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Bearing Capacity of Footing on Reinforced Flyash Slope

Dr. A.I. Dhatrak[1], Nidhi Gandhi[2]
Associate Professor, Department of Civil Engineering, Government College of Engineering, Amravati, Maharashtra, India[1]
P.G. Student, Department of Civil Engineering, Government College of Engineering, Amravati, Maharashtra, India[2]

ABSTRACT
Fly ash is the waste from factories used in 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 square footing is rest at various position on steep slope of 60^0 and bearing capacity is checked. From the experimental study, load and settlement were measured. For optimum configuration the same test were conducted on circular footing.From test results it is observed that the 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 sufficient amount of soil of required quality is not available easily as fill materials for low-lying areas, backfill materials in retaining structures, and construction of earth embankments. So to meet the requirement of suitable amount of soil that to be used in the construction of roads and highways large amount of trees are being cut which cause deforestation, soil erosion and loss of fertile soil which also hampers in the agricultural productivity. The effective uses of the industrial wastes which are used as a substitute for natural soil in the construction not only solve the problems of disposal and environmental pollution but also help to preserve the natural soil. One of the industrial wastes used as a construction material is the flyash. In many countries, coal is the primary fuel in thermal power stations and other industries. Less than half of this is used.Thus disposal of industrial wastes is a major issue for the present generation. One of the common and feasible ways to utilize these waste products is to go for construction of roads, highways and embankments. If these materials can be suitably utilized in construction of roads, highways and embankments then the pollution problem caused by the industrial wastes can be greatly reduced.

In India utilization of Flyash is less than 25% of the total flyash produced. In this direction over the past few years many researchers have attempted to convert this waste into useful civil engineering construction material. Hence, the proper utilization flyash is major concerned in India. It may be used in embankment. Steepened slopes can reduce the cost up to 50 % as compared to retaining walls. Flyash can be utilized as a fill material in many civil engineering applications, mainly in the construction of roads and embankments. Flyash provides an economical and suitable alternative to good earth for construction of embankments. The performance of such materials can substantially improved by introducing reinforcing element such as geogrid. Reinforced soil slopes have broad applicability in the construction of highways.

II. LITERATUREREVIEW

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 *et al*.(2009)**,** Alamshahi, *et.al* (2009), Gill, *et.al*(2011), Adhana, *et.al*(2011), Zhan, *et.al*(2012), Choudhary, *et.al* (2012), Lal, *et.al* (2012), Mansour (2015). The various parameter studied were, distance of footing from crest slope, slope angle, type of reinforcement on slope, number of reinforcement layer etc

Kumar and Ilamparuthi[1] (2009) 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.

Choudhary[2]*et al.* (2009) 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[3] (2011) 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.

Dr. Abbas and Sabbar[4] (2011) used finite element method to investigate the ultimate bearing capacity of rectangular footing resting on cohesive soil near slope. They concluded that the ultimate bearing capacity for rectangular footing adjacent to slope of cohesive soils decreases when slope angle (β) and the effect of slope diminishes as the distance ratio (b/B) approaches (0.75).

Gill *et al.*[5](2011) 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[6](2012) conducted study on undrained bearing capacity of Footings on Slopes. They study bearing capacity behavior of strip footings on purely vertical loading on bearing capacity for footings adjacent to slopes, by using the finite element analysis method. The footings were placed at different position on slope and its effect was studied. They concluded that bearing capacity factor decrease with increase in slope angle.

Gill*et al.*[7](2012) carried out study on load bearing capacity of the footing resting on a reinforced fly ash slope. They conducted the numerical study by using software GEO5 and PLAXIS and laboratory test to investigate the efficacy of a single layer of reinforcement in improving the load-bearing capacity when it gets incorporated within the body of a model fly ash embankment slope. They concluded that the location of the single geogrid layer at a depth of 0.5 to 1.0 times the footing width improves the load carrying capacity significantly

Lal and Mandal[8] (2012) conducted the experimental studies on fly ash for proper selection of moisture content at which fly ash should be compacted and the degree of compaction required when it is used as a backfill material in cellular reinforced wall. They concluded that the shear strength of fly ash is mainly governed by angle of internal friction except under compacted unsaturated condition. They proposed that fly ash can be used as alternative to conventional material.

