

# **Bearing Capacity of Square Footing on Reinforced Flyash Slope**

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**ABSTRACT:** To use waste fly ash in the construction of slopes and highway embankment the laboratory model tests were conducted with and without reinforcement in fly ash to check the strength and stability of fly ash slope. In this study fly ash was used as a filling material and geogrid is used as reinforcement to improve the bearing capacity of slope. The footing is rest at various position on steep slope of 60° and bearing capacity is checked. From the experimental study, load and settlement were measured. It has been observed from test results that load carrying capacity of fly ash slope reinforced with geogrid is more than that of unreinforced slope.

**KEYWORDS:** fly ash, backfill material, steep slope, reinforced, bearing capacity.

## **I. INTRODUCTION**

The thermal power plants throughout the world use pulverized coal as a fuel to generate electricity which produce annually million tons of fly ash. Disposal of fly ash without causing any kind environment pollution and management is a major problem for thermal power plants. Research based upon effective utilization of fly ash is constantly in progress. In this direction over the past many years several researchers have attempted to convert this waste into useful geotechnical engineering construction material [Gayathri and Kaniraj (2003), Mandal and Bhardwaj (2008), Mandal and Adhana (2011), Mandal and Lal (2012), Salunkhe and Mandal (2014), Tereza Cihakiva (2014) and Mhaiskar and Mandal have used metallic and cellular reinforcement for reinforced soil walls and slopes. In this study fly ash was used as a filling material and geogrid is used as reinforcement to improve the bearing capacity of slope. The test were conducted on unreinforced and reinforced flyash slope. The results from the experimental analysis were recorded. From the result it is observed that bearing capacity of reinforced slope is more than unreinforced slope.

This paper is organized as follows. Section II describes previous similar work done by various researchers. The material used for test and the test procedure is given in Section III. Section IV presents experimental results. Finally, Section V presents conclusion.

## **II. RELATED WORK**

The study of effect on bearing capacity by provision of shallow foundation on slope is observed in various literature. Several experimental, analytical and numerical analyses were performed on shallow foundation placed on crest as well as at certain setback distance from crest of the slope by various author.

Kumar and Ilamparuthi(2009)<sup>1</sup> had conducted study on response of footing on sand slopes. A numerical study was carried out using Plaxis FEM code and compared with the model test results. They had done a comparative study on performance of a strip footing on a reinforced slope with the unreinforced slope. They concluded that ultimate bearing capacity of the unreinforced Slope is improved by reinforcing the slope.

Alamshahi and Hataf(2009)<sup>2</sup> had conducted study on bearing capacity of strip footings on sand slopes reinforced with geogrid and grid-anchor. The test where conducted by varying parameters such as geogrid type, number of geogrid layers. They concluded that geogrid anchor are more effective than geogrid. The optimum number of reinforcements is 2.

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Choudhary *et al.* (2009)<sup>3</sup> conducted laboratory investigation of bearing capacity behaviour of strip footing on reinforced flyash slope. The results of the investigation indicate that both the pressure–settlement behaviour and the ultimate bearing capacity of footing resting on the top of a flyash slope can be enhanced by the presence of reinforcing layers. However the efficiency of flyashgeogrid system increases with the increasing number of geogrid layers and edge distance of footing from the slope.

Adhana and Mandal (2011)<sup>4</sup> conducted the model test in the laboratory with and without reinforcement in fly ash steep slope on soft foundation to check the stability of steep slope. In experiment fly ash is used as a filling material and two types of reinforcement were used. They concluded that load carrying capacity of geocell is more than that of geogrid strip. The deformation of geocell is slightly more than that of geogrid strip.

Gill *et al.* (2011)<sup>5</sup> conducted numerical study of footing on single layer reinforced soil. Two different soil; sand and silty soil were considered. Ultimate load carrying capacity can be improve by using reinforcement. The optimum depth of location of the single geogrid layer for silty soil is a depth of 0.75 to 1 times the footing width and for sand it is 0.5B.

Zhan and Liu(2012)<sup>6</sup> conducted study on undrained bearing capacity of Footings on Slopes. They study bearing capacity behaviour of strip footings on purely vertical loading on bearing capacity for footings adjacent to slopes, by using the finite element analysis method. They concluded that bearing capacity factor decrease with increase in slope angle.

### III. METHODOLOGY

The experimental set up was required for conducting the model test in the laboratory on flyash slopes to check its stability. In this study an attempt had been made for proper utilization of fly ash as fill material in slopes.

#### 1. Material

- Fly ash

For the model tests, dry and clean fly ash as shown in Fig. 1 was used. The fly ash was collected from Ratan India Power Limited, Nandgaon Peth, Amravati, Maharashtra.



