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Comparative Study on Stabilized Black Cotton Soil

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Abstract: Every Structure rests on soil! So, the properties of soil extraordinarily influence the dependability of the structure laid on it. In India, a large portion of land is of clayey nature & among this, expansion soil is of great proportion. Black Cotton Soil (Expansion soils) have got the property of swelling and shrinkage when exposed to variation in climatic conditions. This mercurial behavior is mainly due the presence of clay mineral montmorillonite. In spite of the fact that having extraordinary agricultural worth, these soils are posing serious threat to the structures founded on it due to the swelling and shrinking behavior. So, to overcome the problem of swelling and shrinking vast number of studies have been carried out from the past decades so as to enhance the properties of Black Cotton Soils. From the experimental experience and data analysis, Soil Stabilization was way out for this problem. Soil Stabilization technique has proven a best method for enhancing the properties of Black Cotton Soil. In this study, the Black Cotton Soil is stabilized by lime, fly ash, GGBS (ground granulated blast furnace) at different percentages & a comparative study is carried out to study the properties of Stabilized Black Cotton Soil with the properties of simple Black Cotton Soil obtained from the site. Also, studies were carried out to find the best stabilizing agent among the one used during this study.

Keywords: Black Cotton Soil (BCS), Fly-Ash, GGBS, Lime, Liquid Limit, Plastic Limit, Shrinkage, Stabilisation, Swelling, Unconfined compressive strength.

1. Introduction

From last decades, utilization of land has increased due to increase in population, Industries, factories etc. This has led to decrease in available land and hence results in increase in demand of land on which construction has to be carried out. Now, due to increase in demand of land, constructors have started laying foundation on soft or weak soils. Soft soil deposits with low bearing capacity, large settlement, Swell & shrink behaviour, etc are posing serious threat to the structures laid on these soils. One of the important problems Geotechnical Engineers are often to deal with is the reliable assessment behaviour of soft soils. So, to improve the mechanical behaviour of these soils different ground improvement techniques were employed which include soil stabilisation and soil reinforcement **[1]**. After vast research work and studies, Engineers find the way out for all the problems which they were facing while dealing with soft soils and it was the "Soil Stabilisation" technique. Soil Stabilisation is the technique of improving the engineering properties of soil by varying its properties in such a way that it can be used in various engineering works and it behaves quit satisfactorily **[2].** In other words, Soil Stabilisation is the method of enhancing the engineering properties of soil by addition of external material **[1]**. Soil stabilization is a way of improving the, weight bearing capabilities and performance of in-situ sub-soils, sands, and other waste materials. Soil stabilization aims at improving soil strength and increasing resistance to softening by water through bonding the soil particles together. Usually, the technology provides an alternative provision structural solution to a practical problem. The simplest stabilization processes are compaction and drainage (if water drains out of wet soil it becomes stronger). The other process is by improving gradation of particle size and further the improvement can be achieved by adding binders to the weak soils. Soil stabilization can be accomplished by several methods All these methods fall into two broad categories namely Mechanical Stabilization & Chemical Stabilization. In Mechanical Stabilization, soil stabilization can be achieved through physical Process by altering the physical nature of native soil particles by either induced Vibration or compaction or by incorporating other physical properties such as Barriers and nailing. Mechanical stabilization is not the main subject of this review and will not be further discussed & In Chemical Stabilization, soil stabilization depends mainly on chemical reactions between stabilizer (cementitious material) and soil minerals (Pozzolanic materials) to achieve the desired effect. A chemical stabilization method is the fundamental of this review and, therefore, throughout the rest of this report, the term soil stabilization will mean chemical stabilization. Through soil stabilization, unbound materials can be stabilized with cementitious materials (cement, lime, fly ash, bitumen or combination of these). The stabilized soil materials have a higher strength, lower permeability and lower compressibility than the native soil. The method can be achieved in two ways, namely; in-situ stabilization and ex-situ stabilization. Black Cotton Soil, which is considered boon to the agricultural economy is made up of volcanic rocks and lava. These types of soil are famous for cotton cultivation. These soils are rich in Calcium Carbonate, Potash, Lime, and Magnesium Carbonate but poor in

Phosphorous content. These are found in Gujarat, Madhya Pradesh, Tamil Nadu, Maharashtra, Andhra Pradesh, and Karnataka. Swell and Shrink behaviour of black cotton soils can be reduced considerably by replacing expansive soil (black cotton soil) with non-expansive material. Various studies have tried stabilising Black Cotton Soil by using Lime, Cement, Fly-Ash, and Rice Husk etc**[3][4][5][6][7]**. In our study we added Lime (8% & 10%), fly-ash (8% & 10%) and GGBS (8% & 10%) separately with the Black Cotton Soil and investigated the properties of both simple Black Cotton Soil & Stabilized Black Cotton Soil and results were analysed and interpreted properly.

