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EXPERIMENTAL EVALUATION OF SOIL IMPROVEMENT USING CEMENT AND FLY-ASH THROUGH CBR TESTS

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Abstract: Fly-ash is a major by-product of thermal plants. Fly-ash often causes environmental pollution and disposal problems. Black cotton soil derived from basaltic formation is present in major zone of India such as Maharashtra and Madhya Pradesh. Black cotton soil creates many problems in infrastructural use due to its swelling and shrinkage behavior and the plasticity. So, to becomes inevitable to treat this soil using some mixtures to enhance its properties in view to use in civil engineering developments, more specifically in transportation engineering. Present study demonstrates the use of fly ash and cement to mix with black cotton soil and its performance enhancement through California Bearing Ratio (CBR) experimental tests. The main objective of the study is to evaluate the performance of the black cotton soil when mixed with the fly ash and cement. Detailed laboratory investigations were carried out on black cotton soil mixed with various proportions (2%, 4%, 6%, 8%, 10% and 12%) of cement and Fly-ash. California Bearing Ratio (CBR) tests were conducted on untreated soil and then compared with the CBR of the mixture of fly ash, cement and Black cotton soil. A significant performance enhancement was observed in black cotton soil when mixed with fly ash and cement. It was concluded that the use of fly ash and cement to mix with black cotton soil provides necessary improvements in black cotton soils performance and thus facilitates its use in civil engineering developments.

Keywords: *Fly-ash; cement, California Bearing Ratio, Black cotton soil*

I INTRODUCTION

Soil is a naturally available material mainly used in infrastructural developments such as road, slopes etc. Strength of the soil mainly depends on its shear strength properties and also other physical properties such as compaction, consistency limits, specific gravity etc. When used in road development applications, strength of the soil is mainly assessed with the help of California Bearing Ratio (CBR). California Bearing ratio (CBR) is the ratio of pressure up to a 2.5 mm penetration measured to the bearing value of the standard crushed rock [1]. CBR test is the penetration test used to evaluate the strength of sub-grade, sub base and base course material for design of thickness for highways and airfield pavements [2]. It is necessary that soil should have sufficient strength to cope up with external loads applied on it. Majority of the infrastructure development faces either significant cost or more serviceability due to weak soil. So it is necessary to identify a cost effective technique to improve the soil properties. Many different materials have evolved to improve soil properties such as cement [3], Fly-ash [1,2,4], geosynthetics, stone columns, geocell etc. However considering the cost of reuse of industrial waste like fly-ash. The cement and Fly-ash combination appears to be a good option to improve the soil. Fly ash is a residue produced during coal combustion consisting of fine particles derived from minerals [5]. Cement is also known popularly in the construction industry owing to its binding properties [6]. This provides the motivation to the present study in which an experimental investigation is performed with mixing of fly ash and cement in the soil and CBR values obtained.

II AIM AND OBJECTIVES

The aim of this work is to use the industrial waste such as fly ash for the construction of cost effective roads.

1. To determine the index and engineering properties of soil and soft clay from the selected site.
2. To study the properties of Fly ash and Cement
3. To study the California bearing ratio (CBR) by adding Fly ash (FA) and Cement
4. To compare the experimental results obtained for treated soil with Fly ash and Cement to that of untreated soil and to estimate the performance enhancement.

III MODEL MATERIALS

1. Soil-

The type of soil used for the present work is a black cotton soil. The soil sample is obtained from Aurangabad (Maharashtra). Black cotton soil is mostly known for its plasticity and the volume changes. And so makes it very complicated to use for the construction of roads. The following are the various properties of soil.

Table 1: Engineering Properties of Soil

Sr. No.	Property	Value (%)
1	Color	Greyish black
2	Specific Gravity	2.11
3	Liquid Limit	67
4	Plastic Limit	27
5	Plasticity Index	40
6	Free Swell Index	23.08
7	Optimum Moisture Content	15
8	Maximum Dry Density (g/cm3)	1.85
9	California Bearing Ratio Value	2.36

2. Cement-

Ordinary Portland Cement (OPC) was used in the present study which is commercially available with 53 grade cement grade. Following are the properties of the cement used in the present study.

