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Effect of Additives of GGBFS and WMD on properties of Black Cotton Soil

[1]Shirish Sureshrao Maske, [2]Zeeshan Ajib Ahmad, [3]Dr. K . Ravi

[1]ME (Structural Engineering) Student, [2]Assistant Professor (Co-Guide), [3]Professor (Guide)

[1]Department of Civil Engineering,

[1]Babasaheb Naik College

Of Engineering, Pusad, India

Abstract: Collapsible soils are black cotton soils that have very high shear strength while dry but quickly lose strength when wet. Such rapid and substantial loss of strength causes considerable distress, resulting in extensive cracking and differential settlements, instability of building foundations, and even collapse of structures built on these soils. Waste marble dust and Ground Granulated Blast Furnace Slag are industrial byproducts that are produced in huge amounts around the world and constitute an environmental danger. As a result, it is critical to find a long-term solution for its disposal. The current study focused on reducing the collapse potential of black cotton soil using a physio-chemical technique. Because the soil is sensitive to water, it must be stabilised. As an admixture, different percentages of waste marble dust (WMD) and ground granulated blast furnace slag (GGBFS) were utilised. This study investigates the effect of admixture on soil parameters such as specific gravity, plasticity index, swelling index, and shrinkage limit.

I. Introduction

"Because of its colour and aptitude for cultivating cotton crops, expansive soil is also known as Black Cotton soil. Black cotton soil is also known as'regur,' which is derived from the Telugu word'reguda'. The soil is high in calcium carbonate, potash, lime, and magnesium carbonate, but low in phosphorus. [1-2] Black cotton soil is one of India's largest regional soil deposits, encompassing around 3.0 lakh square kilometres. It is primarily found in Gujarat, Madhya Pradesh, and Maharashtra.

Efficient and cost-effective expansive soil stabilisation is critical for a variety of geotechnical applications such as pavement constructions, highways, and building foundations. Admixture stabilisation of expansive soil reduces the capability of soil for volume change and enhances soil strength. This necessitates the use of materials that are inexpensive, affordable, effective, and easily accessible. We must use mineral admixtures such as fly ash, GGBFS, marble powder, iron slag, natural fibres, and so on to stabilise existing soil. GGBFS (Ground Granulated Blast Furnace Slag) and Waste Marble Powder (WMP) are manufacturing waste products. According to earlier studies conducted by various researchers, materials such as GGBFS and WMP have environmental difficulties regarding their use and disposal. These wastes damage the fields and farmland. Land quality, soil characteristics, and mineral content may deteriorate. As a result, utilising industrial waste in the building sector is the greatest solution to solve their disposal problems. GGBFS and WMP can be utilised as a stabilising additive in black cotton soil (BC), reducing environmental concerns. Using industrial waste in the building sector is advantageous in many ways, including waste disposal, preserving bio diversity, boosting soil qualities such as strength, permeability, and so on, preserving natural soil, and creating cost-effective structures. The GGBFS with WMP have been included in this project to investigate the effect of these materials on the qualities of BC soil. Various tests on BC soil were performed in this study, including Specific Gravity, Compaction Test, California Bearing Ratio Test (CBR), and Unconfined Compression Test (UCS), using 5%, 10%, 15%, 20%, 25%, and 30% of GGBFS and WMP in equal amounts. An attempt has also been made to offer specific information on the changes in engineering properties of black cotton soil caused by the addition of admixture in various percentages, with comparisons