2. Stabilising agents

2.1 Lime

Lime provides an economical way of soil stabilization. Lime modification describes an increase in strength brought by cat ion exchange capacity rather than cementing effect brought by pozzolanic reaction. In soil modification, as clay particles flocculates, transforms natural plate like clays particles into needle like interlocking metalline structures. Clay soils turn drier and less susceptible to water content changes. Lime stabilization may refer to pozzolanic reaction in which pozzolanic materials reacts with lime in presence of water to produce cementitious compounds. The effect can be brought by either quicklime, CaO or hydrated lime, $Ca(OH)_2$. Slurry lime also can be used in dry soils conditions where water may be required to achieve effective compaction. Quick lime is the most commonly used lime; the followings are the advantages of quick lime over hydrated lime. (a) Higher available free lime content per unit mass. (b) Denser than hydrated lime (less storage space is required) and less dust. (c) Generates heat which accelerate strength gain and large reduction in moisture content.

2.2 Fly Ash

Fly ash is a by-product of coal fired electric power generation facilities; it has little cementitious properties compared to lime and cement. Most of the fly ashes belong to secondary binders; these binders cannot produce the desired effect on their own. However, in the presence of a small amount of activator, it can react chemically to form cementitious compound that contributes to improved strength of soft soil. Fly ashes are readily available, cheaper and environmentally friendly. There are two main classes of fly ashes; class C and class F. Class C fly ashes are produced from burning sub bituminous coal; it has high cementing properties because of high content of free CaO. Class C from lignite has the highest CaO (above30%) resulting in self-cementing characteristics (FM5-410).Class F fly ashes are produced by burning anthracite and bituminous coal ; it has low self-cementing properties due to limited amount of free CaO available for flocculation of clay minerals and thus require addition of activators such as lime or cement. The reduction of swell potential achieved in fly ashes treated soil relates to mechanical bonding rather than ionic exchange with clay minerals. However, soil Fly Ash stabilization has the following limitations: (a) Soil to be stabilized shall have less moisture content; therefore, dewatering maybe required. (b) Soil-Fly Ash mixture cured below zero and then soaked in water are highly susceptible to slaking and strength loss. (c) Sulphur contents can form expansive minerals in soil Fly Ash mixture, which reduces the long-term strength and durability.

2.3 GGBS (ground granulated blast furnace)

These are the by-product in pig iron production. The chemical compositions are similar to that of cement. It is however, not cementitious compound by itself, but it possesses latent hydraulic properties which upon addition of lime or alkaline material hydraulic properties can developed.

3. Materials

Black Cotton Soil (BCS) is one of those expansive soils which is wide spread and poses great difficulty in the construction industry usually with a little contribution of water, thus it is necessary to stabilize the soil with suitable materials, and therefore BCS is used asa primary material. Lime, Fly Ash, GGBS (Ground Granulated Blast Furnace Slag) were used as stabilising Agents. All these materials were locally and regionally available. However, the stabilizing agents were used in different percentages to ensure proper stabilization

4. Experimental Work

For determination of the properties of Black Cotton Soil & Stabilised Black Cotton Soil different tests were carried out. Three samples were prepared for each test and results were recorded properly and analysed. Following tests were carried out during the study.

