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STRENGTH CHARACTERISTICS OF RED SOILS BLENDED WITH FLY ASH AND LIME

Tarh Reema[1], Ajanta Kalita[2]

Department of Civil Engineering, North Eastern Regional Institute of Science and technology, Nirjuli[1, 2]

Abstract: An experimental testing program was undertaken for evaluating the effect of a class F fly ash and lime on the strength properties of locally available red soils. Compaction tests and unconfined compression tests were carried out. Fly ash and lime were mixed in different proportions ranging from 20-80% and 2-4% by dry weight of soil, respectively. The unconfined compression test results on the soil-fly ash-lime mixtures indicate that addition of lime to soil-fly ash mixtures leads to increase of both peak stress and stiffness as well as change of behaviour to a brittle one. Brittle behaviour is more marked in soil-fly ash-lime specimens after 7 days of curing in case of red soil. The soil-35%fly ash-lime mixes have higher unconfined strength than the soil-50%fly ash-lime specimens. The study indicates that the soil-fly ash mixes are suitable for good subgrade layer of road embankments, and when blended with lime is appropriate as road sub-base or base materials.

I. INTRODUCTION

The increasing demand for electrical power to the rapidly growing industrial as well as agricultural sectors has resulted in the setting up of a number of coal-based thermal power stations in India. Large quantities of fly ash are being produced from these thermal power stations. The disposal of ash has serious problems of environmental pollutions and disposal problem. To avoid these problems, many innovative methods are being explored for its utilization in many fields, especially in geotechnical engineering applications. Prashanth et al. (1998) studied the behaviour of compaction curves of different fly ashes with varying specific gravities. Cokca (2001) evaluated the effectiveness of high calcium and low calcium fly ashes for stabilisation of an expansive soil and by comparing with the effect of lime and cement stabilization. Consoli et al. (2001) evaluated the stress-strain-strength behaviour of sandstone residual soil improved through the addition of carbide lime and fly ash. Kaniraj and Havanagi (1999) conducted compaction test to investigation on the compaction behaviour of fly ashes, the maximum dry density (MDD) and optimum moisture content (OMC) of different fly ash and fly ash-soil mixtures were determined by compaction test. Kaniraj and Gayathri (2003) conducted unconfined compression test to investigate the influence of randomly oriented fiber inclusions on the geotechnical behaviour of Indian Class F fly ashes. The standard proctor compaction test, unconfined compression test and triaxial shear tests were conducted. The aim of the present study is to investigate the strength characteristics of red soils blended with fly ash and lime.

II. EXPERIMENTAL PROGRAM

2.1 Materials

The red soil was collected from the hill top of Rajiv Gandhi University Rono Hill, Doimukh. The soil was being excavated with a spade at the time of collection in plastic bags. After air-drying, the soil aggregates were carefully broken down using a tyre mallet. The soil was classified as ML (Silt with low compressibility). The fly ash used in this present study is an industrial by-product obtained from the “Satyum” thermal power plant located in Banderdewa in Arunachal Pradesh. It is a class F fly ash. Lime used in the present investigation was laboratory grade quick lime (CaO) in powdered state.

2.2 Method of Soil-Fly Ash-lime Mixture Preparation

In the preparation of specimens for strength tests, first the required amount of soil, fly ash and lime were measured and mixed together in dry state, and then the required amount of water was added equal to the corresponding

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OMC of the mix. Cylindrical specimens of the mixes were prepared at their respective optimum moisture content and maximum dry density. For all mixtures, 38-mm diameter and 76-mm long samples were prepared by static compaction. For curing specimens of unconfined compression tests, they were placed at 100% humidity in desiccators kept at room temperature, and then left for 0, 7, 14, and 28 days. Here, RS and FA indicate red soil and fly ash, respectively. 20FA means 20% by weight is fly ash

Table 1. Testing program

Mix Proportion	Proportions of lime used (%)	Curing periods (days)	
		Compaction test	UC test
RS	0,2,3,4	-	0,7,14,28
RS+20FA	-do-	-	0,7,14,28
RS+35FA	-do-	-	0,7,14,28
RS+50FA	-do-	-	0,7,14,28
RS+65FA	-do-	-	0,7,14,28
RS+80FA	-do-	-	0,7,14,28
FA		-	0,7,14,28

