"Compaction Control & Related CBR Behavior of Silty Soil Reclamations with Moorum, Fly ash and Cement"

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Abstract: The challenges posed by silty soil in India have become increasingly apparent in recent years, affecting the stability and performance of various civil engineering structures. The expansive nature, low shear strength, and high compressibility of silty soils contribute to issues such as foundation failures, road pavement distress, and slope instability. This research endeavours to address the critical problem of silty soil in India by exploring innovative solutions for its stabilization. In this study, cement, moorum (a locally available granular material), and fly ash (a byproduct of coal combustion from thermal power plant) were added to silty soil in different proportions to improve its geotechnical properties. The experimental program involved conducting laboratory tests on various mixtures of silty soil, cement(2%,4%) , moorum (5%,10%), fly ash(5%,10%) and Combination of fly ash(5%,10%), Moorum (5%,10%) and Cement(2%,4%) . The tests included Liquid Limit tests, Plastic Limit tests, Heavy Compaction tests and California Bearing Ratio (CBR) tests. The aim was to investigate the effects of the soil-cement- moorum-fly ash mixtures on parameters such as maximum dry density, optimum moisture content, CBR values. The results of the experimental investigation revealed that the addition of cement, moorum, and fly ash significantly improved the engineering properties of silty soil. The maximum dry density increased, indicating better compaction characteristics, and also the optimum moisture content increased. The CBR values and compressive strength of the soil mixtures increased with increasing percentages of cement, moorum, and fly ash.

Keywords: CBR, Cement, Compaction, Fly Ash, Moorum, Silty soil

I. Introduction

Silty soil is a common soil type found in many regions around the world. It is characterized by its fine particle size and moderate plasticity. However, silty soil exhibits several geotechnical challenges due to its low strength, high compressibility, and susceptibility to erosion. These limitations can pose significant obstacles in construction projects, particularly when load-bearing capacity, stability, and durability are crucial factors. To address these challenges, researchers and engineers have been exploring various techniques to improve the engineering properties of silty soil. One promising approach is the incorporation of additives such as cement, moorum, and fly ash into the soil matrix. Cement is widely recognized for its ability to improve soil strength and stability through the process of soil stabilization. Moorum, a locally available granular material, offers potential benefits in terms of enhancing the soil's mechanical properties. Fly ash, a byproduct of coal combustion, has also been found to possess pozzolanic properties and can contribute to soil stabilization.

According to the literature (Amu et al. 2005) had used (Class- F) fly ash and cement for stabilization of Silty soil. It was found that stabilizing effect of 9% cement and 3% fly ash was better than the stabilizing effect 12% cement. (Cokca 2001;Nalbantoglu 2004;Mishra et al.2005) had studied effect of class- C fly ash on different engineering properties of expansive soil and had found varied success. (Sharma and Gupta 2013) had investigated the effect of fly ash(class-F) on sand stabilized black cotton soil based on compaction and CBR test the optimum proportion of soil: sand :fly ash was found to be 63:27:15. (Gopala Krishna et al. 2013) had studied the effect of fly ash (class-F) and zycosyl on soaked and unsoaked CBR of black cotton soil, the highest unsoaked CBR was obtained at 2% zycosyl with 3% fly ash and highest soaked CBR was obtained at 2% zycosyl with 4% fly ash. (Amadi and Lubem 2014) had investigated the effect of cement kiln dust (up to 16%) on10% quarry fine stabilized black cotton soil and had found reduction in IP, maximum dry density (MDD) and increase in optimum moisture content (OMC) and CBR.

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II. Details of The Experiment

This Section provides details of the experiments conducted. Section 2.1 notes the test conducted, and section 2.2 provides the details of materials used.

2.1Tests conducted

In this study, a total of eight experiments were conducted, wherein varying amounts of materials were considered for each experiment. They are following:

1. Soil with 5% Fly ash
2. Soil with 10% Fly ash
3. Soil with 5% Moorum
4. Soil with 10% Moorum
5. Soil with 2% Cement
6. Soil with 4% Cement
7. Soil with 2% Cement, 5% Fly ash, and 5% Moorum
8. Soil with 4% Cement, 10% Fly ash, and 10% Moorum.

Specifically, the following tests were conducted for this study:

- Grain Size Analysis: This test is carried out as per IS: 2720 (Part 4) – 1985.
- Atterberg Limits: Liquid Limit & Plastic Limit test is carried out as per IS: 2720-(Part 5) & Shrinkage Limit test is Carried out as per Indian Standard IS: 2720 (Part 6) – 1972.
- Standard Proctor Test : This test is carried out as per IS-2720-PART-7
- California Bearing Ratio test (Soaked): This test is carried out as per IS: 2720- 16.