4.1 Determination of water content

Soil contains some finite amount of water called Soil moisture content. This water lies within and outside of soil aggregates. Generally, Soil pore spaces are either filled with air or water. If all the pores are filled with water, the soil is called saturated and if all the pores are filled with air, then the soil is said to be dry. Compaction of soil greatly depends upon the water content of the soil and the compactive effort is directly proportional to the water content of the soil within the saturation limit. The samples were prepared and tested for water content as per standard procedure **[8]**

4.2 Determination of Atterberg Limits

Liquid limit, Plastic limit & Shrinkage limit are included in Atterberg Limits. It helps us to determine the engineering properties of soil. Liquid and Plastic limit tests was conducted as per standard procedure **[9]**

4.3 Determination of OMC & MDD

Compaction is one of the cheap methods of soil stabilisation. It improves the property of soil so that the required shear strength is achieved. It is method of improving strength of soil by reducing the air voids. It depends on soil material, energy application & its amount. Samples were prepared and test was conducted as per standard procedure **[10]**

4.4 Determination of Soil Parameters by UCT

It is a quick test for determining the strength of cohesive soil for stability of slopes etc. It is one of the basic tests conducted to determine the compressive strength of the soil specimen. However, the results obtained by this test will lead to understand other parameters and properties of soil like standard penetration resistance, sensitivity etc., thus the value of compressive strength becomes utmost importance. In this test rate of loading is fast but drainage is very slow. Samples were prepared and test was conducted as per standard procedure **[11]**

5. Results & Discussion

In this study above mentioned tests were first carried out for the Black Cotton Soil to determine its properties & also, these tests were carried out for Black Cotton Soil containing 8% Lime, 10% Lime, 8% Fly Ash, 10% Fly Ash, 8% GGBS & 10% GGBS. These tests were conducted mainly to identify the effect on soil parameters with addition of different stabilizing agents. The test results were recorded properly and are discussed one by one in following section

5.1 Water Content

Experiment	BC Soil	BC Soil with 8% Lime	BC Soil with 10% Lime	BC Soil with 8% Fly-Ash	BC Soil with 10% Fly-Ash	BC Soil with 8% GGBS	BC Soil with 10% GGBS
Water content	6.62%	3.80%	7.7%	6.72%	5.50%	12.67%.	5.22%

Table 5.1: Determination of Water Content for various agent proportions

Moisture content test was conducted by using oven drying method, three samples were taken for every trial and the average result is considered for calculation. The results of moisture content shows an increasing trend with increase in percentage of lime but in case of Fly-Ash & GGBS a decreasing trend was observed with increase in percentage of Fly-Ash & GGBS. The results also showed that at 8% GGBS Black Cotton Soil has highest moisture content & at 8% Lime Black Cotton Soil has least moisture content.

5.2 Liquid Limit

Table 5.2: Determination of Liquid Limit for various agent proportions

Sl. No	BCS		BCS+8% Lime		BCS+10% Lime		BCS+8% Fly-Ash		BCS+10% Fly-Ash		BCS+8% GGBS		BCS+10% GGBS	
	WC (%)	No. of blows	WC (%)	No. of blows	WC (%)	No. of blows	WC (%)	No. of blows	WC (%)	No. of blows	WC (%)	No. of blows	WC (%)	No. of blows
1	55.76	21	39.56	22	44.50	27	48.13	29	40.87	30	26.50	26	18.80	23
2	63.17	23	46.97	23	44.07	28	54.12	24	37.94	27	27.66	21	23.38	21

3	66.80	26	39.32	28	45.23	25	58.46	22	53.96	25	23.99	28	16.41	27
4	Liquid Limit (%) = 65.12		Liquid Limit (%) = 43.91		Liquid Limit (%) = 45.23		Liquid Limit (%) = 53.21		Liquid Limit (%) = 53.96		Liquid Limit (%) = 26.73		Liquid Limit (%) = 17.60	