III. COMPACTION TESTS

Compaction generally leads to an increase in shear strength and helps to improve the bearing capacity and stability of a soil. In the field, the subgrade layer should be compacted to not less than 97% of the laboratory maximum dry density. The compactive unit weight of the soil material depends mainly on four factors: (i) type of soil, (ii) water content, (iii) method of compaction, and (iv) compactive energy. Figs. 1 and 2 show the variation of MDD and OMC of the red soil-fly ash mixes respectively. It is observed that the MDD of the red soil-fly ash mixes does not get significantly altered up to 20% replacement of red soil with fly ash. The results show that as the fly ash content increases, the MDD of the mix decreases whereas the OMC increases. The increase in the OMC of the mix can be attributed to the higher water holding capacity of the porous and hollow fly ash particles. Figs. 3 and 4 show the variation of MDD and OMC of the red soil-fly ash-lime mixes respectively. It can be noted from the results that the MDD of the soil reduces continuously with the increase in the proportion of fly ash. The reason for this change can be explained from the low MDD of the fly ash and its dilution effect. The OMC of the soil is also significantly affected by the addition of lime and fly ash as clearly illustrated in Fig. 4. For a given proportion of fly ash, the OMC increases with the increase in the amount of lime. The patterns of decrease in MDD and increase in OMC with increasing fly ash percentage are similar to that of soils with increasing content of finer fraction. Further, it can be noted from Figs. 3 & 4 that the magnitudes of change in MDD and OMC of all the mixes are greater with 2% of lime addition than 4% lime addition. This is due to the reduced demand for lime for short-term modification of the mixes.

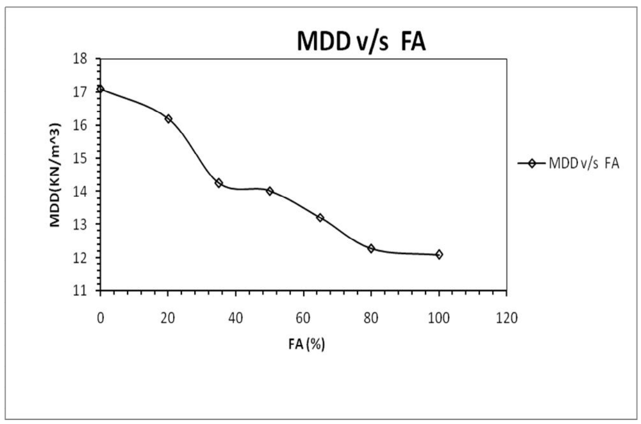

Fig. 1: Variation of MDD of the red soil – fly ash mixes

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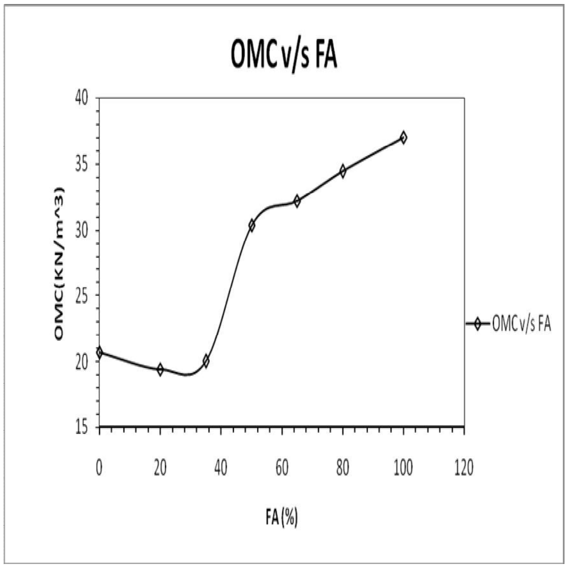

