

Net Safe Bearing Capacity of Fly Ash - Bentonite in Layered System

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Abstract

The present work has been undertaken to get a viable solution to save the top soil and earth from its bulk use in construction industry and to facilitate the en mass use of fly ash, which is a surplus material and needs to be used in bulk, in conformation with Fly ash Mission (1994). In this paper, net safe bearing capacity (q_{ns}) of plain fly ash, plain bentonite and fly ash-bentonite layered samples with varying number of interfaces ($N = 1, 2$ and 3) and different fly ash to bentonite ratios ($1:1, 2:1, 3:1$ and $4:1$) was evaluated. It was observed that the net safe bearing capacity of mix increased as the number of interfaces among the different materials were increased. It was found that the maximum improvement in the net safe bearing capacity of fly ash occurred at a fly ash to bentonite ratio of $3:1$ when the number of interfaces was three and this combination can be safely adopted as the optimum usage combination based upon the results of the study undertaken.

Keywords: Fly ash; bentonite; layered system; bearing capacity.

1. Introduction

Coal based power plants not only produce millions of mega-watts of power but also millions of tons of fly ash. Till about a decade back, fly ash had been considered a "Polluting Industrial Waste" and most of it was being dumped in the ash ponds. About 1000 million tons of ash is estimated as dumped in ash ponds in India and every year 100 million tons of ash is being added to this quantity (Murthy, 1996). Bentonite-Çatalağzı fly ash mixture could be used as a bottom and/or upper liner at waste disposal areas and can be expected to serve the purpose if the long term increasing trend of the permeability be taken into account in the design (Mollamahmutoglu and

Yilmaz, 2001). In a bentonite fly ash mix, the plasticity, hydraulic conductivity and swelling properties i.e. the shrinkage properties of the mixtures decrease and the dry unit weight and strength increase with an increase in fly ash content (Kumar and Sharma, 2004). Fly ash-bentonite mixtures possess low shrinkage and hence do not crack. Compacted fly ash-bentonite mixtures undergo minimal volume changes under different stress conditions. Besides above properties, addition of bentonite improves the geotechnical properties of fly ash such as cation exchange capacity. Though the addition of bentonite to fly ash leads to an improvement in most of the geotechnical properties of fly ash, the unconfined compressive strength of the mixture is usually found to be lower than that of fly ash alone but still the fly ash-bentonite mixture possesses good strength (Sivapullaiah and Lakshmikantha, 2004). Improvement of bearing capacity of a soft clay bed can be affected by replacing some material from the top with a stiffer layer of compacted fly ash (Chakraborti, 1986). The consolidated undrained shear strength of layered soil fly ash matrix depends upon the the interface characteristics of layered soils under cyclic loads (Khan et al, 2008). Younus and Sreedeeep (2012) indicated that upto 70 % fly ash content can be used to satisfy the requirements of compacted landfill liners. Utilization of fly ash is necessary to save huge quantity of construction material, especially the soil or earth in huge quantity, at various stages of construction. Though fly ash and bentonite possess contradictory characteristics, they can still serve to complement each other in terms of reduced swelling tendency in bentonite and improved shear strength, seepage characteristics in case of fly ash.

2. Materials Used

The fly ash and bentonite used in the study were brought from National Thermal Power Station situated at Dadri (Ghaziabad) in Uttar Pradesh and public department works, Aligarh respectively. Fly ash collected was dried, sieved through IS sieve 425 microns and stored in airtight containers in the laboratory. Scanning electron microscope (SEM) and energy-dispersive X-ray spectroscopy (EDX) were also carried out on materials as shown in Fig.1. Particle size distribution of the materials is shown in Fig. 2. Various properties of materials are present in Table 1.

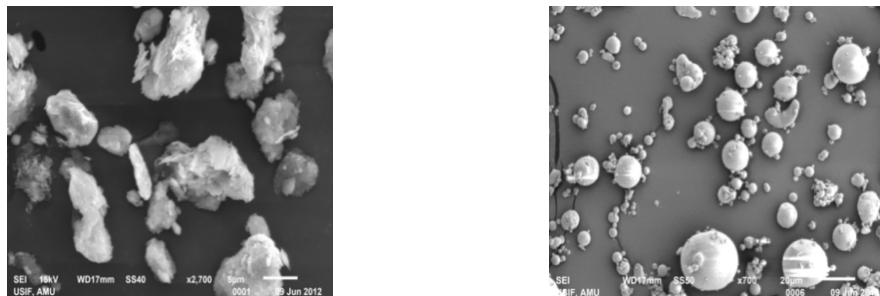


Figure 1: Scanning Electron Microscope (SEM): (a) Fly ash particles at 700 x magnification, (b) Bentonite particles at 2700 x magnification

Table 1: Physical Properties of Fly ash and Bentonite.

