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CBR Values of Soil Mixed with Fly Ash and Lime

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Abstract **- Several geotechnical and structural constructions are made on weak, soft and incompatible soils. This becomes extremely perilous in geotechnical field because such soils are more liable to differential settlements, poor shear strength and high compressibility. This paper represents the CBR valuesof soil mixed with fly ash and limein different percentages. The fly ash has been collected from the West Bengal, India and lime has been collected from the local market of Agartala, India. The analysis has been carried out by conducting tests to analyze the compaction and CBR (Unsoaked) characteristics of the locally available soil (NITA soil) mixed with fly ash and lime at different percentages. Soil was mixed with lime at 5%, 8%, 10% and 12% and with fly ash at 10%, 20%, 30% and 40% to enhance its CBR values. The optimum moisture content increases and dry density decreases with increase in fly ash and lime percentage due to the variation in clay and silt size particle. Addition of flyash and lime enhanced the Unsoaked CBR value of the soil. Thus the fly ash and lime mixed soil may be used in different geotechnical fields.**

Keywords: Maximum dry density, Optimum moisture content, California bearing ratio, NITA soil, Lime, Fly ash, Mix percentages

1. INTRODUCTION

CBRvalues of soil forms an essential engineering property in geotechnical structures design like pavements and foundation etc. Engineers usually face a series of potential soil problems due to the bad soil. In many cases, the soil in the construction field is not suitable for developing engineering projects. The conventional geotechnical engineering techniques for infrastructure become problematic, not only for the high economy but even more for environmental conditions. In such cases the improvement of the strength behaviour of the soil mixed with various materials may be an excellent solution. There are several materials such as cement, lime and also some industrial waste products like fly ash which may be used as an additive for improving the strength of soil. The use of waste products like fly ash as a material to stabilizing the soil may help economically and environmentally to a great extent. Several researchers have been successively analyzed to study the strength behaviour with various materials on the basis of CBR values.

Joulani (2002) has investigated the effect of stone powder and lime on strength, compaction and CBR properties of fine soils and found that on addition of lime with stone powder the angle of internal friction, maximum dry density and optimum moisture content decreases whereas CBR value increases. Introduction of fly ash in soil is also useful in various geotechnical fields. When lime is added to soils, it reacts with soil particles, which leads to the improvement in many engineering properties of soils. Some investigators found that the strength behavior of soils was greatly improved after lime treatment (Balasubramaniam et al., 1989).

Bell (1996) indicated that soils treated with lime experienced notable increase in optimum moisture content while undergoing a decrease in maximum dry density.

Neeraja (2010) has suggested the influence of lime and plastic jute on strength and CBR characteristics of soft clayey (expansive) soil and the outcomes shows that the addition of lime and plastic jute the CBR value increases considerably. Effect of fly ash on strength is not only due to its free lime content alone but also due to hydraulic and pozzolanic reactions (Kolias et al. 2005). Prabakar et al. (2004) carried out a research which describes the influence of fly ash on strength behavior of typical soils and found that the soils mixed with fly ash have significant improvement over load bearing capacity and CBR value which would be beneficial especially for pavement. Saha and Pal (2012) has carried out a research on influence of fly ash on unconfined Compressive strength of soil and fly ash layers placed successively and the result shows that the silt size fly ash has more unconfined compressive strength than the local laterite silty sand soil. Satyanarayanaet al. (2013) have recommended a study on strength characteristics of expansive soil-fly ash mixes at various moulding water contents and found a 30% optimum value of fly ash. Sai Darshan T R et al. (2014) has suggested the influence of fly ash on the strength behaviour of lime and cement treated red soil.Ramesh et al. (2012) has performed an experiment to show the effect of lime on the compaction and strength behaviour of red earth treated with mine tailings. Sezer et al. (2006) carried out a research on the utilization of a very high lime fly ash for improvement of Izmir clay. Strength behaviour of soil with fly ash and limehas been studied by the several researchers and to some extents similar trend observed by walker, P.J. (1995), Indraratna, B (1996), Indraratna, AS (1995), and Ahmed et al. (2013).