III. METHODOLOGY

The experimental set up was prepared for conducting the model test in the laboratory without and with reinforcement in Flyash slopes on soft foundation to check its stability. In this study an attempt has been made for proper utilization of Flyash as fill material in slopes with geogrid reinforcement.

3.1 Materials

The material required for experimental investigation are described in following section

3.1.1 Flyash

For the model tests, dry and clean Flyash was used as the filling material. This Flyash was collected from Ratan India Power Limited, NandgaonPeth, Amravati, Maharashtra. The tested Flyash has uniform grey colour. Flyash used for experimental programme is shown in fig. 3.1.1

Figure 3.1.1 Flyash

The geotechnical and engineering properties of Flyash 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 table3.1.1

Table 3.1.1 Properties of Flyash

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

3.1.2 Geogrid

Geogrid is usually made from polymer material, such as polypropylene, polyethylene or polyester. Commercially available continuous biaxial geogrid was used for reinforcing the Flyash bed. The use of geogrid is to improve 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 layers of a geogrid reinforcement placed below a square footing to create a composite material with improved performance. Biaxial geogrid as shown in Fig 3.1.2.was use for experimental study.

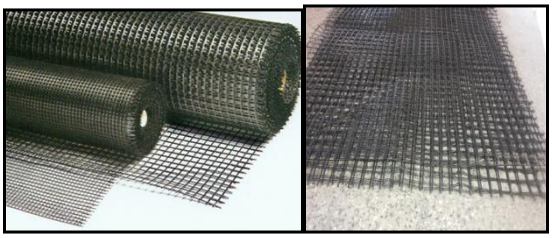

Figure 3.1.2. Geogrid

The various properties of geogrid such as ultimate tensile strength, elongation at break, aperture size etc., are mention in table 3.1.2.

Table 3.1.2: 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/m2)	MD		7
	CD		6.5
Tensile Strength at 5% strain (kN/m2)	MD		13
	CD		12
Aperture Size (mm)	MD X CD		26 X 26

3.2. Procedure for Test Setup The detailed test procedure adopted for experimental investigation is explained below

3.2.1 Preparation of slope

The required quantity of dry Flyash was mixed with a predetermined amount of water corresponding to the optimum moisture content (OMC). The well mixed Flyashwas then spread in the tank in layers, which will be compacted as shown in fig. 3.2.1.

Figure 3.2.1 Compaction Process

Uniform compaction of each layer will be achieved. In order to verify the uniformity of test bed, undisturbed samples will be 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%). The placement dry unit weight/density achieved by this procedure was 90% of the standard proctor density. To ensure uniform moisture distribution throughout the test, compacted Flyash bed was left for 24 h and the top surface was kept covered with wet gunny bags in order to prevent the moisture loss if any. After 24 [hr the compacted Flyash bed was cut to desired slope with the help of a sharp edged trowel as shown in fig 3.2.2 .

Figure 3.2.2 Desired Slope

In case of reinforced Flyash slope, the reinforcements was placed at the desired depth within the fill and the compaction was continued in a similar manner until the desired height was reached.

3.4.2 Model Plate Load Test Procedure

For the experimental investigations, the model plate load tests were conducted on Flyash as per IS 1888:1982 to evaluate the bearing capacity and settlement. After preparation of Flyash bed, the model footing of size 100 mm x 100 mm is on the slope. Two dial gauges are then placed on the sides of footing. The load is applied on the footing with the help of screw jack in increments. The load transferred to the footing was measured with proving ring. Footing settlement were measured through two dial gauges.

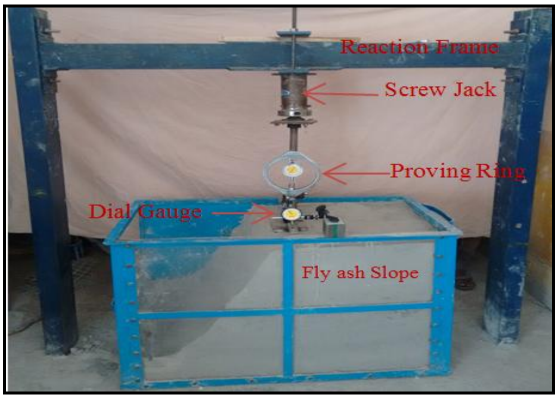

Figure 3.2.3. Test Setup

The footing settlement is 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 as shown in fig 3.2.4