Fig. 2: Variation of OMC of the red soil – fly ash mixes

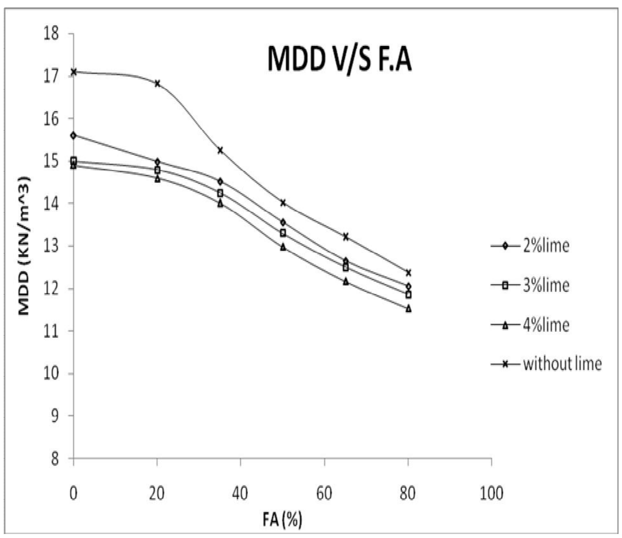

Fig.3: Variation of MDD of the red soil-fly ash-lime mixes

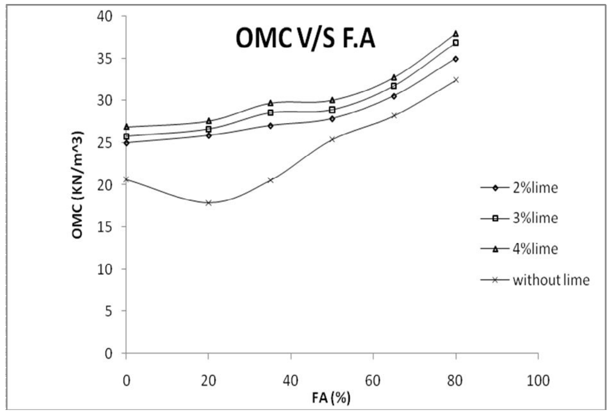

Fig.4: Variation of OMC of the red soil-fly ash-lime mixes

IV. UNCONFINED COMPRESSION TESTS

The quality of amended soils is usually assessed on the basis of the unconfined compressive strength test on compacted samples that have been allowed to harden for a specified period. The rate of strength development and the level of such strength depend on several factors including: type of clay minerals present in the soil, type of fly ash, amount of replacement of soil with fly ash, mix proportions, ambient temperature, curing environment, nature and amount of lime. To study the effect of pozzolanic reactions on the shear strength of the soils when blended with different fly ash contents, the specimens were cured up to 28 days. Three specimens of each mix and curing time were subjected to the test.

Figs. 5 and 6 illustrate the development of the unconfined compressive strength in relation to curing time for red soil-fly ash mixes and red soil-fly ash-lime mixes respectively. When fly ash is added to the red soil, 28 days unconfined compressive strength (UCS) values are observed to be the highest for mixes with 35% fly ash content followed by 20% fly ash content. There is no benefit of fly ash addition above 50%, and the UCS values of these mixes remain less than that of the red soil alone. Addition of lime to the red soil significantly improves the UCS. Addition of more amount of lime to soil is not an economical option. The presence of fly ash is fundamental to improve the strength of the soil mix by facilitating time-dependent pozzolanic reactions. To allow this, maximum replacement of the red soil by 35% can be made so as to satisfy strength requirements.

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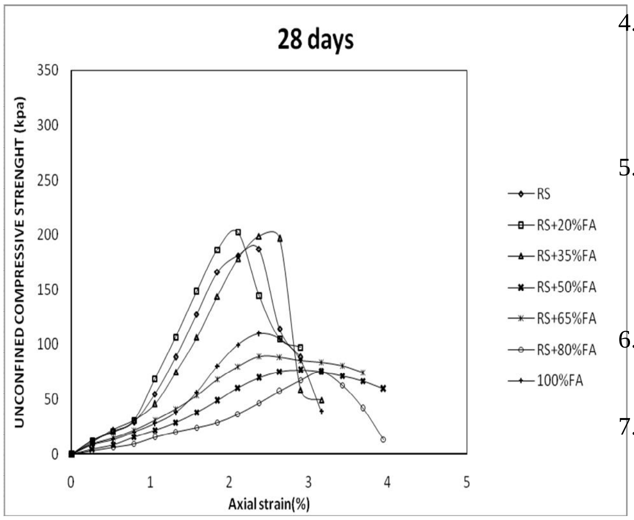

Fig. 5: Stress-strain plots of RS + different % FA mixes (28 days curing)

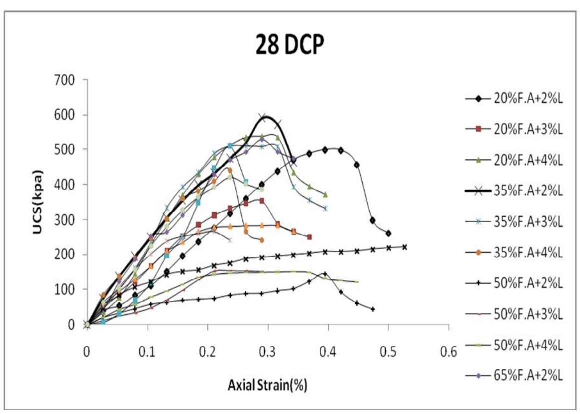

Fig. 6: Stress-strain plots of RS + different % FA mixes + lime (28 days curing)

V. CONCLUSIONS

1. The MDD of the red soil does not get significantly altered when replaced with fly ash up to 20%, but tends to decrease with further increase in fly ash content.
2. The OMC initially decreases up to 20% fly ash addition and then gradually increases with higher fly ash content.
3. The addition of lime to the red soil-fly ash mixes leads to the reduction of MDD and the increase of OMC.
4. The soil shows considerable increase in its unconfined compressive strength when compacted to maximum dry density. The fly ash exhibits a much lower unconfined compressive strength compared to that of the soil.
5. When fly ash is added to the red soil, 28 days UCS values are observed to be the highest for mixes with 35% fly ash content followed by 20% fly ash content. There is no benefit of fly ash addition above 50%, and the UCS values of these mixes remain less than that of the red soil alone.
6. The overall stress-strain-strength response is significantly affected by the addition of lime to the red soil-fly ash mixes.
7. Among all the soil-fly ash-lime mixes, the mix containing 35% fly ash and 4% lime shows highest long-term unconfined compressive strength. When the lime addition is limited to 3%, mix containing 20% fly ash shows the maximum long-term unconfined compressive strength. The long-term unconfined compressive strength of the soil-fly ash-lime mixes containing 50% fly ash remains much below the level than shown by the other two Mixes.

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