Color-Greenish grey
Fineness of cement- 3.30%
Setting time-Initial setting time- 35min
-Final setting time- 8 hrs 25min
Consistency Limit- 28%

3. Fly Ash-

Fly ash is the main byproduct of the furnace and considered as an environmental waste. It is widely known for its fine grained structure and the low specific gravity. A commercially available fly ash was used in the present study with following properties.

Color- Whitish Grey
Bulk Density- 0.924 g/cc
Specific Gravity- 2.26
Moisture - 3.14%

IV STUDY PARAMETERS AND EXPERIMENTAL PROGRAM

Figure 1 shows the experimental package and the study parameters used in the present study. All the tests were performed in the form of conventional CBR test procedure. Parametric variation was made as untreated soil vs soil mixed with cement alone, soil mixed with fly ash alone and soil mixed with cement as well as the fly ash.

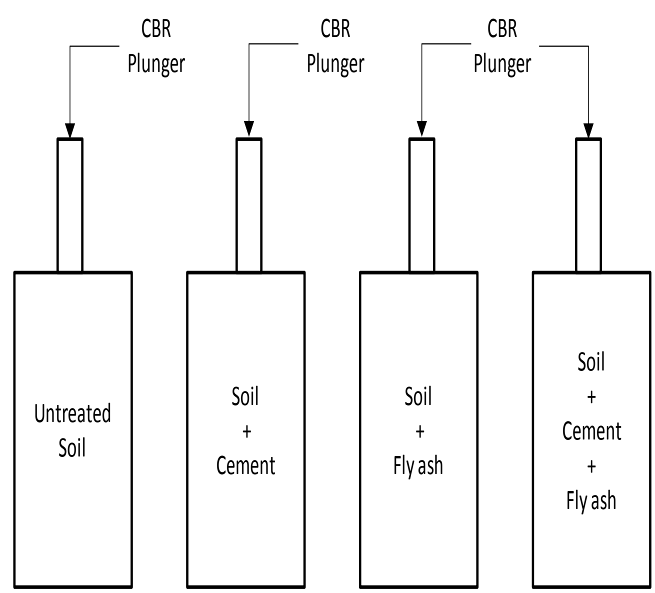

Figure 1: Experimental package and study parameters

Table 1 shows the test legends, the description of the parametric variation and the objectives behind the series of tests conducted under the changes in the parameters considered. Parameters were varied mainly to estimate the improvement in the California Bearing Ratio of the soil with the inclusion of the hybrid mixes like cement alone, fly ash alone and the combination of the fly ash and the cement with black cotton soil. Total 25 physical experiments were performed starting with untreated soil, followed by soil mixed with 2 to 12% of cement, followed by soil mixed with 2 to 12 % of Fly ash, followed by soil mixed with 2 to 12% of cement as well as fly ash. A conventional CBR test apparatus was used which is explained in the next section of this research study.

Table 1: Test program with parametric variation

Test legend	Description	Objectives
T-01	Untreated	To set a benchmark to measure the improvements due to Addition of Cement and Fly ash
T-02 to T-07	Soil treated with increasing cement content from 2% to 12% respectively	To evaluate the performance enhancement of the soil due to addition of cement.
T-08 to T-13	Soil treated with increasing Fly-Ash content from 2% to 12% respectively	To evaluate the performance enhancement of the soil due to addition of Fly.-ash.
T-14 to T-19	Soil treated with 2% cement and increasing Fly-ash content from 2% to 12% respectively	To evaluate the performance enhancement of the soil due to addition of various Percentages of Cement and Fly-ash.
T-20 to T-25	Soil treated with 4% cement and increasing Fly-ash content from 2% to 12% respectively	To evaluate the performance enhancement of the soil due to addition of various Percentages of Cement and Fly-ash.