Figure 1: Flyash

The geotechnical and engineering properties of fly ash such as specific gravity, density of flyash, dry density and optimum moisture content were determined by conducting various lab test. The values of these properties are given in table 1

Table 1 Properties of Fly ash

Sr.No.	Properties	Value
1	Specific gravity	2.22
2	Max dry density	13.62 kN/m <sup>3</sup>
3	Optimum moisture content	25%
4	Cohesion	20 kN/m <sup>2</sup>
5	Angle of friction	15°

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- Geogrid

The use of geogrid improves the bearing capacity and settlement performance of shallow foundations has proven to be a cost-effective foundation system. A reinforced soil foundation (RSF) consists of two layers of a geogrid reinforcement placed below a square footing to create a composite material with improved performance. Biaxial geogrid as shown in Fig 2. was used for experimental study.

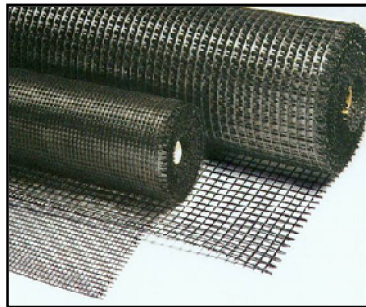


Figure 2 Geogrid

The various properties of geogrid such as ultimate tensile strength, elongation at break, aperture size etc., are mentioned in table 2.

Table 2: Property of Geogrid

Property		Test method	TGB-30	
Ultimate Tensile Strength (kN/m)	MD	ASTM D 6637 EN ISO-10319	30	
	CD		30	
Elongation at break (%)	MD		13	
	CD		13	
Tensile Strength at 2% strain (kN/m <sup>2</sup> )	MD		7	
	CD		6.5	
Tensile Strength at 5% strain (kN/m <sup>2</sup> )	MD		13	
	CD		12	
Aperture Size (mm)	MD X CD			26 X 26

## 2. Preparation of Slope

The required quantity of dry fly ash was mixed with a predetermined amount of water corresponding to the optimum moisture content (OMC). The well mixed fly ash was then spread in the tank in layers and compacted. Uniform compaction of each layer should be achieved. Initially, a few trial foundation beds were made for standardization of compaction and checking of unit weight. In order to verify the uniformity of test bed, undisturbed samples were collected from different locations of the test bed in order to determine the in-situ unit weight and the values were found to be almost same (coefficient of variability within 1.5%). To ensure uniform moisture distribution throughout the test, compacted fly ash bed was left for 24 h for moisture equilibration and the top surface was kept covered with wet gunny bags in order to prevent the moisture loss if any. After 24 h; the compacted fly ash bed was cut to desired slope with the help of a sharp edged trowel. In case of reinforced fly ash slope, the reinforcements were placed at the desired depth within the fill and the compaction was continued in a similar manner until the desired height was reached. At any given position, the location of the reinforcement was such that it extended up to the face of the slope.

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### 3. Model Test Procedure

For the experimental investigation, the model slope stability tests were conducted on fly ash to evaluate the strength and stability of fly ash. The test tank was made of 4 mm thick mild steel having internal dimension 900 mm X 500 mm in plan and 650 mm high. The experimental set up is shown in fig.3.



Figure 3: Experimental Set-Up

After preparation of fly ash slope, the model footing of size 100 mm x 100 mm and 10 mm thick was placed on the slope. Two dial gauges were then placed on the sides of footing. Footing had a little groove at the center to facilitate the application of load. The footing was provided with the two flanges on two sides of footings to measure the settlement of footing under the action of load with the help of dial gauges. The load was applied on the footing with the help of screw jack. The load transferred to the footing was measured with the help of proving ring. Footing settlement were measured through two dial gauges. The footing settlement was reported as the average value of the reading taken at two different points. In all the test, load was applied until the failure indicated by crack and deformation of slope. The geometry of test configuration is shown in fig. 4

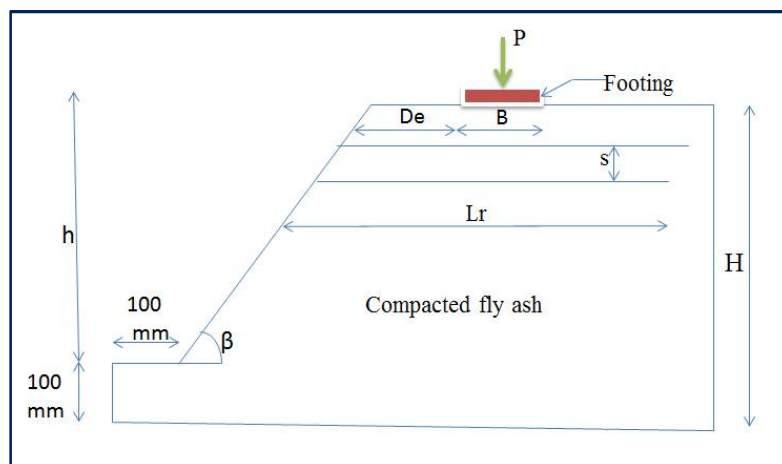


Figure 4: Schematic view of test configuration

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Where,

H=Total Height

B=Width of footing

h= Height of Slope

De=Edge Distance

P= Load

S= spacing of reinforcement

Lr= Length of reinforcement

De/B ratio = Edge distance/ width of footing

N= Number of reinforcement

$\beta$ = Slope angle

The various parameter studied in experimental work are mentioned in table 3. Height of slope, angle of slope, width of footing, spacing of reinforcement and length of reinforcement are kept constant. Edge distance is varying