2.2Materials used

2.2.1 Silty Soil

Silty soil is a common soil type found in many regions around the world. It is characterized by its fine particle size and moderate plasticity. Soil is excavated from a depth of 2.0 m from the Check Dam situated near Rani Durgawati Samadhi , Barela, Jabalpur M.P.

Table 1:- Properties of Silty Soil

Property	**Value**
Colour	Greyish Black
Liquid Limit	38.9
Plastic Limit	26.09
Plasticity Index	12.81
OMC (%)	13.77%
MDD (g/cm3)	1.53
CBR	2.88
Soil Classification	ML

2.2.2 Moorum

Moorum was mixed with Silty soil. Locally available moorum from the surrounding area of Jabalpur was collected and was used for this investigation. Moorum collected from this region is found to have good geotechnical properties.

2.2.3 Fly ash

Fly ash was mixed with Silty Soil. It was collected from the Koradi Power Plant, Nagpur, India. Table 2 shows typical characteristics of fly ash found in this region.

Table 2:- Properties of fly ash in Nagpur region

Property	**Value**
Colour	Grey
Specific gravity	1.90–2.55
Plasticity	Non-plastic
OMC (%)	38–18
MDD (g/cm3)	0.9–1.6
Cohesion (kN/m2)	Negligible
Angle of internal friction	30μ–40μ
Compression index (cc)	0.05–0.4
Permeability (cm/s)	8 x 10^{6} – 7 x 10^{4}
Coefficient of uniformity	3.1–10.7

Note: Source: Mehta et al. (2013).

2.2.4 Cement

Silty soil underwent a blending process with Portland cement, a pivotal step in soil stabilization. The acquisition of Portland cement was facilitated through a local supplier, underscoring the practical approach to sourcing materials for this geotechnical application.

III. Experimental Work

3.1 Preparation of Soil Samples

Different samples were prepared with the mixture of Silty soil with addition of Fly ash, Moorum and Cement. In order to maintain homogeneous mix, proper care was taken while the mixing of sample. The Grain size analysis, OMC, MDD and CBR value of different samples containing different percentage of Fly ash, Moorum and Cement was carried out.

3.2 Index properties

Indian Standard 2720 (Part V) to ascertain the liquid limit (LL) and plastic limit (PL) of silty soil combined with fly ash, moorum, and cement across diverse proportions. The assessment, crucial for evaluating the plasticity characteristics of fine-grained soils like clays, involved calculating the Plastic Limit (PL) as the difference between LL and PL, indicating the soil's plastic behaviour range. Shrinkage Limit (SL) was determined according to Indian Standard IS: 2720 (Part 6) – 1972, involving the preparation of a specific soil mixture, forming a shrinkage pat and using mercury displacement. The concise presentation of the test results, conducted on specimens with varied ratios of fly ash, moorum, and cement, is tabulated in Table 3.

Table 3:- Liquid limit, Plastic Limit, Shrinkage Limit and Plasticity index of various design mix

Type of Design mix	LL	PL	IP	SL
Virgin Soil	39.00	23.50	15.50	19.78
95% Soil + 5%Fly ash	37.50	24.00	13.50	19.23
90% Soil + 10% Fly ash	36.50	24.50	12.00	18.78
95% Soil + 5% Moorum	38.50	25.00	13.50	19.46
90% Soil + 10% Moorum	37.00	25.50	11.50	18.91
98% Soil + 2% Cement	38.50	25.50	13.00	18.88
96% Soil + 4% Cement	38.00	26.00	12.00	18.33
88% Soil + 5%Fly ash + 5%Moorum + 2%Cement	36.00	26.50	9.50	18.43
76%Soil + 10%Fly ash + 10% Moorum + 4% Cement	35.50	27.00	8.50	18.05

3.3 Grain Size Analysis

Silty soil blended with Fly Ash, Moorum, and Cement underwent standard testing for liquid limit and plastic limit according to Indian Standard 2720 (Part IV). Grain size analysis is a fundamental test in geotechnical engineering to determine the distribution of particle sizes in a soil sample. For silty soil, which contains a significant portion of fine particles, the analysis provides valuable information about its engineering properties.