IV EXPERIMENTAL SETUP

All the tests were performed in a conventional CBR test mold as shown in the figure 2. All the tests were tested at optimum moisture content and maximum dry density of the soil. California bearing ratio test is mainly used to evaluate the quality if the soil for the construction of the flexible pavement in the form of base or sub-base. It is a penetration test in which a standard piston, with a diameter of 50 mm, is used to penetrate the soil at a standard rate of 1.25 mm/minute. The pressure up to a penetration of 2.5 mm is measured and its ratio to the bearing value of a standard crushed rock is termed as the CBR. The laboratory CBR apparatus consists of a mold of 150 mm diameter with a base plate and a collar, a loading frame and dial gauges for measuring the penetration values and the expansion on soaking. Figure 3 shows the loading frame utilized for the CBR tests. The loading arrangement was such that the motorized platform where the CBR mold is placed lifts at the rate of 1.25 mm/minute. Top surface of the soil placed in CBR mold is placed with a 50mm diameter plunger attached to proving ring. The resistance provided by the specimen to penetration of the plunger was recorded at the proving ring for each mm of penetration. Results obtained are discussed in next section of this paper.

Figure 2: CBR mold with compaction hammers

Figure 3: Loading frame for CBR test

V RESULTS AND DISCUSSIONS

Figure 4 shows the variation of penetration resistance to the penetration variation for CBR tests conducted on virgin soil and the addition of fly ash from 2 to 12%. It was observed that the penetration resistance increases with increase in fly ash content. A maximum penetration resistance of 60 kg and 84 kg was observed for the case of 10 % addition of the fly ash. For further addition of fly ash, resistance was observed to decrease. It can be conveniently said that the penetration resistance of the soil in CBR increases with increase in fly ash content upto 10 % addition. Further increase in fly ash content decreases the resistance and thus the optimum mixture of fly ash could be noted as 10% maximum.

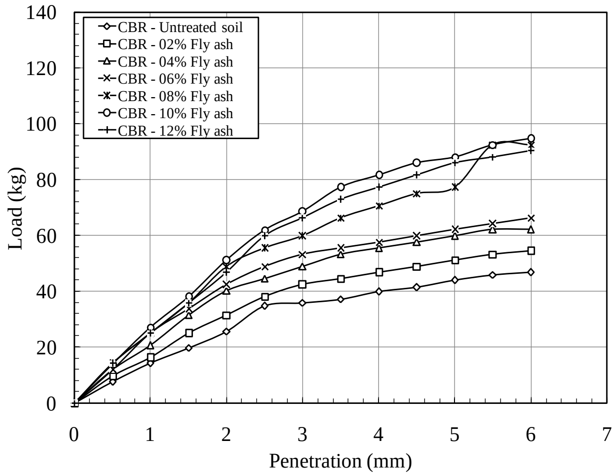

Figure 4: Load with penetration for increasing fly ash content

Figure 5 shows the variation of penetration resistance to the penetration variation for CBR tests conducted on virgin soil and the addition of cement from 2 to 12%. It was observed that the penetration resistance increases with increase in cement content. A maximum penetration resistance of 75 kg and 101 kg was observed for the case of 12 % addition of the cement. Steady growth of resistance was observed with addition of cement content which continued till 12 % addition. Based on the trend observed it can be conveniently said that as the cement content increases the penetration resistance of the soil increases. A similar trend will be produced with further addition of the cement. This is mainly due to adherence of the cement particles providing higher cementation with introduction of water.