Table 3: Parameter Studied

Type of footing	Constant Parameter	Varying Parameter
Unreinforced	H=600 mm B=100 mm h =500 mm s= 25 mm Lr=5B $\beta=60^\circ$	De/B=0.0, 0.5, 1.0, 1.5
Reinforced	H=600 mm B=100 mm h =500 mm N=2,3,4 s= 25 mm Lr=5B $\beta=60^\circ$	De/B=0.0, 0.5, 1.0, 1.5

## IV. EXPERIMENTAL RESULTS

The test was conducted at various De/B ratio. From which it is observed that bearing capacity increases with increase in De/B ratio. The result of various De/B ratio are shown in fig.5. The bearing capacity is minimum at crest of slope.

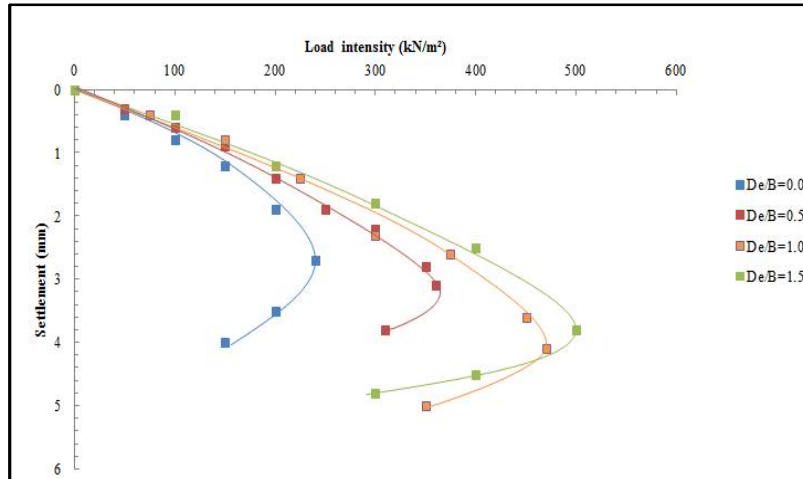


Figure 5: Load versus Settlement graph for unreinforced slope at different De/B ratio

The same test was conducted at various De/B ratio for 2, 3, 4 number of reinforcement layer. From which it is observed that bearing capacity of reinforced case more as compare to unreinforced case. As number of reinforcement increases the bearing capacity increases. The result of various De/B ratio for reinforced case are shown in fig.6. The value of bearing capacity increase as De/B increases.

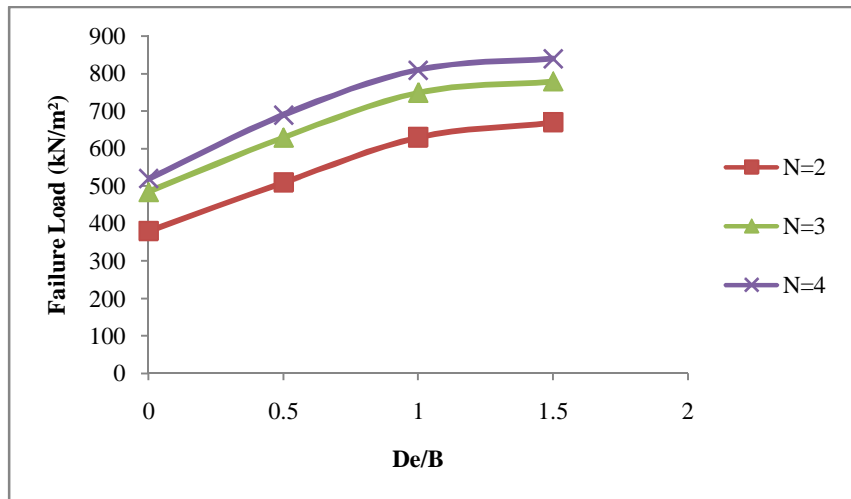


Figure 6: Failure load versus De/B ratio for reinforced slope at different De/B ratio

## V. CONCLUSION

Based on experimental investigation following conclusions can be drawn:

1. Fly ash can be used successfully as backfill material.
2. As edge distance increases the bearing capacity increases.
3. Bearing capacity of reinforced slope is more than unreinforced slope.
4. As number of reinforcement layer increases the bearing capacity also increases.

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