2.MATERIALS AND EXPERIMENTAL PROGRAMME

2.1 MATERIALS

In this paper the laboratory test has been done on soil and soil mixed with different materials to determine the CBR value of the soil. Materials used in the laboratory are: NITA campus soil, lime, fly ash

(1) NITA campus soil (locally available soil) - The soil was collected from the National Institute of technology Agartala campus. Soil sample is reddish in colour.

(2) Lime – lime was collected from Agartala market

Table1. Chemical composition of lime
(Harichane et al., 2010)

Chemical name	Composition (%)
CaO	>83.3
MgO	<0.5
Fe_2O_3	<2
Al_2O_3	<1.5
SiO_2	<2.5
SO_3	<0.5
Na_2O	0.4-0.5
CO_2	<5
$CaCO_3$	<10

(3) Fly ash- Fly ash was collected from the Kolaghat Thermal Power Station, Kolaghat, West Bengal, India. The fly ash is grey in colour.

Table2. Chemical composition of fly ash
Ghosh et al. (1998)

Chemical name	Composition (%)
SiO_2	53.30
Al_2O_3	31.73
Fe_2O_3	5.27
CaO	1.40
MgO	0.10
LOI	5.50
Other	2.70
LOI- loss on ignition	

2.1EXPERIMENTAL PROGRAMME

Physical and engineering properties of the materials were determined by the different laboratory experiments as specific gravity test, grain size analysis test, Atterberg limit test, modified Proctor compaction test and Unsoaked California bearing ratio test at room temperature 27°C as per ASTM. In this work thefly ash and limehas been mixed with different percentages of soil to carry out the test and are mentioned below.

Table 3: Preparation of soil mixed with fly ash and lime.

`	symbol	Fly ash	symbol	Lime
Soil Mix	M1	100 % soil + 0% F.A	M1=M6	100 % soil + 0% lime
	M2	90 % soil + 10% F.A	M7	95% soil + 5% lime
	M3	80 % soil + 20% F.A	M8	92% soil + 8% lime
	M4	70 % soil + 30% F.A	M9	90% soil + 10% lime
	M5	60% soil + 40% F.A	M10	88% soil + 12% lime

3. RESULTS AND DISCUSSIONS

3.1 RESULTS

To carry out the research work the locally available soil has been mixed with fly ash and limein different percentages as mentioned in table 3. Experimental test results on physical and engineering properties of soil and materials are shown in table 4 to table 6. The dry density vs. optimum moisture content curve and load vs. penetration curve of soil and soil mixed with fly ash and lime in different percentages are shown in figure-1 to figure-4.

Table 4: physical and engineering properties of NITA soil

Physical Properties	Experimental data
Specific Gravity (G)	2.58
Sand particles (4.75mm - 0.075mm, %)	53.28
Silt particles (0.075 - 0.002, %)	25.32
Clay size (≤ 0.002mm, %)	21.40
Liquid Limit (%) Plastic Limit (%)	26.37 21.25
Shrinkage Limit (%)	21.16
Plasticity index (%)	5.12
Plasticity	Low plastic
Maximum dry density (kN/m^3), modified proctor test	19.30
Optimum moisture content (%), modified proctor test	12.08
California bearing ratio value Unsoaked (%)	5.045

Table 5: physical and engineering properties of fly ash

Physical Properties	Experimental data
Specific Gravity(G_f)	2.13
Sand size particles (4.75mm-0.075mm, %)	15
Silt size particles (0.075-0.002mm, %)	81
Clay size particles (≤0.002mm, %)	4
Classification	SM
Plasticity	Non plastic
Maximum dry density (kN/m^3), light compaction	11.75
Optimum moisture content (%)	29.8

Table 6: compaction characteristics and Unsoaked California bearing ratio value of the soil-fly ash mix

S.NO.	Symbol	Soil (%)	Fly ash (%)	MDD (kN/m^3)	OMC (%)	CBR (%)
1	M6	100	0	19.30	12.08	5.04
2	M7	90	10	18.70	12.50	5.20
3	M8	80	20	18.10	13.05	5.69
4	M9	70	30	17.68	14.25	6.34
5	M10	60	40	16.50	14.50	8.83

Table 7: compaction characteristics and Unsoaked California bearing ratio value of the soil-lime mix

S.NO.	Symbol	Soil (%)	Lime (%)	MDD (kN/m^3)	OMC (%)	CBR (%)
1	M1	100	0	19.30	12.08	5.04
2	M2	95	5	18.60	13.06	10.41
3	M3	92	8	18.50	13.70	16.11
4	M4	90	10	18.10	14.40	17.57
5	M5	88	12	18.05	14.60	20.83

3.2 DISCUSSIONS

Based on the laboratory test results the discussions have been made herein, effects of fly ash and limeon compaction characteristics and CBR value of the soil in different percentage has been discussed in this section.

