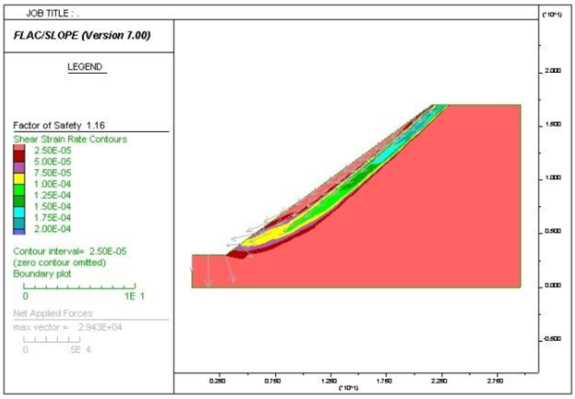

Fig. 5 Shear strain rate contour for stabilized soil with 30% fly ash slope of 14.0 m height and 2.0 m water level (FoS=1.162).

Similarly FoS has been evaluated for other conditions. The variations in FoS for all the conditions are shows in Figure 6. From Figure 6, it can be revealed that the slope with native soil was stable up to 12.0 meter height under both summer and rainy season as its FoS is greater than 1. With further increase in height, the slope becomes critically stable and failed under rainy season at 14.0 meter height (2.0 m water level). The addition of fly ash enhances the strength and provides resistance to slope instability under both summer and rainy season up to 14.0 meter height.

It has been observed from the analysis that the FoS increases with increase in percentage of fly ash up to 30%, after that slight reduction in FoS is observed. From the present study, 30% fly ash is considered as optimum amount as stabilizer for a slope of certain height.

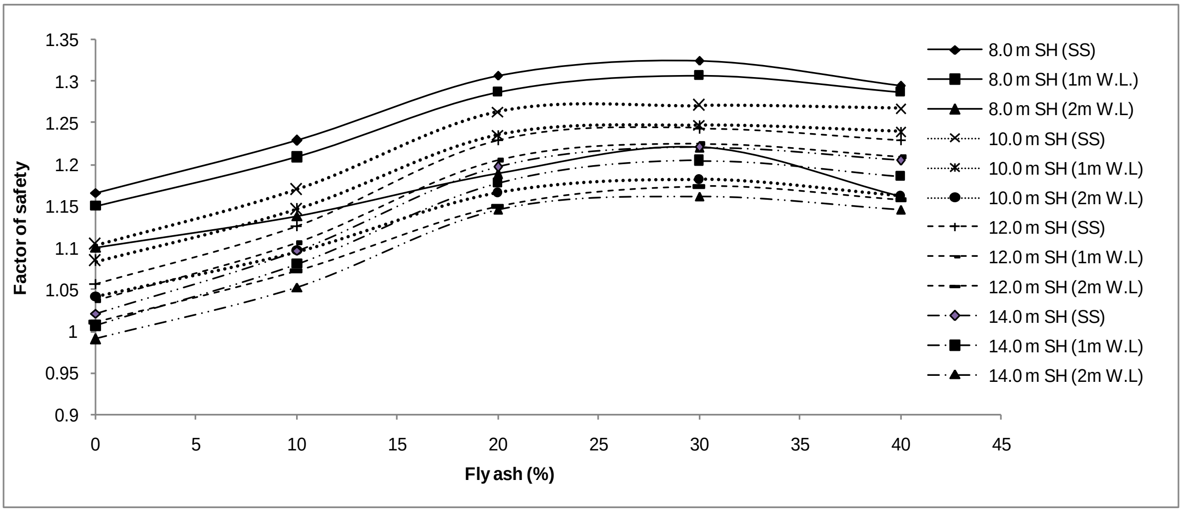

Fig. 6 Variation in FoS with different slope height and fly ash content at summer and rainy season.

SH- Slope Height, SS- Summer Season, W.L. - Water Level at rainy season.

6 CONCLUSION

The soil has been stabilized with different proportion of fly ash. Further study has been conducted to analyze the slope stability of fly ash stabilized soil slope. Based on the test results and numerical modelling following conclusions has been made.

- The MDD of the soil decreases and OMC increases with increase in the percentage of fly ash in soil.
- The increase in the percentage of fly ash increases the angle of internal friction and decreases the cohesion of the soil.
- The increase in the percentage of fly ash increases the FoS up to addition of 30% fly ash, after that there is a slight reduction in FoS.
- Numerical modelling infers that by addition of certain amount of fly ash, slope height can be raised even with the presence of water level.
- Based on the value of FoS optimum value of fly ash is 30% for stabilizing the soil.

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