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A Comparative Study of Soil Stabilization Using Cement, Lime and Fly Ash

Amrita Shekhar[1], N. K. Saxena[2]

[1]M. Tech Student, Civil Engineering Department, KNIT, Sultanpur (U.P.) 228118 India

[2]Professor, Civil Engineering Department, KNIT, Sultanpur (U.P.) 228118 India

Abstract: ***Soil stabilization can be explained as the alteration of the soil properties by chemical or physical means in order to enhance the engineering properties of the soil. The main objectives of the soil stabilization are to increase the bearing capacity of the soil, its resistance to weathering process and soil permeability. The long-term performance of any construction project depends on the soundness of the underlying soils. Unstable soils can create significant problems for pavements or structures, Therefore, soil stabilization techniques are necessary to ensure the good stability of soil so that it can successfully sustain the load of the structure especially in case of soil which are highly active, also it saves a lot of time and lot of money when compared to the method of cutting out and replacing the unstable soil. This paper presents a study of Cement, Lime and Fly Ash as the admixture in improving the maximum dry density (MDD), optimum moisture content (OMC), California Bearing Ratio (CBR).***

1. Introduction

Soil stabilization is a very useful technique for road, airfield construction and other major civil engineering works. To utilize the full advantage of the technique, quality control must be adequate. Soil stabilization is the alteration of one or more soil properties, by mechanical or chemical means, to create an improved soil material possessing the desired engineering properties. Soils may be stabilized to increase strength and durability or to prevent erosion and dust generation. Regardless of the purpose for stabilization, the desired result is the creation of a soil material or soil system that will remain in place under the design use conditions for the design life of the project. Engineers are responsible for selecting or specifying the correct stabilizing method, technique, and quantity of material required. This study is aimed at helping to make the adequate decisions. Soils vary throughout the world, and the engineering properties of soils are equally variable.

A complete network of road system in developing countries like India is not easy due to limited finances available for the construction of the roads. The reduction of available land resources and the increased cost associated with the use of high quality materials have led to the need for local soils to be used in geotechnical construction. However, poor engineering properties of these soils pose difficulties for construction projects and need to be stabilised to improve their properties. The stabilisation of soil for use in subgrade for pavement is an economic substitute of costly paving materials. Improvement of certain desired properties like bearing capacity, shear strength (c and φ) and permeability characteristics of soil can be undertaken by a variety of ground improvement techniques such as the use of prefabricated vertical drains or soil stabilisation. Several additives, which may be utilized for ground modification such as cement, lime and mineral additives such as fly ash, silica fume and rice husk have been used under various contexts. On the other hand, extensive studies have been carried out on the stabilisation of soft soils using various additives mentioned above. There are many techniques for soil stabilisation, either mechanical or chemical, but all of them require skilled manpower and equipment to ensure adequate performance.

This paper is an attempt towards the study of Cement, Lime and Fly Ash as the admixture in improving the maximum dry density (MDD), optimum moisture content (OMC), California Bearing Ratio (CBR). The objective of this work is to estimate the effect of Cement, Lime and Fly Ash on some geotechnical properties of soil, in order to determine their suitability for use as a modifier in the treatment of soil for roadwork.

2. Experimental Investigation

A number of experiments have been conducted on virgin soil and soil mixed with additives viz., Cement, Lime and Fly Ash. The experiments have been carried out to determine various properties as mentioned below:

1) Specific Gravity
2) Sieve Analysis
   a) Mechanical Sieving
   b) Hydrometer Test
3) Atterberg's Limits (Liquid Limit, Plastic Limit and Plasticity Index
4) Proctor Compaction Test
5) California Bearing Ratio (CBR) Test

The additives viz. Cement, Lime and Fly Ash have added to the soil in ratios as 0%, 3%, 6%, 9%, 12% and 15% by weight.

2.1 Properties of Virgin Soil

Various tests have been conducted on virgin soil taken from Kunda, Pratapgarh, India, to determine different properties of soil. The properties of Virgin Soil are given in Table 1.

Table 1: Properties of Virgin Soil

S. No.	Property	Value
1	Specific Gravity	2.727
2	Grain Size Analysis	
	Gravel and Sand Size Particles	8.22

	Silt and Clay Size particles	91.78
3	Atterberg's Limits	
	Liquid Limit	15
	Plastic Limit	13.53
	Plasticity Index	1.47
4	Optimum Moisture Content	17.45%
5	Maximum Dry Density	1.678 g/cc
6	CBR	4.83

The CBR test is depicted in Fig. 1, 2 and 3.