made. [3-5] The addition of GGBFS and marble powder to the soil is likely to aid in the development of cementitious substance.
Abdul Waheed et al. [6] are working on a project called Soil Improvement Using Waste Marble Dust for Sustainable Development. Collapsible soils have very high shear strength in dry conditions but rapidly lose strength when wet. Such rapid and significant strength loss causes considerable distress, resulting in extensive cracking and differential settlements, instability of building foundations, and even the collapse of structures built on these soils. Waste marble dust is an industrial byproduct that is produced in enormous quantities around the world and constitutes an environmental risk. As a result, it is critical to seek a long-term solution for its disposal. The current study focused on reducing the collapse potential of CL-ML soil via a physio-chemical approach. Because the soil is susceptible to soaking, it must be stabilised. As an admixture, varied percentages of waste marble dust (WMD) were utilised. The study's optimization method revealed that adding waste marble dust enhanced the geotechnical properties of collapsible soil significantly. Plasticity was reduced, but Unconfined Compressive Strength (UCS) rose dramatically, and edoema was reduced to an acceptable level. The California Bearing Ratio (CBR) has also improved significantly. This research evaluates the safe disposal of hazardous waste and converts it into appropriate material for engineering needs.
G. Tozsin et al. [7] investigated the use of marble wastes as a soil additive for acidic soil neutralisation. Soil pH is one of the most fundamental elements limiting plant growth. The purpose of this research is to assess the efficacy of marble waste applications in neutralising soil acidity. A laboratory incubation test was used to determine the efficiency of marble quarry waste (MQW) and marble cutting waste (MCW) in neutralising acid soil. The results showed that MCW and MQW sprays elevated soil pH from 4.71 to 6.36 and 6.84, respectively. It was proposed that MQW and MCW might be employed as soil additives for acid soil neutralisation, reducing the negative environmental impact of marble wastes.
Sabat, A.K., and Nanda [8] investigated the effect of marble dust on the strength and durability of expansive soil stabilised with rice husk ash. It summarises the findings of a laboratory investigation into the effect of marble dusts on the strength and durability of an expanding soil stabilised with the optimal percentage of Rice Husk ash (RHA). Based on Unconfined Compressive Strength (UCS) tests, the optimum proportion of RHA was determined to be 10%. Marble dust was added to RHA stabilised expansive soil at 5% increments up to 30% by dry weight of the soil. After 7 days of curing, these samples were subjected to compaction testing, UCS tests, Soaked California Bearing Ratio (CBR) tests, swelling pressure tests, and durability tests. The UCS and Soaked CBR of RHAstabilized expansive soil increased by up to 20% when marble dust was added. The addition of more Marble dust had a negative impact on these qualities. Regardless of the quantity of marble dust added to RHA stabilised expansive soil, the Maximum Dry Density (MDD) and Swelling pressure of expansive soil decrease while the Optimum Moisture Content (OMC) increases. According to the Durability test results, the inclusion of Marble dust made the RHA stabilised expansive soil more robust. For the best stabilisation effect, the optimal ratio of The ratio of soil to rice husk ash to marble dust was discovered to be 70:10:20.
A.K. Sharma and P.V. Sivapullaiah [9] investigate the use of ground granulated blast furnace slag treated fly ash as an expansive soil stabiliser. This study looks at the possibility of utilising a binder made of fly ash and ground granulated blast furnace slag (GGBS) to stabilise expansive soils. The combination of these two components to produce a binder opens up new avenues for enhancing pozzolanic activities, which may minimise swell potential and boost unconfined compressive strength of expansive clays. The effect of varied binder percentages on the Atterberg limits, compaction properties, and unconfined compressive strength of an artificially mixed soil was investigated. The addition of binder was demonstrated to significantly improve these soil qualities. With the addition of binder, the liquid limit and plasticity index of the expansive soil reduced significantly, while the strength increased. A tiny amount of lime (one percent) added to the soil increased its characteristics by increasing the pozzolanic reactivity of the binder. The addition of 20% binder is advised as the optimum content based on the results of the unconfined compressive strength tests. Furthermore, mineralogical and morphological examinations of soil specimens stabilised with optimal binder content showed the development of hydrated particles and cementitious compounds as a result of the clay-binder reaction. In addition to economic benefits, test results show that using GGBS mixed fly ash as a binder to stabilise expansive is well suited for sustainable building.
A.K. Pathak et al [10] investigated soil stabilisation using ground granulated blast furnace slag. Stabilisation is a broad term that refers to the different methods of altering the qualities of a soil in order to improve its technical performance and use in a variety of engineering undertakings. Soil stabilisation is a serious concern for civil engineers nowadays, both for road construction and for increasing the strength or stability of soil while lowering construction costs. The soil is stabilised in this job using ground granulated blast furnace slag (GGBS), which is acquired from the cement plant's blast furnace as a byproduct of iron production (from ACC plant, sindri). It is often available in three shapes: air cooled, foamed, and granulated. The use of waste

materials for stabilisation benefits both the environment and the economy. In the current project, ground granulated blast furnace slag (GGBS) is employed to stabilise soil (clay). The primary goals of this study were to investigate the effect of GGBS on the engineering properties of the soil (optimum moisture content and maximum dry density, plastic limit, liquid limit, compaction, unconfined compressive strength, triaxial and California bearing ratio test) and to determine the engineering properties of the stabilised soil. Granulated shaped blast furnace slag is most suited for boosting soil strength, and we look at the following soil properties. When GGBS is added from 0% to 25% by dry weight of soil, first check all soil properties at 0% (no GGBS) and then compare after GGBS addition from 5% to 25%. The investigations revealed that the addition of GGBS increased the engineering qualities in general. The addition of GGBS resulted in a significant improvement across the program's test ranges. With increasing GGBS percentage, the maximum dry density increased while the optimal moisture content declined, and the maximum dry density was obtained at 25%.