Effect of Fly Ash on MDD and OMC of the Soil-fly ash mix

The maximum dry density (MDD) and optimum moisture content (OMC) of the NITA campus soil and the soil mixed with fly ash are summarized in Figure 1 and Table 6. From Figure 1, it can be observed that with increase of fly ash content in the soil the dry density of the soil-fly ash mix decreases and optimum moisture content increases. It may be due to the soil has large sand content as compared to silt and clay, and on the other side fly ash has large amount of silt size particles, as a results in mixed soil sand content decreases and thereby the dry density decreases. The similar trend has been observed by the Darshan et al. (2014) Brooks (2009) has been found that on mixing the fly ash with soil the MDD of the soil- fly ash mix decreases and OMC increases.

Effect of Lime on Compaction Characteristics of Soil

The maximum dry density (MDD) and optimum moisture content (OMC) of the NITA campus soil and the soil mixed with lime are presented in Figure 2 and Table 7. From figure 2, it can be observed that with increase of lime content in the soil the dry density of the soil-lime mix decreases and optimum moisture content increases. It may be due to the soil has large sand content as compared to silt and clay, and on the other side lime has large amount of clay size particles, as a results in mixed soil sand content decreases and thereby the dry density decreases. The similar trend has been noticed by Kumar et al. (2009) and also Ramesh (2012) has been found that on mixing the lime with soil the MDD of the soil- lime mix decreases and OMC increases.

Effect of Fly Ash on CBR Value of Soil-fly ash mix

The California bearing ratio of the NITA campus soil and soil mixed with fly ash has been conducted on laboratory. The results of CBR value of soil-fly ash mix has been shown in Figure 3 and Table 6. From these results, it can be observed that the CBR value of the soil-fly ash mix increases with increases of fly ash content. The reason may be due to cation exchange in the soil- fly ash mix during which the sodium ions in the soil are replaced by the calcium ions in the fly ash thus reduces the settlement and hence increases the CBR value. The similar trend has been observed by Modak et al. (2012) and Satyanarayana et al. (2013) has been studied the similar result on CBR value of soil- fly ash mix.

Effect of lime on CBR value of the soil- lime mix

The California bearing ratio of the NITA campus soil and soil mixed with lime has been conducted on laboratory. The results of CBR value of soil-lime mix has been shown in Figure 4 and Table 7. From these results, it can be revealed that the CBR value of the soil-lime mix increases significantly with increases of lime content. The gain in strength of lime stabilized soil is primarily a result of pozzolanic reactions between silica and alumina from the soil and lime to form various types of cementing agents. The similar observation has been noticed by Neeraja (2010) and Ahmed et al. (2013) has been revealed that the CBR value of the soil- lime increases with increase in lime percentage.

