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Laboratory Evaluation of Stabilising Components for Effective Treatment of Expansive Soil

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Abstract: The experimental study is to understand the mix ratio of fly ash and GGBS (ground granulated blast-furnace slag) in improving the shrink-swell characteristic of soil. The strength of the soil improved considerably after the addition of these stabilisers. In this study, experiments were conducted to observe the influence of the soil stabilisers in the improvement of the strength of the subgrade in expansive soil regions. This influential study will reveal the percentage of Flyash and GGBS mixture. Then the Standard Proctor Compaction test is used to determine the optimum moisture content required to compact the soil with Flyash and GGBS to attain the maximum dry density. The soil's California Bearing ratio (CBR) was computed to understand the behaviour of improved soil if used as a subgrade. Hence the existing soil can be used as a subgrade with effective treatment of soil.

Key words: Expansive soil, GGBS, fly ash, CBR, compaction, swelling behaviour.

Introduction

Clayey soils are most problematic compared to sandy or gravelly soils. Settlement of buildings due to uneven compression of soil below the foundation is one of the causes of cracks in buildings. The problem gets worsen if the clayey soil expands or shrinks due to a change in moisture content. Expansive soils got this name because of their volume change behaviour when the water content varies. Expansive soils contain clayey minerals like montmorillonite, whose volume changes with wetting and drying. The minerals present in soil expand when it reacts with water and thereby increase the soil volume. This change in volume below lightweight structures like single-story buildings, platforms, shoulders, roads, and pipelines, causes stress leading to damage (Aishwarya et al., 2014a, 2014b; Ammireddy et al., 2018; Dayalan, 2016). Clayey soil with higher cation exchange properties, when confronted with water molecules, leads to the expansion of soil layers. Expansive soils are found extensively in southern parts of Peninsular India.

Due to their comparatively low cost, industrial by-product materials like fly ash, blast furnace slag, cement kiln dust, and limestone dust are becoming more and more popular as additives. The ability of the stabiliser to give an adequate amount of calcium is its most crucial component in the stabilisation of clayey soils (Aishwarya et al., 2010b, 2010a; Raja et al., 2020; Rao et al., 2011). Due to their siliceous and calcareous nature, industrial wastes like fly ash and ground granulated blast furnace slag (GGBS) can be employed as stabilising agents. While lime has a comparatively high calcium oxide level, fly ash has a low calcium oxide content but is rich in silica and alumina (Gokul et al., 2020; Mujtaba et al., 2018; Neeladharan et al., 2019; Venkatesan et al., 2020, 2018, 2023b, 2023c, 2023d, 2022a). The two components

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may be more advantageous when used together as a stabilising agent (Karunanithi et al., 2021; Sharma et al., 2016; Shivakumar et al., 2014; Venkatesan et al., 2015, 2022b).

Each can deliver enough lime or silica to enable a pozzolanic reaction, requiring fewer chemical activators as a result. Few researchers have investigated the use of fly ash mixes in blended cement and concretes. For the majority of expansive clays, researchers found that the safe expansion percentage is equal to or less than 10% (Jones et al., 2012; McCarthy et al., 2014; Gobinath et al., 2020; Venkatesan et al., 2014, 2019). Dayalan (2016) studied the different amounts of fly ash and GGBS mixed separately, i.e., 5%, 10%, 15%, and 20% by dry weight of soil and conducted various physical and strength performance tests like specific gravity, Atterberg limits, standard proctor test, and CBR tests. From the results, it was found that the optimum value of fly ash is 15% and GGBS is 20% for stabilisation of given soil based on CBR value,

Ammireddy et al. (2018) studied the stabilisation of the expansive soil by using fly ash and GGBS. Laboratory experiments like compaction CBR and UCS tests were conducted by varying percentages of 0%, 2.5%, 5%, and 7.5% of GGBS, and 2.5%, 5%, and 7.5% Fly ash were blended into the expansive soil (Mujtaba et al., 2018; Venkatesan et al., 2012, 2016b, 2016a, 2023a). From this experimental study, the strength parameters have been increasing by increasing the GGBS to 5% and flyash to 5%, respectively.

The present study investigates the influence of fly ash and GGBS in the stabilisation of problematic soils, mainly expensive soils.

Site Selection for the Study

In the present study, clay soil samples have been taken from a site in Poonamalle, located on the outskirts of Chennai, Tamil Nadu, India. The soil samples have been taken from a depth of 1 m to 2 m below the soil surface. The site location is shown in Figure 1 as a yellow-coloured pointer.