S. No.	Properties	Fly ash	Bentonite
1	Specific gravity	2.19	2.78
2	Optimum moisture content (OMC), %	22	28
3	Unit weight, kN/m ³	14.39	21.5
4	Maximum dry density (MDD), kN/m ³	11.8	16.8
5	Liquid limit (W _L), %	24	261
6	Plastic limit (W _P), %	0	38
7	Co-efficient of permeability, (10 ⁻¹⁰ m/sec)	951	3.24
8	Unconfined compression strength, kN/m ²	34	176
9	Classification	Class F	CH

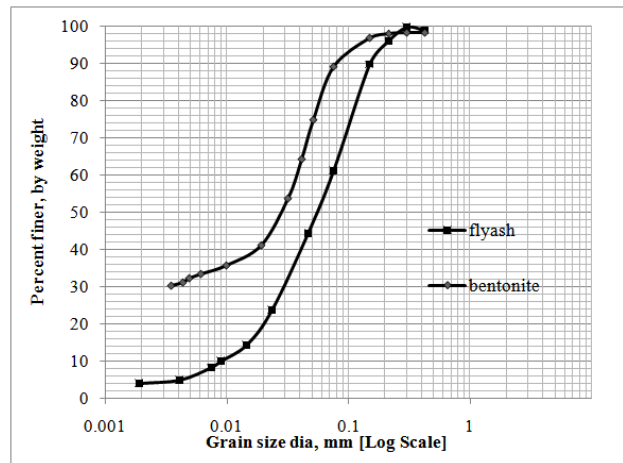


Figure 2: Particle size distribution curve for plain fly ash, plain bentonite.

3. Methodology and Experimentation

In the present experimental investigation, triaxial compression tests were carried out on 34 mm diameter, 84 mm length samples under three different confining pressures (100, 200 and 300 kPa).

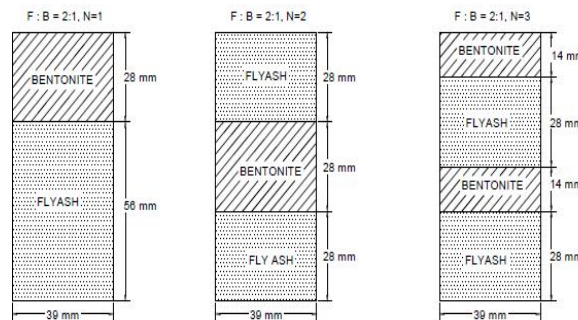


Figure 3: Diagrams representing the layered arrangement in samples.

Fly ash (F) and bentonite (B) were used in the ratio (by volume) of: 1:1 (50% fly ash: 50% bentonite), 2:1 (67% fly ash: 33% bentonite), 3:1 (75% fly ash: 25% bentonite) and 4:1 (80% fly ash: 20% bentonite). Tests were conducted on layered samples with different number of interfaces i.e: 1, 2 and 3 for each ratio as shown in fig. 3.

4. Results and Discussion

Triaxial shear tests were carried out to evaluate the deviator stress. A particular specimen of length 8.4 cm, diameter 3.9 cm was tested on three different confining pressures (100, 200 and 300 kPa) under the vertical axial load in layered system. Apart from the different layers used, ratio of fly ash to bentonite has been subjected to variation from 1:1 to 4:1. Mohr circle diagrams were used to evaluate the shear strength parameters c and ϕ . Net safe bearing capacity was evaluated using the equation given below as per I.S. 6403-1981 "Code of Practice for Determination of Bearing Capacity of Shallow Foundations" for local shear failure condition. For the calculation purpose, an isolated square footing with $1.0 \text{ m} \times 1.0 \text{ m}$ size provided at 1.5 m depth below the ground level.

$$q_{ns} = 1/F \{ c_m N'_c S_c d_c i_c + q(N'_q - 1) S_q d_q i_q + \frac{1}{2} \gamma B N'_\gamma S_\gamma d_\gamma i_\gamma W' \} \quad (1)$$

It was observed that net safe bearing capacity, q_{ns} of fly ash-bentonite layered system reduced with increase of fly ash-bentonite ratio from 1:1 to 4:1 with the number of interfaces remaining unchanged. In case of two and three interfaces, the value of net safe bearing capacity displayed an overall decreasing trend for fly ash-bentonite ratios of 1:1, 2:1 and 4:1. However, the value increased at F:B ratio of 3:1 with the maximum net safe bearing capacity being recorded for $N=3$ which is the optimised value. The trend is reflected in fig.4.

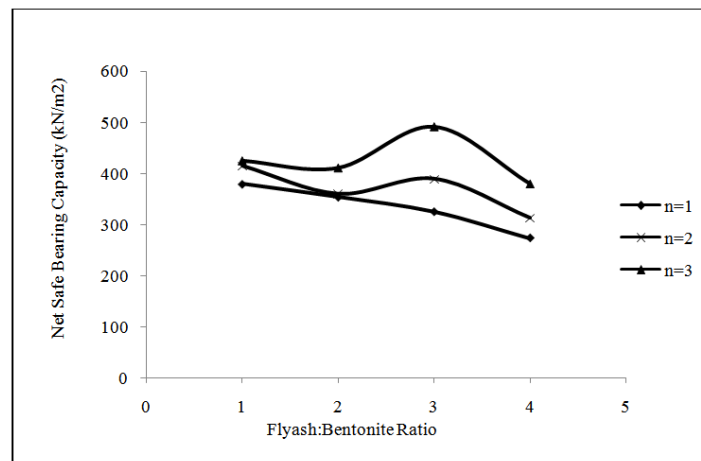


Figure 4: Graph representing net safe bearing capacity values against Fly ash bentonite ratios.