Table 4:- Grain size Analysis of various design mix

Type of Design mix	% Gravel	% Sand	% Silt + Clay
Virgin Soil	0.23	10.24	89.53
95% Soil + 5%Fly ash	0.21	10.04	89.75
90% Soil + 10% Fly ash	0.20	9.97	89.83
95% Soil + 5% Moorum	0.94	13.22	13.50
90% Soil + 10% Moorum	1.75	15.38	82.87
98% Soil + 2% Cement	0.19	10.14	89.67
96% Soil + 4% Cement	0.22	9.85	89.93
88% Soil + 5%Fly ash + 5%Moorum + 2%Cement	0.25	11.95	87.80
76% Soil + 10%Fly ash + 10%Moorum + 4%Cement	.99	12.92	86.09

3.4 Maximum dry density (MDD) and Optimum Moisture content (OMC)

Following Indian Standard 2720 (Part VII) (ISI, 1974) specifications, the Light Compaction Test was executed to establish Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) for soil samples. These samples, derived from air-dried soil, were methodically blended with diverse proportions of fly ash, moorum, cement, and a triadic combination of these additives.

Table 5:- OMC and MDD of Various mix

Types of Design mix	OMC	MDD
Virgin Soil	13.77%	1.54
95% Soil + 5%Fly ash	14.17%	1.52
90% Soil + 10% Fly ash	14.70%	1.49
95% Soil + 5% Moorum	13.09%	1.64
90% Soil + 10% Moorum	12.70%	1.67
98% Soil + 2% Cement	14.07%	1.66
96% Soil + 4% Cement	14.74%	1.70
88% Soil + 5%Fly ash + 5%Moorum + 2%Cement	15.54%	1.73
76%Soil + 10%Fly ash + 10%Moorum + 4% Cement	16.31%	1.75

3.5 California bearing ratio test

California bearing ratio test (soaked 4 days). The CBR test was conducted as per specifications of Indian Standard 2720 (Part XVI) (ISI, 1987). CBR is a crucial geotechnical test used to evaluate the strength and load-bearing capacity of subgrade soils and base course materials. The ratio is usually determined for penetration of 5 mm. CBR values for various mixes was calculated and shown in Table 6.

Table 6:- CBR values of various mix

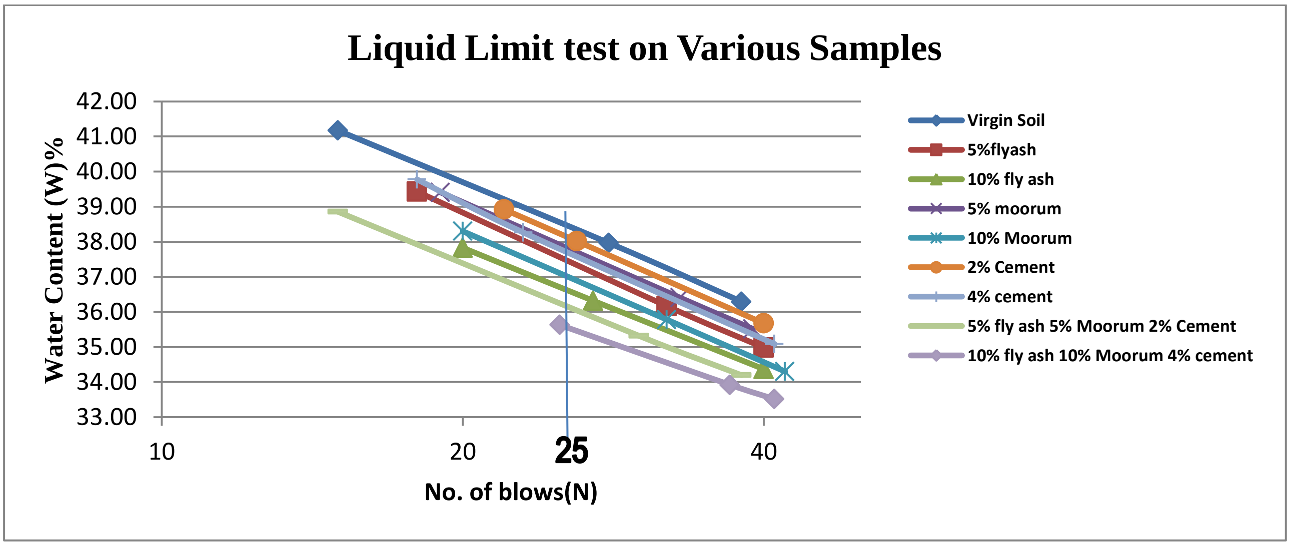
Types of Design mix	CBR
Virgin Soil	2.88
95% Soil + 5%Fly ash	3.67
90% Soil + 10% Fly ash	5.16
95% Soil + 5% Moorum	3.38
90% Soil + 10% Moorum	3.77
98% Soil + 2% Cement	5.16
96% Soil + 4% Cement	7.65
88% Soil + 5%Fly ash + 5%Moorum + 2%Cement	9.43
76%Soil + 10%Fly ash + 10%Moorum + 4% Cement	14.10