Figure 1: Filling CBR mould at optimum moisture content

Figure 2: CBR mould kept under water for soaking of 4 days

Figure 3: Setting up dial gauges before testing

2.2 Sieve Analysis of Soil Mixed with Additives

2.2.1 Sieve Analysis of Soil Mixed with Cement

Sieve analysis has been carried out using Mechanical Sieving and Hydrometer Test for soil mixed with different percentages of additive i.e., Cement. The results are given in Table 2.

Table 2: Grain Size Analysis results for different percentages of Cement

S. No.	Percentage of Cement	Gravel & Sand Size Particle Content (%)	Silt & Clay Size Particle Content (%)
1		8.22	91.78
2	3	3.2	96.8
3	6	3.42	96.58
4	9	4.06	95.94
5	12	3.2	96.7
6	15	4.79	95.21

2.2.2 Sieve Analysis of Soil Mixed with Lime

Sieve analysis has been carried out using Mechanical Sieving and Hydrometer Test for soil mixed with different percentages of additive i.e., Cement. The results are given in Table 3.

Table 3: Grain Size Analysis results for different percentages of Lime

S. No.	Percentage of Lime	Gravel & Sand Size Particle Content (%)	Silt & Clay Size Particle Content (%)
1	0	8.22	91.78
2	3	10.18	89.82
3	6	11.89	88.11
4	9	7.98	92.02
5	12	6.33	93.67
6	15	7.91	92.09

2.2.3 Sieve Analysis of Soil Mixed with Fly Ash

Sieve analysis has been carried out using Mechanical Sieving and Hydrometer Test for soil mixed with different percentages of additive i.e., Cement. The results are given in Table 4.

Table 4: Grain Size Analysis results for different percentages of Fly Ash

S. No.	Percentage of Lime	Gravel & Sand Size Particle Content (%)	Silt & Clay Size Particle Content (%)
1	0	8.22	91.78
2	3	10.11	89.89
3	6	10.86	89.14
4	9	10.22	89.78
5	12	10.39	89.61
6	15	13.96	86.04

2.3 Standard Proctor Test on Soil Mixed with Additives

2.3.1 Standard Proctor Test on Soil Mixed with Cement

Standard Proctor Test has been performed on Soil mixed with varying percentages of Cement to determine the Optimum Moisture Content (OMC) and Maximum Dry Density (MDD). The values of OMC and MDD so determined are given in Table 5.

Table 5: Standard Proctor Test results for different percentages of Cement

S. No.	Percentage of Cement	OMC (%)	MDD (g/cc)
1	0	17.45	1.678
2	3	17.92	1.743
3	6	18.83	1.715
4	9	17.93	1.71
5	12	18.21	1.7
6	15	17.45	1.693

2.3.2 Standard Proctor Test on Soil Mixed with Lime

Standard Proctor Test has been performed on Soil mixed with varying percentages of Lime to determine the Optimum Moisture Content (OMC) and Maximum Dry Density (MDD). The values of OMC and MDD so determined are given in Table 6.

Table 6: Standard Proctor Test results for different percentages of Lime

S. No.	Percentage of Cement	OMC (%)	MDD (g/cc)
1	0	17.45	1.678
2	3	18.12	1.702
3	6	19.26	1.709
4	9	18.97	1.696
5	12	17.87	1.695
6	15	16.35	1.577

2.3.3 Standard Proctor Test on Soil Mixed with Fly Ash

Standard Proctor Test has been performed on Soil mixed with varying percentages of Fly Ash to determine the Optimum Moisture Content (OMC) and Maximum Dry Density (MDD). The values of OMC and MDD so determined are given in Table 7.

Table 7: Standard Proctor Test results for different percentages of Fly Ash

S. No.	Percentage of Cement	OMC (%)	MDD (g/cc)
1	0	17.45	1.678
2	3	17.63	1.701
3	6	17.89	1.736
4	9	16.68	1.715
5	12	16.29	1.687
6	15	16.02	1.675

2.4 California Bearing Ratio (CBR) Test on Soil Mixed with Additives

2.4.1 California Bearing Ratio (CBR) Test on Soil Mixed with Varying Percentages of Cement

CBR tests were performed on soil mixed with varying percentages of Cement. The results of CBR values and its variation with respect to percentage of Cement is shown in Fig. 4