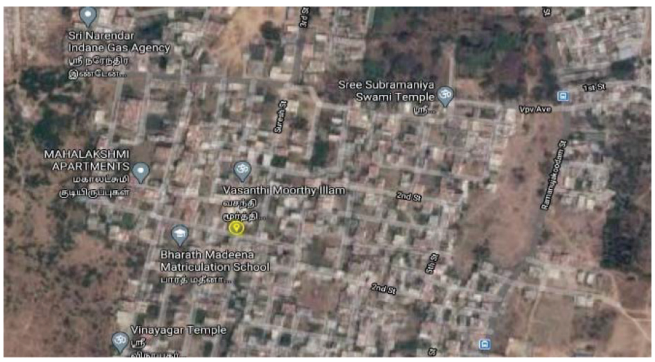

Figure 1: Site location: Poonamalle, Chennai, India.

Subgrade

The subgrade is the soil layer underneath the roads or railway tracks. It possesses the following basic characteristics: stiffness, bearing capacity of the soil, adequate moisture content to compact soil, etc.

Methodology

In this study, we will present the experimental results (i) to study the properties of GGBS & FLY ASH, (ii) to determine strength properties and (iii) to determine the influence of various percentages of GGBS and fly ash towards California-bearing ratio of soil. The detailed methodology flowchart is represented in Figure 2. The soil samples were collected at an excavated pit of depth 2 m, from the site location in Poonamalle, Chennai. The additives namely, GGBS and fly ash were also collected. The index properties were determined for the original soil sample and soil with different proportions of GGBS and fly ash. The compaction requirement for the natural soil and stabilised soil is obtained based on the Compaction test. CBR was determined to evaluate the improvement of soil strength, which can be a subgrade if treated using the same combination of stabilising agents.

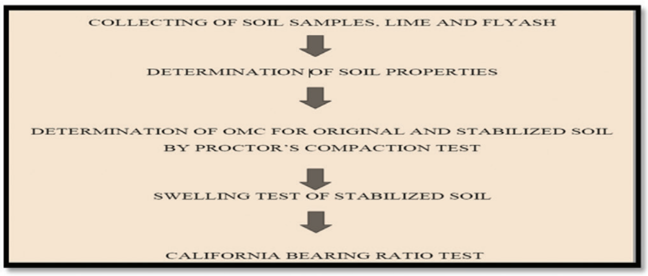

Figure 2: Methodology flow chart.

Results and Discussions

Test Result of Atterberg's Limits

The consistency limit tests namely Casagrande's test and rolling thread test were conducted with natural soil and stabilised soil. The soil was stabilised with nine combinations of three percentages of flyash (10, 15, and 20) and three percentages of GGBS (5, 7.5, and 10). Consistency indices such as the Plasticity index were computed to evaluate the effect of stabilisation on the index properties of soil. The same is tabulated in Table 1. Figure 3 shows the variation of liquid limit for the different combinations of GGBS and fly ash. The test

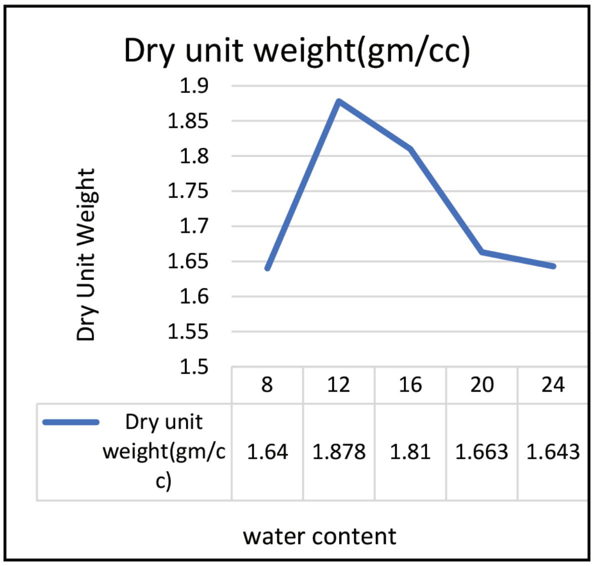

Figure 3: Experimental observation for the combination of GGBS and fly ash.

Table 1: Plasticity index sample on replacement of fly ash and GGBS

% of fly ash	*% of GGBS*	*Liquid limit*	*Plastic limit*	*Shrinkage limit*
10%	5%	42	40	32
	7.5%	55	36	26
	10%	48	33	22
15%	5%	41	25	15
	7.5%	30	23	12
	10%	29	22	11
20%	5%	49	31	20
	7.5%	40	30	20
	10%	38	29	18

result shows the Atterberg limits reduced for 15% fly ash and 10% GGBS.