IV. Result And Discussions

4.1 Index properties

Adding fly ash to soil reduced liquid limit, increased plastic limit, and decreased plasticity index (PI) across different percentage mixes (Table 3). Similar effects were observed when moorum or cement were added, with a decrease in liquid limit, an increase in plastic limit, and a decrease in PI. The combined addition of fly ash, moorum, and cement significantly decreased liquid limit and increased plastic limit, leading to a substantial reduction in PI. Figure 1 illustrates the comparisons of liquid limit with moisture content for various mixes.

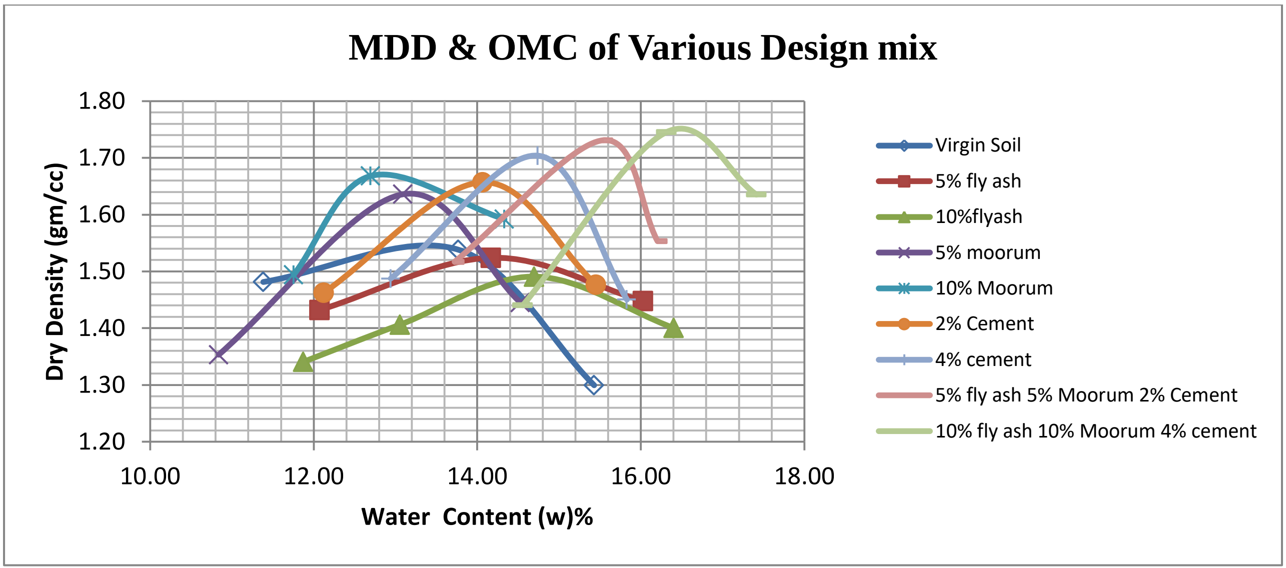
Figures 1 Comparison of Liquid Limit of various mixes



4.2 Compaction test

Analysis of Table 4 and Figure 2 reveals a noteworthy correlation: an augmentation in fly ash content within the soil sample leads to an increase in the Optimum Moisture Content (OMC) of the specimen, accompanied by a decrease in the Maximum Dry Density (MDD) of the soil. This phenomenon is attributed to the lower Specific Gravity of fly ash and its finer particle nature compared to the soil sample. Conversely, an increase in Moorum content results in an elevated MDD and a reduced OMC of the specimen. This effect is likely influenced by the inherent characteristics of Moorum. Furthermore, an escalation in Cement content is associated with an increase in both OMC and MDD. This pattern suggests that the addition of cement contributes to higher moisture content and density in the specimen. Remarkably, the combination of fly ash, Moorum, and cement content exhibits a significant increase in both OMC and MDD of the specimen. This implies a synergistic effect of the combined materials on the moisture and density characteristics of the soil, as illustrated in Table 5 and Figure 2.