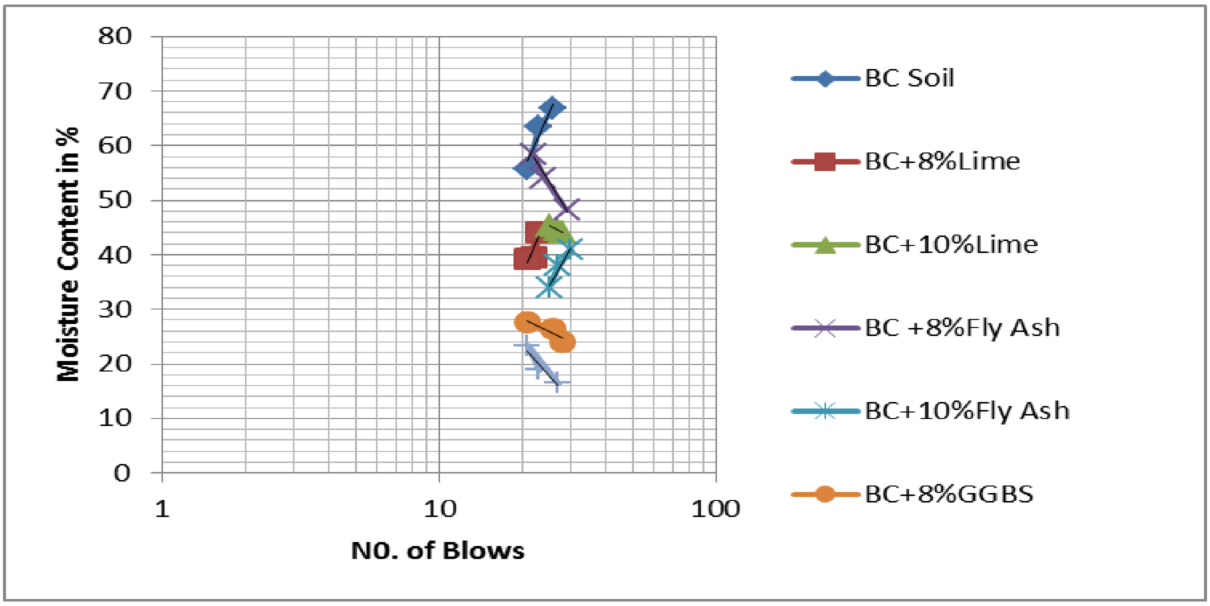

Fig 5.1 Comparison of Liquid Limit for BC Soil, BC+8% Lime, BC+10% Lime, BC+8% Fly Ash, BC+10% Fly Ash, BC+8% GGBS, BC+10%GGBS

Standard Casagrande's apparatus was used to conduct liquid limit test. This test helps in identifying the state of soil and its workability. The liquid limit was observed for 25 number of blows as per the standard procedure. The liquid limit obtained for the black cotton soil without any addition of stabilizing agent is 65.12%. For the comparison, the lowest and the highest percentage decrease are with the addition of lime and GGBS. The percentage decrease in liquid limit in BCS stabilized by 8% lime was 32.57% whereas the percentage decrease in liquid limit in BCS stabilized by 10% lime was 30.54%. Also, the percentage decrease in liquid limit in BCS stabilized by 8% GGBS was 58.95% whereas, the percentage decrease in liquid limit in Black Cotton Soil stabilized by 8% GGBS was 72.97%. From the above data it can be summarized that the percentage decrease in liquid limit is maximum in case of BCS stabilized with 10% GGBS. The graphical representation of the liquid limit values for all percentages of added stabilizing agents is as shown above for the comparison.

5.3 Plastic Limit

Table 5.3: Determination of Plastic Limit for various agent proportions

Sl. No.	Composition of soil	Plastic Limit (%)	Plasticity Index (Ip)
1	Black Cotton soil	30.92	34.2
2	Black Cotton soil+8% Lime	41.23	2.68
3	Black Cotton soil+10% Lime	31.96	13.27
4	Black Cotton soil+8% Fly-Ash	34.30	18.91
5	Black Cotton soil+10% Fly-Ash	44.83	9.13
6	Black Cotton soil+8% GGBS	19.86	6.87
7	Black Cotton soil+10% GGBS	12.61	4.99

Plastic limit test was conducted as per the standard procedure by rolling the soil into 3mm threads under the palms, the test results helped in determining the values of plasticity index for the latter research on the BCS with the plasticity chart. There is a large variation in the results of the plastic limit values for different stabilizing agents added. However, the plasticity index is maximum for BCS with no added stabilizing agents and least for BCS with 8% lime. Also, the percentage increase in plastic limit in BCS stabilized by 10% Fly-Ash was 44.98% which is the highest and the percentage decrease in plastic limit in BCS stabilized by 10% GGBS was 12.61%.