Figure 3.2.4 Failure of slope

3.3 Test Plan

The details of parameter studied in experimental work are given in table 3.3.1. The geometry of test configuration is given in Fig.3.3.1

Table 3.3.1 Details of Parameter Studied

Type of Footing	**Condition**	**Constant Parameter**	**Varying Parameter**
Square	Unreinforced	H=600 mm B=100 mm h =500 mm β=60°	De/B=0.0, 0.5, 1.0, 1.5 d/h=0.2, 0.4, 0.6
	Reinforced	H=600 mm B=100 mm h =500 mm S= 25 mm Lr=5B β=60°	De/B=0.0, 0.5, 1.0, 1.5 N=2,3,4
			d/h=0.2, 0.4, 0.6 N = 3
Circle	Unreinforced and Reinforced	H=600 mm D=100 mm h =500 mm S= 25 mm De/B=1 Lr=5B β=60°	N=0, 2,3,4

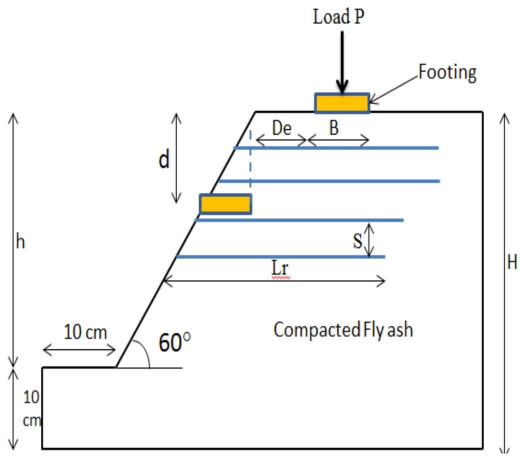

Figure 3.3.1: Schematic view of test configuration

Where,
H=Total Height
B=Width of footing
D= Diameter 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
β= Slope angle

IV. RESULTSAND DISCUSSION

The primary objective of the experimental investigation is to evaluate the efficiency of flyash slopes. Geogrid reinforcement is used to improve the load carrying capacity of the flyash slope. Various test were conducted to study the effect of various parameter such as location of footing, effect of reinforcement, shape of footing. It is convenient to present the results of the reinforced system with respect to the corresponding results derived for the footing on an unreinforced slope. The results of plate load tests conducted on footing resting over unreinforced and reinforced flyash bed are discussed below:

4.1 Effect of Location

4.1.1 At Various De/B ratio

In order to study the effect of the proximity of a loaded footing to the slope crest, tests were carried out on Square footing resting on flyash slope at varying edge distances from the slope crest (De = 0.0B, 0.5B, 1.0B, 1.5B) for both unreinforced and reinforced cases. From the trial experiments it was also observed that ultimate bearing capacity increase as edge distance increase however there is no significant increase in bearing capacity after De/B=1.0. This change in bearing capacity of footing with its location relative to the slope crest can be attributed to soil passive resistance from the slope side and the reinforcement effect. When the footing is placed at sufficient distance away from the slope crest, the passive resistance from the slope side to failure wedge under the footing increases and geogrid reinforcement decreases the lateral displacement which results in wider and deeper failure zone thus increasing the bearing capacity load

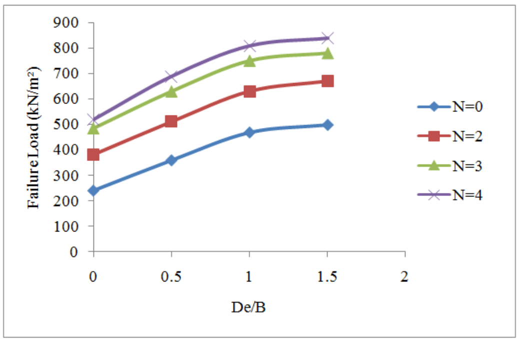

Figure 4.1.1.1 Graph Between U.B.C. and De/B Ratio

4.1.2 At Various d/h Ratio

As the test were conducted at various edge distance onflyash slope, similar test were carried out on sloping surface of slope. The square footing was placed at various location on the sloping surface. d/h=0.2, 0.4, 0.6. From the test result it is observed that as d/H ratio increases the bearing capacity decreases.