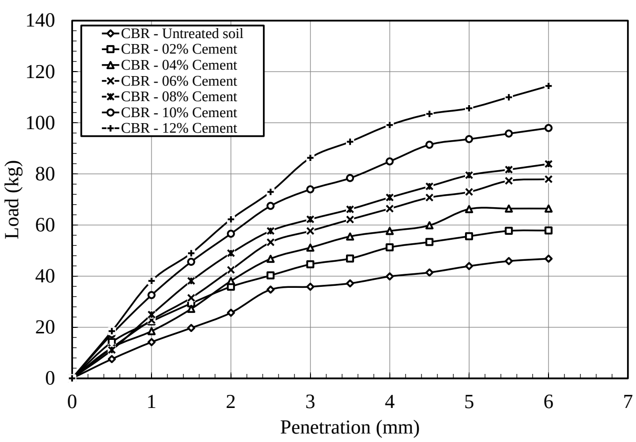

Figure 5: Load with penetration for increasing cement content

Further, a combination of cement and fly ash was addded to soil and the penetration resistance was noted. A significant enhancement was observed. Figure 6 to Figure 9 show the variation of penetreation resistance to the pentration for different fly ash content with increase in cement content. A maximum resistance of 85 kg and 124 kg was observed for the case of 10% fly ash and 6% cement content in the soil. With further addition of cement and fly ash no improvements were observed. This is mainly due to the fact that the fly ash provides more surface area and nullifies the effect of excess cement in the soil. An optimum case of cement 6% and fly ash 10% mixed in soil was concluded to be the best improvement for the black cotton soil.