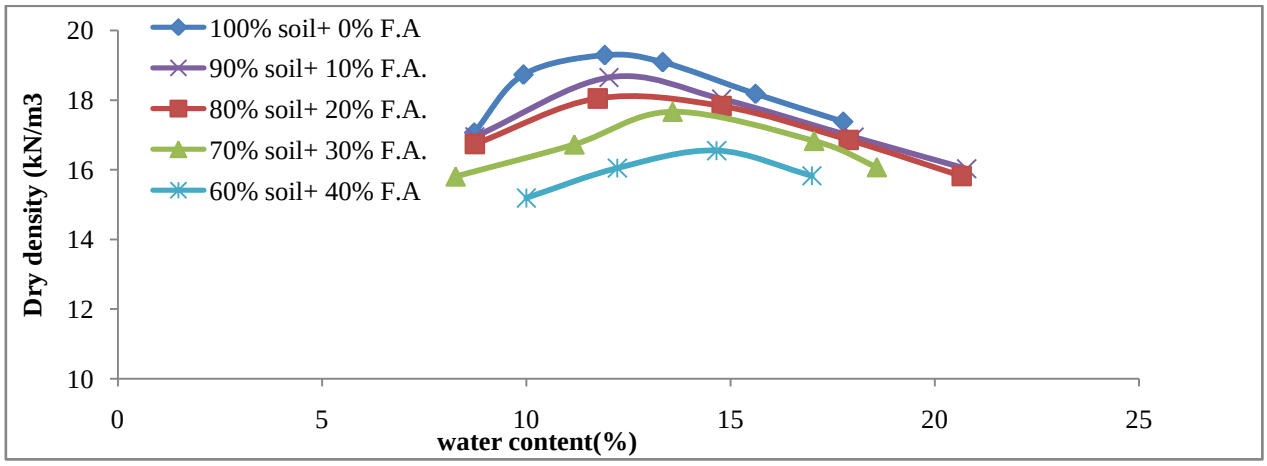

Figure 1: Dry density vs. moisture content curve of soil-fly ash mix.

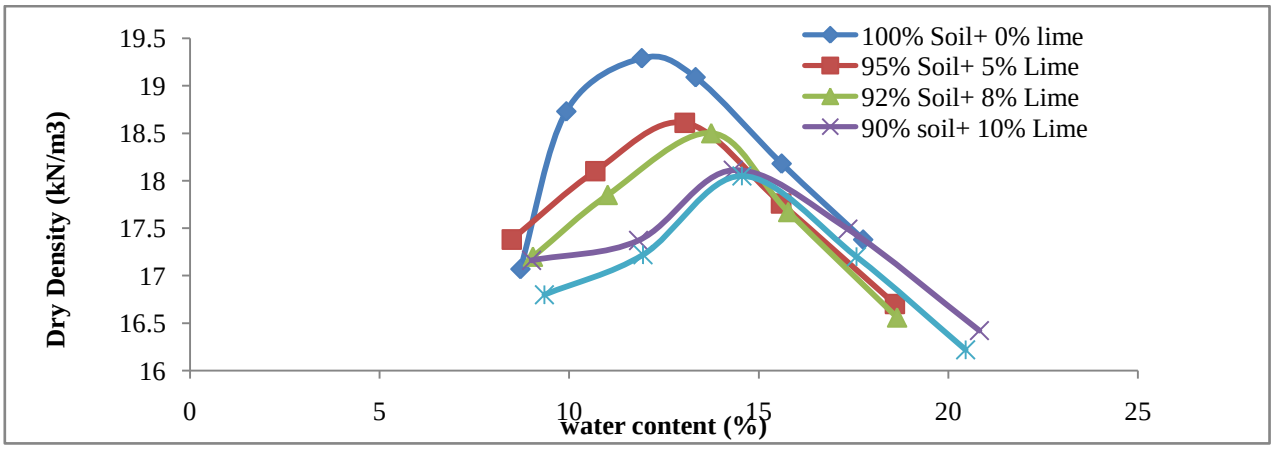

Figure 2: Dry density vs. moisture content curve of soil-lime mix.