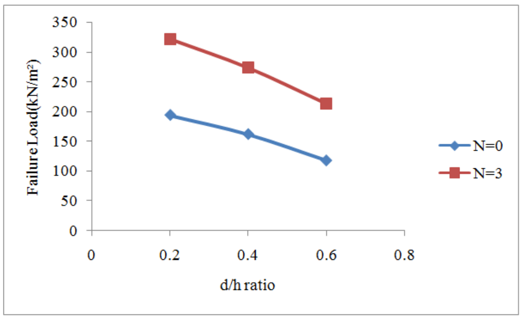

Figure 4.1.2.1 Graph between U.B.C. and d/h Ratio

4.2 Effect of number of reinforcement

In order to study the effect of number of reinforcing layers of the footing on slope, tests were carried out in which all other parameters were kept constant except the number of reinforcement layers (N). Typical variation of Ultimate bearing capacity with number of reinforcing layers (N) for 100 mm wide footing located at varying edge distances has been shown in Fig. 4.1.1. It is seen that for a given edge distance, UBC increases with the increasing number of geogrid layers (N) within the fill, however the rate of increase in UBC becomes less significant once the number of geogrid layers incorporated in the flyash fill are more than three.

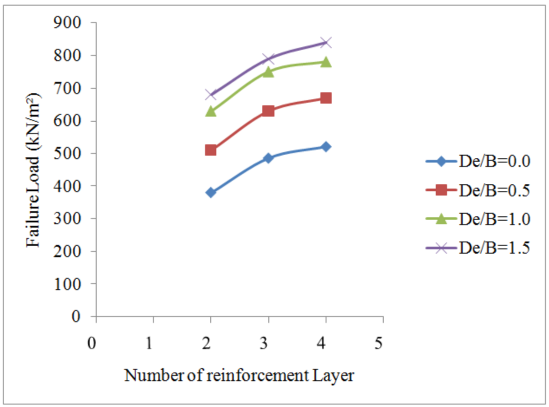

Figure 4.2.1 Graph between UBC and Number of Reinforcement at Various De/B Ratio

4.3 Effect of Shape of footing

The test were conducted on square footing by varying the edge distance ratio i.e De/B=0.0, 0.5, 1.0, 1.5. From the result it is observed that after De/B=1.0, there is no significant increase in bearing capacity. For circular footing the test were conducted on optimum configuration i.e De/B= 1.0 for unreinforced and reinforced case (N=2, 3, 4). Fig. 4.3.1 shows the comparison between square and circular footing for unreinforced slope. From the result it is observed that the bearing capacity of circular footing is less than square.

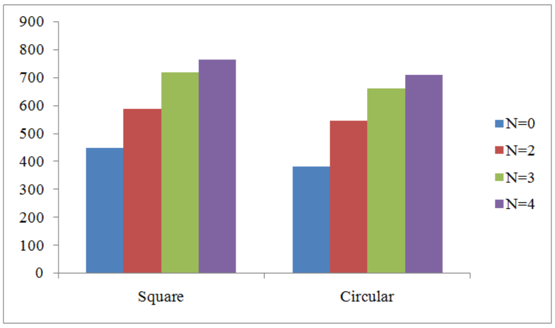

Figure 4.3.1 Comparison between Square and Circular Footing at De/B= 1.0

V. CONCLUSIONS

5.1 Conclusions

The present work studied the performance of model square footing under unreinforced and reinforced Flyash slope. The geogrid was used as reinforced material for Flyash. The geogrid was used in 2,3,4 layers having length five times the width of footing. The footing was placed at different De/B ratio. The model plate load test were conducted to understand the performance. The performance was presented in terms of bearing capacity ratio. The following conclusion are drawn from the work.

- Bearing capacity of footing on slope is less than bearing capacity of footing when placed on top of slope.
- As De/B ratio increases the bearing capacity increases. However there is significant increase in bearing capacity upto De/B=1.0
- Insertion of geogrid layer increase the bearing capacity of Flyash slope. As number of geogrid layer increases the bearing capacity increases. There is significant increase in bearing capacity upto three layer of reinforcement
- Bearing capacity of square footing is more than circular footing.

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