Cement (%)	CBR value (%)
0	4.83
3	5.39
6	5.58
9	5.92
12	6.32
15	6.32

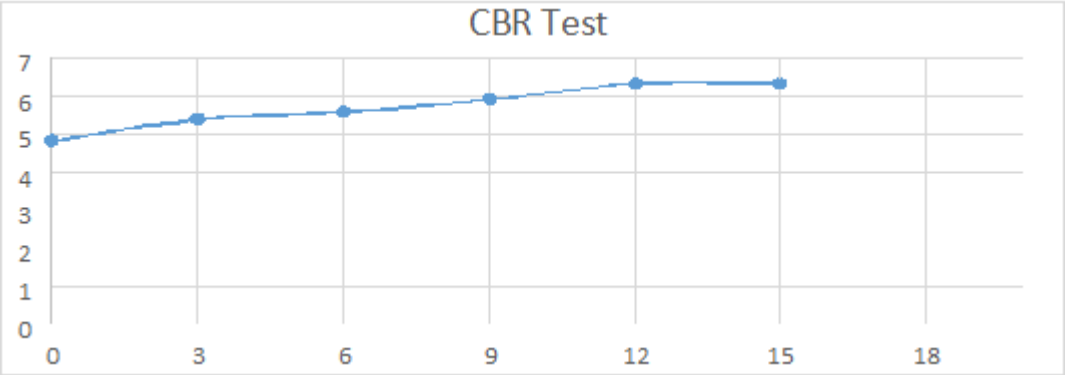

Figure 4: Comparison of CBR values of soil with different percentage of Cement

2.4.2 California Bearing Ratio (CBR) Test on Soil Mixed with Varying Percentages of Lime

CBR tests were performed on soil mixed with varying percentages of Lime. The results of CBR values and its variation with percentage of Lime is shown in Fig. 5.

Lime (%)	CBR value (%)
0	4.83
3	5.39
6	6.13
9	7.25
12	8.55
15	9.85

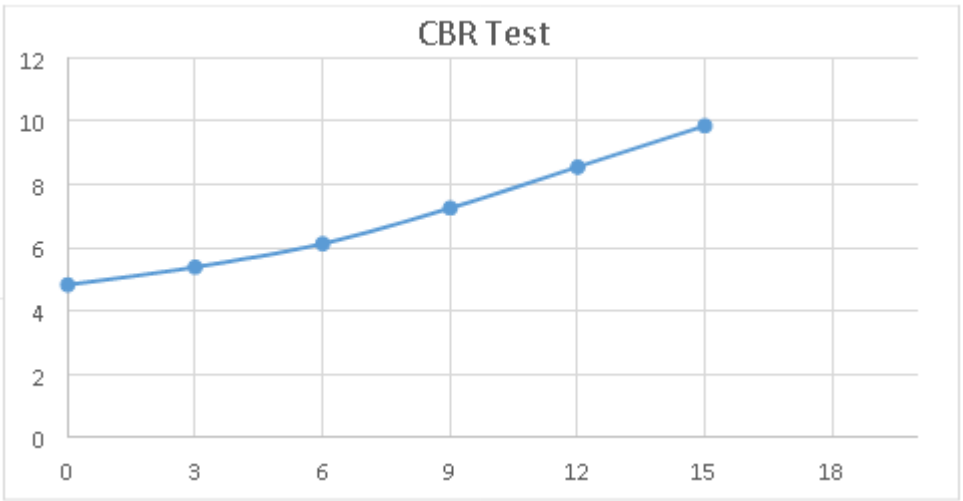

Figure 5: Comparison of CBR values of soil with different percentage of Lime

2.4.3 California Bearing Ratio (CBR) Test on Soil Mixed with Varying Percentages of Fly Ash

CBR tests were performed on soil mixed with varying percentages of Fly Ash. The results of CBR values and its variation with respect to percentage of Fly Ash is shown in Fig. 6.

Fly Ash (%)	*CBR value (%)*
0	4.83
3	5.2
6	5.33
9	5.45
12	5.58
15	5.95

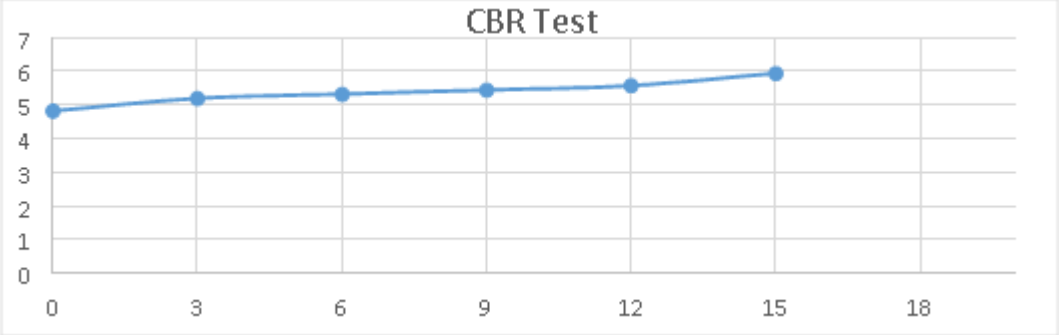

Figure 6: Comparison of CBR values of soil with different percentage of Fly Ash

The comparison of CBR values for Cement, Lime and Fly Ash is depicted in Fig. 7.