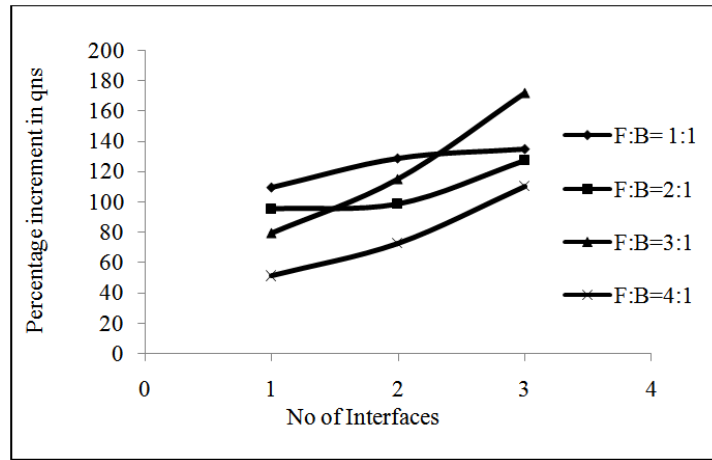


Figure 5: Graph representing percentage increment in q_{ns} at different number of interfaces.

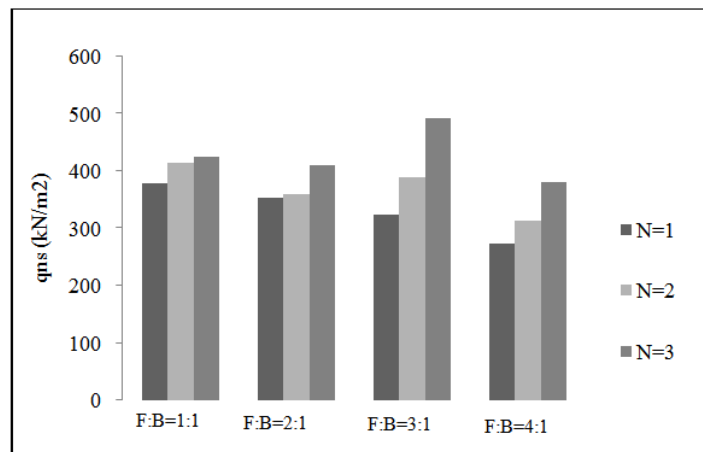


Figure 6: Chart representation of net safe bearing capacity.

Also, upon the analysis of results, a progressive increase in the net safe bearing capacity was registered as the number of interfaces was increased with the increment declining as the fly ash content in the layered system was increased. However, the best result related to the maximum percentage increase in the net safe bearing capacity was observed to be a significant 171 % in the case of sample containing fly ash: bentonite ratio = 3:1 with the number of interfaces equal to 3. Fig. 5 and Fig. 6 illustrate the same.

5. Conclusions

On the basis of experimental investigation undertaken, following conclusions are drawn:

1. Fly ash is almost cohesionless material which gets the binding effect at the interfaces of fly ash-bentonite layered system.
2. The values of net safe bearing capacity of fly ash-bentonite layered system increase with the increasing number of interfaces and confining pressures.
3. The embankment may provide greater stability if it is constructed for fly ash to bentonite ratio of 3:1 (33% of bentonite and 67% of fly ash in layers) by keeping the number of interfaces as $N=3$.
4. It is expected that fly ash to bentonite ratio 3:1 with 3 interfaces could be successfully used for filling low lying areas and in various other engineering constructions and at the same time affords a means of utilizing the same without adversely affecting the environment.

References

- [1] A.V.S.R. Murty (1996), "Fly ash in construction of Roads and Embankments", *Central Road Research Institute India*
- [2] B. R. Phani Kumar and Radhey S. Sharma (2004), "Effect of Fly ash on Engineering Properties of Expansive Soils" *Journal of Geotechnical and Geoenvironmental Engineering*, **Vol. 130**, No. 7, ASCE, 764–767
- [3] M. Mollamahmutoglu and Y. Yilmaz (2001), "Potential Use of Fly ash and Bentonite Mixture as Liner or Cover at Waste Disposal Areas", *Environmental Geology*, **40** (11/12): 1316-1324
- [4] M. A. Khan, A. Usmani, S. S. Shahand and H. Abbas (2008), "A Study of Multilayer Soil-Fly ash Layered System Under Cyclic Loading" *International Journal of Civil Engineering*. **Vol. 6**, No. 2
- [5] M. M .Younus and S. Sreedeeep (2012), "Evaluation of Bentonite-Fly ash Mix for Its Application in Landfill Liners" *SEDL / Journals / Journal of Testing and Evaluation (JTE) / Citation Page*, **Volume 40**, Issue 3
- [6] P. V. Sivapullaiah and H. Lakshmikantha (2004), "Properties of Fly ash as Hydraulic Barrier", *Soil and Sediment Contamination*, **Vol.13**, pp. 489-504