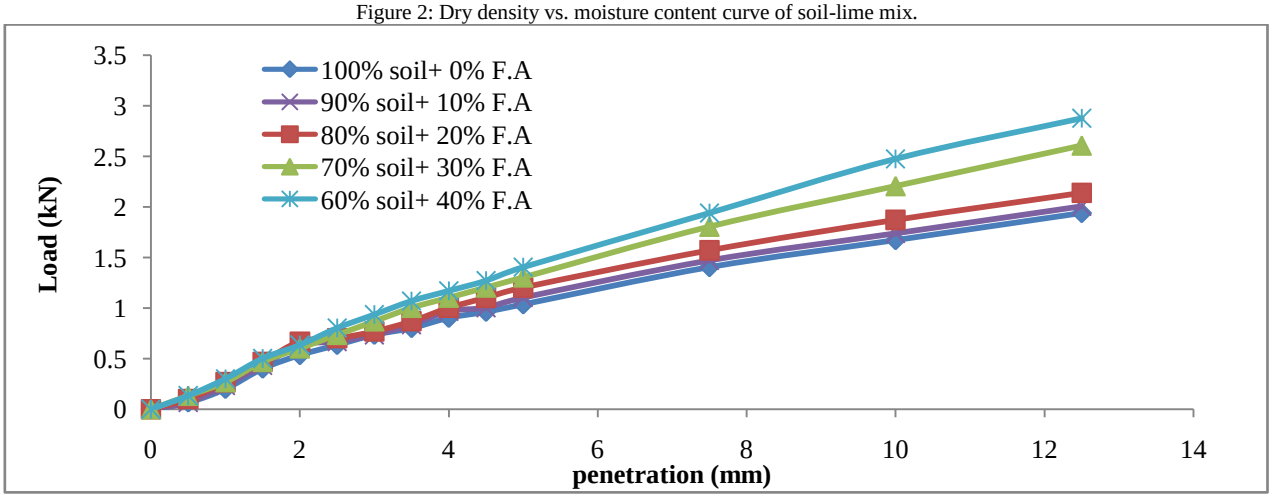

Figure 3: Load vs. Penetration curve of soil- fly ash mix.

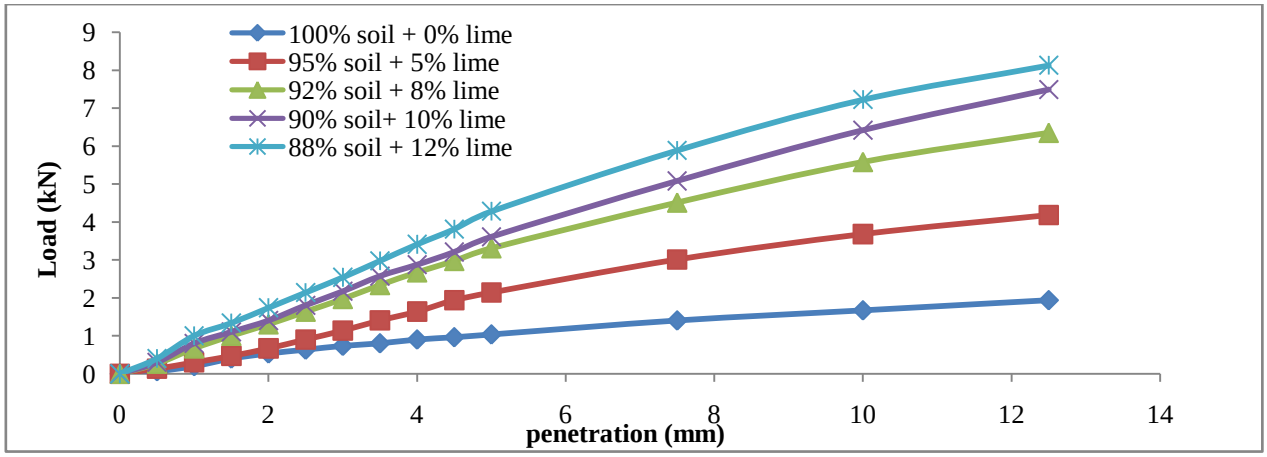

Figure 4: Load vs. Penetration curve of soil- lime mix.

4. CONCLUSION

This research has been conducted to improve the strength behaviour of soil with flyash and limeon the basis of CBR values and also for utilization of materials in different geotechnical fields. Based on the above test results and discussions following conclusion may be made.

- The MDD and OMC of the NITA soil vary considerably when mixed with fly ash and lime. The MDD value of the soil-fly ash mix and soil-lime mix decreases with increase of fly ash and lime content respectively. The OMC value of the soil-fly ash mix and soil-lime mix increases with increase of fly ash and lime content respectively.
- The optimum moisture content increases even with small amount of the lime as compared to fly ash.
- The CBR value of the NITA soil shows better results when mixed with fly ash and lime. The California bearing ratio of the soil mixed with fly ash and lime increases as increase in percentages of fly ash and lime.
- The CBR value of the soil-lime mix has a higher value as compared to the soil- fly ash mix even with small percentages of lime in soil.

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