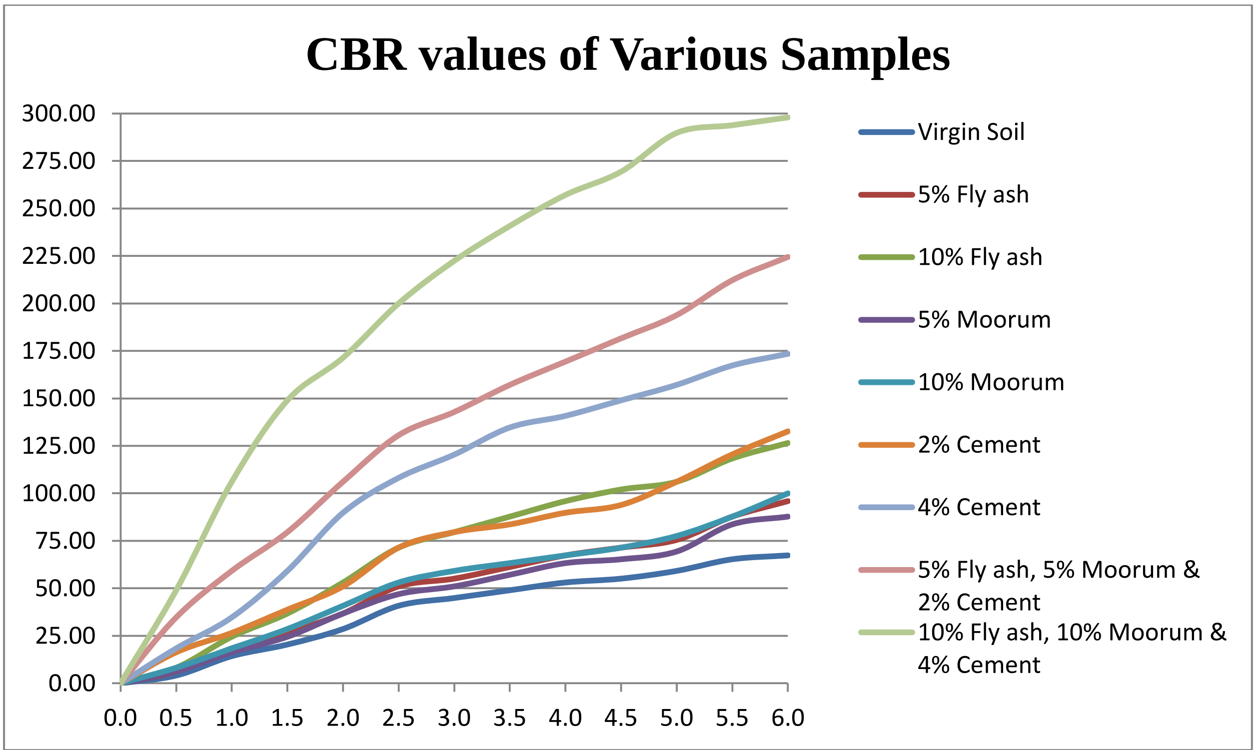
Figure 2 OMC and MDD of various mixes



4.3 California Bearing Ratio test

It is observed by Table 6 and Figure 3 that the CBR value is increasing for all the various mixes but combination of Fly ash, Moorum and Cement, the value of CBR is considerably increased in comparison of other. CBR Graph is shown as follows:-

Figure 3 CBR Values of Various mixes



V. Conclusion

The experimental investigation of silty soil mixed with moorum, fly ash, and cement demonstrates the potential for significant improvement in the geotechnical properties of the soil. The addition of these stabilizing agents enhances the compaction characteristics and improves the load-bearing capacity of the soil. These findings suggest that the stabilized soil mixtures can be effectively utilized in various geotechnical applications, such as road embankments, foundation construction, and slope stabilization, to overcome the challenges associated with silty soils.

1. An increase in fly ash content correlates with a rise in the Optimum Moisture Content (OMC) of the soil specimen. Simultaneously, there is a notable decrease in the Maximum Dry Density (MDD) of the soil, attributed to the finer particle nature and lower Specific Gravity of fly ash compared to the soil sample.

2. The augmentation in Moorum content results in an elevated MDD and a reduction in OMC for the soil specimen.This effect is likely influenced by the inherent characteristics of Moorum, showcasing its distinct impact on soil density and moisture content.

3. An escalation in cement content is associated with an increase in both OMC and MDD of the specimen. This pattern suggests that the addition of cement contributes to higher moisture content and density in the soil sample.

4. The combination of fly ash, Moorum, and cement content exhibits a remarkable increase in both OMC and MDD of the soil specimen.

5. Across different mixes, there is a consistent increase in the CBR values, indicating an overall enhancement in the load-bearing capacity of the soil.

6. The considerable increase in CBR for the combination mix suggests a synergistic effect of Fly Ash, Moorum, and Cement, indicating that their combined influence significantly enhances the soil's ability to withstand applied loads.

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