Standard Proctor Compaction Test

Compaction brings the soil particles closer, thereby increasing the soil's relative density. The OMC required for compacting the soil such that the maximum dry density is achieved, is obtained by conducting Proctor Compaction Test. The observed values are given in Table 2 and the graph is plotted as shown in Figure 4.

Weight of cylindrical mould with base plate = 3571 g

California Bearing Ratio Test

The CBR (California Bearing Ratio) test was done in the laboratory to evaluate the suitability of the stabilised expansive soil. Based on IS 2720-16, CBR

Table 2: Observation of standard proctor test

Percentage of water added	*Weight of cylindrical (Mould+Soil+Base) plate (g)*	*Weight of Soil (g)*	*Wet unit weight (g/cc)*
8	5493	1922	1.96
12	5769	2198	2.24
16	5693	2122	2.16
20	5519	1948	1.91
24	5496	1925	1.96

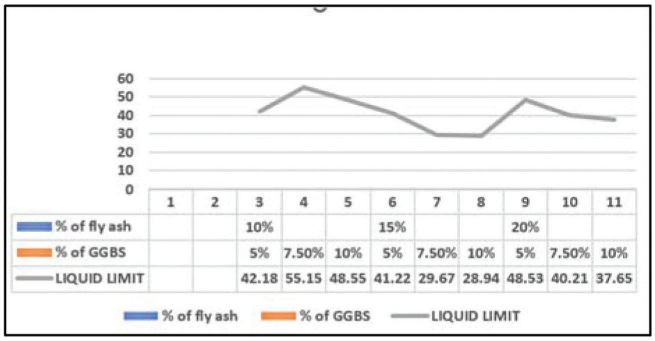

Figure 4: Determination of OMC - standard proctor compaction test.

tests were done in the laboratory. The load was recorded to correspond to the penetration of 2.5, 5, 7.5, 10 and 12.5 mm.

This test was carried out for the three percentages of fly ash and three percentages of GGBS that showed fewer shrinkage characteristics. The CBR value for 15% fly ash and 10% GGBS is shown in Table 3. CBR value for replacing 15% Fly ash & 10% GGBS, are plotted in Figure 5.

Table 3: Observation of CBR

S. No	*Penetration (mm)*	*Standard pressure* (kg/cm^2)	*Pressure on the soil before stabilisation* (kg/cm^2)	*Pressure on stabilised soil* (kg/cm^2)
1	2.5	70	1.68	2.87
2	5	105	2.51	4.3
3	7.5	134	3.22	5.49
4	10	162	3.88	6.64
5	12.5	183	4.4	7.5

The tests indicate the improvement in the strength of expansive soil and are hence suitable for subgrade if the recommended quantity of fly ash and GGBS are added to expansive soil. Standard Proctor test and CBR

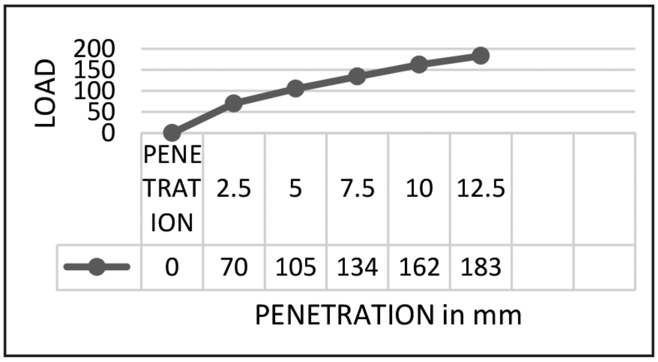

Figure 5: Plot of CBR test for 10% of flyash and 15% GGBS.

test were carried out for nine different combinations of fly ash percentages (10%, 15%, 20%) and GGBS percentages (5%, 7.5%, 10%). The optimum moisture content to achieve maximum dry density during the compaction of subgrade was obtained from the Proctor compaction test, which is 12%. The soil sample for the CBR test was compacted with obtained optimum moisture content.

Conclusions

This study evaluates the effect or impact of stabilising agents like fly ash and GGBS on expansive soil. A comparison of various properties of soil with the stabilised soil has been studied. As inferred from the test results, the addition of stabilising agents has decreased optimum moisture content. Reduction in OMC saves water quantity to be added and hence environment friendly and cost-effective. The addition of stabilising agents in combination with fly ash 15% and GGBS 10% has resulted in the improvement of the soil's compressible properties, that is the soil which was classified as CH (highly compressible clay) got modified to CI (low compressible plastic soil) according to IS 1498-1970. This combination of stabilising agents has improved the CBR value and hence is recommended for further studies.

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