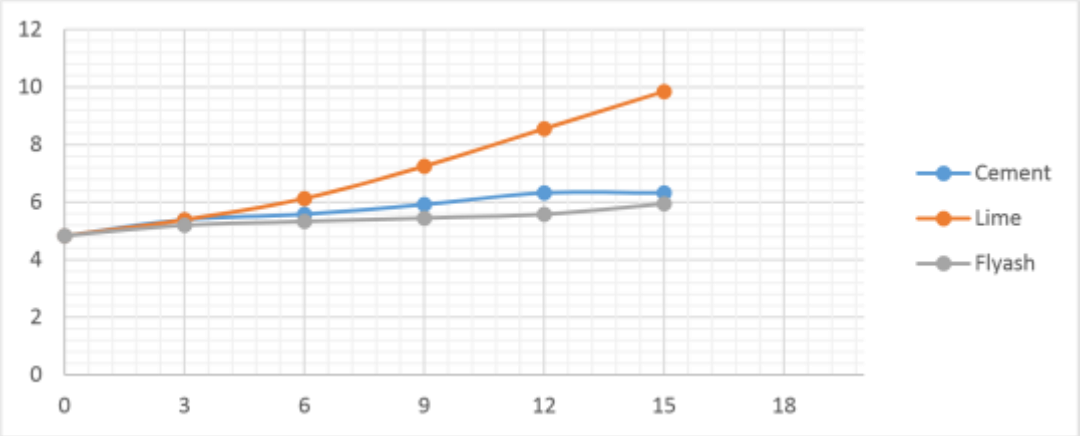

Figure 7: Comparison of CBR values of soil at different percentage of Additive

3. Conclusions

Based on the experimental data collected and analysed, for soil (ML in present case), replaced with cement, lime & fly ash in six different proportions (0-15%), the main conclusions may be drawn as given below:

1) For soil only:

a) The specific gravity of the soil used is 2.727 and has been classified as ML soil (Inorganic silts with none to low plasticity) with LL, PL, PI, OMC and MDD as 15, 13.53, 1.47, 17.47% and 1.678 g/cc respectively.
b) The CBR value obtained experimentally is 4.83.

2) Soil mixed with cement in different proportions

a) The optimum moisture content changes from 17.45% to 16.8% and shows increasing and then decreasing trend with increase in % addition of cement from 0% to 15% with a maximum value at 6%.
b) The dry density changes from 1.678 to 1.696 and shows an increasing and then decreasing trend with a maximum value at 3%.
c) The experimentally obtained CBR values shows a continuous increasing trend with maximum value as 6.32 for 15% addition of cement which is about 31% more compared with 0% addition of cement.

3) Soil Mixed with Lime in Different Proportions

a) The optimum moisture content changes from 17.45% to 16.35% and shows increasing and then decreasing trend with increase in % addition of lime from 0% to 15% with a maximum value at 6%.
b) The dry density changes from 1.678 to 1.577 and shows an increasing and then decreasing trend with a maximum value at 6%.
c) The experimentally obtained CBR values shows a continuous increasing trend with maximum value as 9.55 for 15% addition of lime which is about 98% more compared with 0% addition of lime.

4) Soil Mixed with Fly Ash in Different Proportions

a) The optimum moisture content changes from 17.45% to 15.8% and shows increasing and then decreasing trend with increase in % addition of fly ash from 0% to 15% with a maximum value at 3%.
b) The dry density changes from 1.678 to 1.675 and shows an increasing and then decreasing trend, almost a bell shaped curve with a maximum value at 6%.
c) The experimentally obtained CBR values shows a continuous increasing trend with maximum value as 5.95 for 15% addition of fly ash which is about 23% more compared with 0% addition of fly ash.

The final conclusion that may be drawn that the % increase in CBR value is about 98% for selected soil sample Soil+15%Lime i.e. soil sample stabilized with 15% addition of lime in comparison with raw soil sample. Further, other samples of cement and fly ash added to soil sample shown an increase of 31% and 23% respectively. This shows that the CBR value is higher for lime stabilized soil sample as compared to soil samples stabilized with cement and fly ash. While lime alone works well as a stabilizer, a combination of lime and fly ash is beneficial for low plasticity, higher silt content soil.

The fly ash provides the pozzolanic reactants, silica and alumina, lacking in such soils. Further, cost can be reduced by stabilizing the poor soil subgrade rather than removing and replacing it with granular material. Lime stabilization increases the subgrade structural strength and stiffness, asphalt and granular base layers can be reduced in thickness.

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