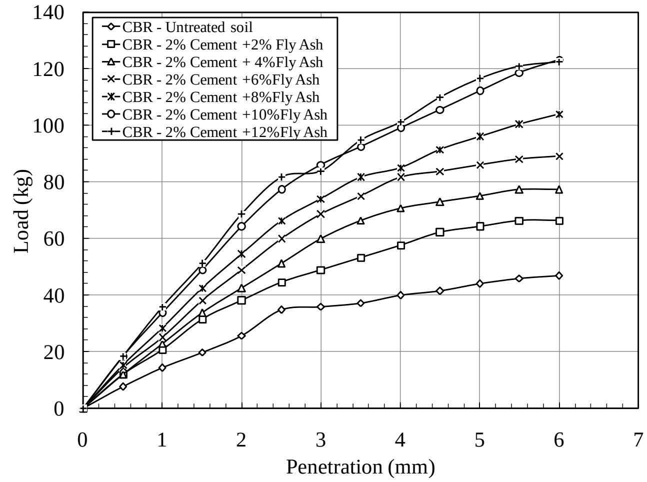

Figure 6: Load with penetration for increasing fly ash at 2% cement

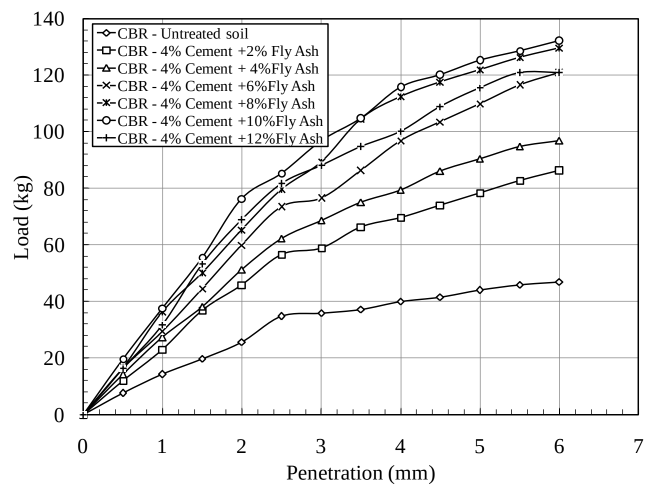

Figure 7: Load with penetration for increasing fly ash at 4% cement

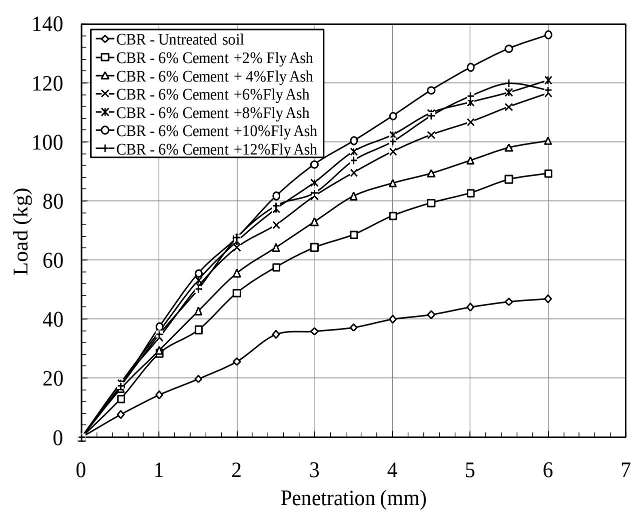

Figure 8: Load with penetration for increasing fly ash at 6% cement

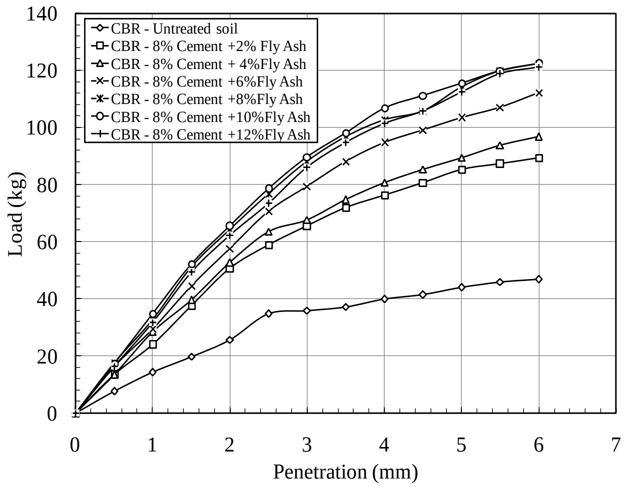

Figure 9: Load with penetration for increasing fly ash at 8% cement

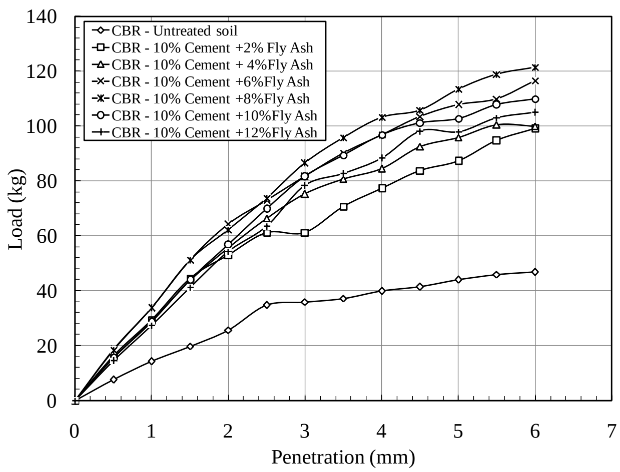

Figure 10: Load with penetration for increasing fly ash at 10% cement

VI CONCLUSION

Following conclusions were drawn from the experimental research performed on enhancement of soil due to addition of cement and fly ash.

1. With addition of fly ash soil capacity enhances, a maximum penetration resistance of 60 kg and 84 kg was observed for the case of 10 % addition of the fly ash.
2. With addition of cement soil capacity enhances significantly, maximum penetration resistance of 75 kg and 101 kg was observed for the case of 12 % addition of the cement.
3. Addition of cement content was found to more effective than the addition of fly ash only. With around 10% better performance than fly ash alone.
4. Addition of cement shall perform better and thus shall be considered effectively for important infrastructural developments.
5. Combination of fly ash and cement was found to give better results. A maximum resistance of 85 kg and 124 kg was observed for the case of 10% fly ash and 6% cement content in the soil. With further addition of cement and fly ash no improvements were observed.

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