5.4 Standard Proctor Test

Table: MDD and OMC values for various agent proportions

Experiment	BCS		BCS+8% lime		BCS+10% lime		BCS+8% Fly Ash		BCS+10% Fly Ash		BCS+8% GGBS		BCS+10% GGBS	
Standard Proctor	MDD KN/m^2	OMC %	MDD KN/m^2	OMC %	MDD KN/m^2	OMC %	MDD KN/m^2	OMC %	MDD KN/m^2	OMC %	MDD KN/m^2	OMC %	MDD KN/m^2	OMC %
8%	-	-	15.21	13.90	14.95	14.77	15.46	12.00	14.35	11.87	15.20	6.94	16.36	5.97
10%	15.18	38	17.40	16.54	16.29	22.51	16.19	17.09	15.85	15.37	18.27	9.40	17.34	7.35
12%	17.32	40	17.71	21.10	17.03	35.80	17.66	20.25	16.50	18.32	16.39	11.52	15.48	9.90

The test was conducted by taking a representative oven-dried sample, approximately 5 kg in the given pan and mixing the sample with sufficient water to dampen it to approximately four to six percentage below optimum moisture content. The proctor mould is weighed without base plate and collar. The soil is placed in the Proctor mould and compacted in 3 layers giving 25 blows per layer with the 2.5 kg rammer falling through, the collar is then removed and the compacted soil is trimmed evenly, a small sample is taken for water content determination and above procedure is repeated with increased percentages of water content until there is either a decrease or no change in the wet unit weight of the compacted soil. The result shows that there is marginal increase in the dry

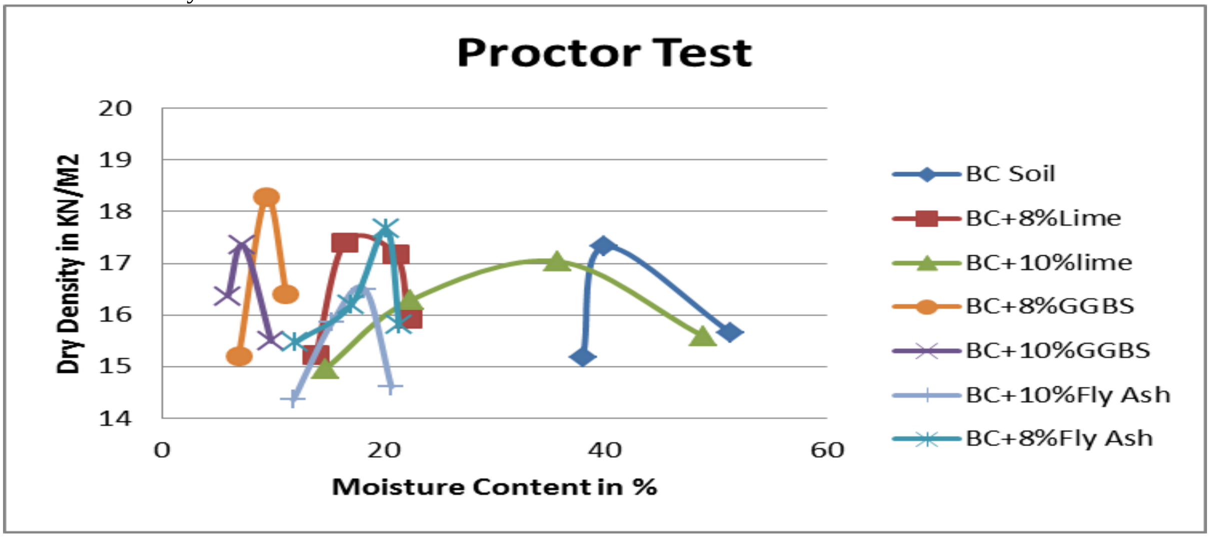

Fig 5.2 Comparison of Proctor for BC Soil, BC+8% Lime, BC+10% Lime, BC+8% Fly Ash, BC+10% Fly Ash, BC+8% GGBS, BC+10%GGBS

density values with the addition of stabilizing agents. However, the maximum dry density is obtained for the BCS compacted at 8% addition of GGBS as graphically represented above in the diagram.

5.5 Unconfined Compression Test

Compressive Strength values for various agent proportions

Experiment	BCS	BCS with 8% Lime	BCS with 10% Lime	BCS with 8% Fly-Ash	BCS with 10% Fly-Ash	BCS with 8% GGBS	BCS with 10% GGBS
Unconfined Compressive Strength(KN/m^2)	9.553	9.6443	10.005	7.0569	7.1631	3.9206	5.8156

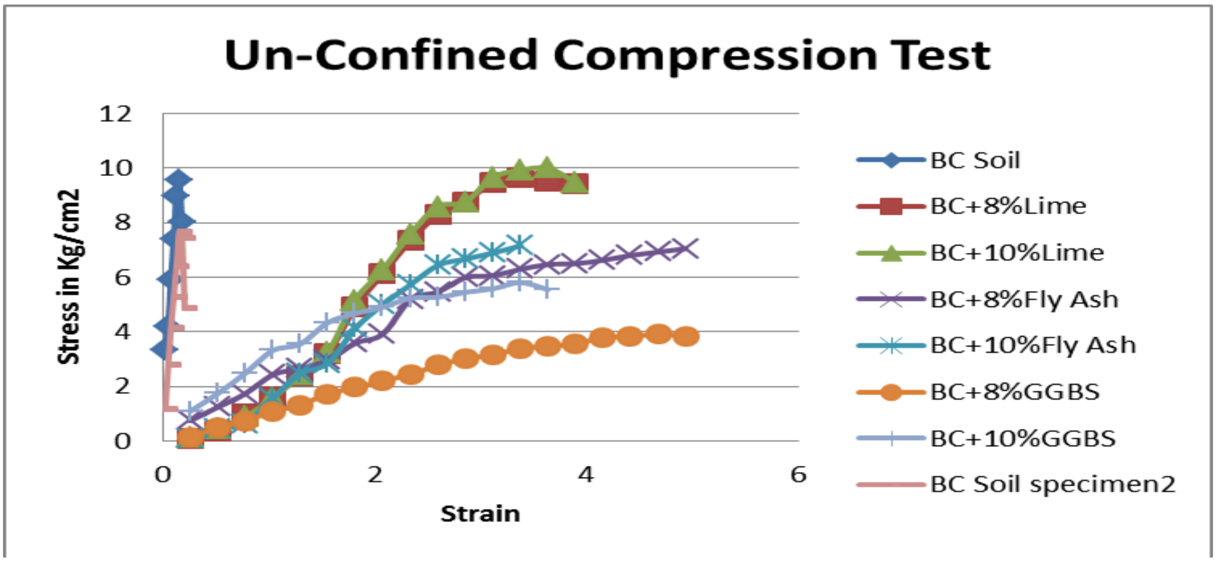

Fig 5.3 Comparison of Un-Confined Compression Test for BC Soil, BC+8% Lime, BC+10% Lime, BC+8% Fly Ash, BC+10% Fly Ash, BC+8% GGBS, BC+10% GGBS

The procedure includes placing the specimen on the base plate of the load frame (sandwiched between the end plates) and a hardened steel ball on the bearing plate.A dial gauge is adjusted to measure the vertical compression of the specimen.The readings of the proving ring dial is recorded for every 5 mm compression.In lime stabilised Black Cotton Soil the unconfined compressive strength increases with increase in lime content and is found to be maximum when 10% lime is used for stabilisation. In Fly-Ash stabilised Black Cotton Soil the unconfined compressive strength decreases with increase in fly-ash content but comparatively the percentage decrease in strength decreases with increase in fly-ash content. In GGBS stabilised Black Cotton Soil the unconfined compressive strength decreases with increase in GGBS content but comparatively the percentage decrease in strength decreases with increase in GGBS content.

6. Conclusion

In this study the effect of lime, Fly-Ash, GGBS on the geotechnical properties of Black Cotton Soil were investigated. The effect of these stabilising agents was studied by using the results obtained from the series of experiments that were carried out during the study. From the results the outcomes of this study can be concluded in below mentioned points

- With the increase in the percentage of stabilising agents used the liquid limit and Plasticity index decreases considerably. However, the values of plasticity indices for 8% and 10% addition of stabilizing agents are moderately in agreement and sync.
- Dry density shows an increasing trend with increase in lime, fly-ash, and GGBS content. Moreover, optimum moisture content decreases with the increase in stabilising agents used during the study.
- Unconfined Compression Strength also increases with the increase in the percentage of Stabilising agents used.
- However, as the percentage of stabilizing agents increases the soil strength parameters has kept on increasing because as the particle size decreases the surface area increases due to which a proper bond gets established between the soil particles ensuring proper stabilization.
- Keeping in view the test results and economy, GGBS can be considered the best stabilising agent among all the stabilizing agents utilized for tests.

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