Thomas, A. et al. [11] conduct research on soil stabilisation using enzymes and alkali-activated ground granulated blast-furnace slag. The development and application of non-traditional stabilisers for soil stabilisation, such as enzyme and alkali-activated ground granulated blast-furnace slag (GGBS), helps to reduce costs and negative environmental consequences. The purpose of this study is to compare the efficacy of alkali-activated GGBS and enzyme to conventional Portland cement (OPC) on soil taken from the Tilda region of Chhattisgarh, India. Geopolymers are alkali alumino-silicates formed when a solid alumina-silicate is combined with an aqueous alkali hydroxide or silicate solution. The effects of various dosages of the selected stabilisers on optimal moisture content (OMC), maximum dry density, plasticity index, unconfined compressive strength (UCS), and shear strength parameters were studied. The effect of the cure period has also been investigated. Microstructural changes in stabilised soils exhibit particle aggregation, and the addition of stabilisers results in significant improvements in soil properties, including an increase in OMC, UCS, and shear strength indices. With the addition of stabilisers, the cohesiveness of the soil sample increases dramatically, whereas the angle of internal friction changes just marginally. Thus, the data suggest that non-conventional stabilisers such as alkali-activated GGBS and enzyme are more suited and environmentally friendly than OPC for soil stabilisation.

Mujtaba, H. [12] investigated the use of ground granulated blast furnace slag to improve the engineering properties of expansive soils. The primary goal of this study is to improve the engineering features of expansive soils by mixing ground granulated blast furnace slag (GGBFS). Two large soil samples were taken from the DG Khan and Sialkot locations for this purpose (Pakistan). According to the Unified Material Classification System, the DG Khan sample was fat clay (CH), while the Sialkot soil was lean clay (CL). GGBFS was added to these soil samples in varied quantities ranging from 0% to 55% to investigate its effect in soil stabilisation. According to laboratory results on composite soil samples, adding 50% GGBFS to both samples increased maximum dry unit weight by up to 10%. By mixing 50% GGBFS, the California bearing ratio (CBR) increased from 3.2% to 11.5% for DG Khan soil and from 2.4% to 10.7% for Sialkot soil. The addition of 30% GGBFS to DG Khan soil lowered swell potential from 8% to 2%, whereas the addition of 20% GGBFS to Sialkot soil reduced swell potential from 5% to 2%. With the addition of 30% GGBFS, the unconfined compressive strength of a remoulded sample cured for 28 days rose by roughly 35%. The results showed that combining GGBFS with expansive soil samples significantly increased their engineering qualities. It is also an effective and environmentally beneficial method of disposing of steel industrial waste.

The purpose of this paper is to investigate the use of ground granulated blast furnace slag (GGBFS) and marble powder in equal proportions for the stabilisation of black cotton soil in various percentages by weight of soil, in order to evaluate the effect of this waste material on engineering properties of soil.

2. Materials

The materials used for this study are Black cotton soil, Ground Granulated Blast Furnace Slag (GGBS) and Waste Marble powder .The properties are mentioned below.

2.1 Black Cotton Soil:

The expansive type of soil is in black color and also it has ability to grow cotton it is known as black cotton soil. This type of soil expand suddenly when came in contact of moisture and start swell and shrink when the moisture is removed so due to its swell- shrink behavior it is a very problematic soil for consideration of its use as a construction material.

The following are the properties of black cotton soil:

Table 2.1 Geotechnical properties of BC. Soil

Sr.No	Properties	Values
1	Soil classification	Black cotton soil
2	Liquid Limit (LL)	59%
3	Plastic Limit (PL)	3.947%
4	Plasticity Index (PI)	41.71%
5	Specific gravity (G)	2.1
6	Free Swell Index(FSI)	33.33
7	Optimum Moisture Content (OMC)	19.618 %
8	Maximum Dry Density (MDD)	1.642 gm/cc

2.2 Ground Granulated Blast Furnace Slag (GGBFS) :

These are the by-product in pig iron product. The chemical compositions are similar to that of cement. It is however, not cementitous compound by itself, but it possesses latent hydraulic properties which upon addition of lime or alkaline material the hydraulic properties can develop. Depending on cooling system, Sherwood itemized slag in three forms, namely air cooled slag hot slag after leaving the blast furnace may be slowly cooled in open air, resulting into crystallized slag which can be crushed and used as aggregate. Granulated slag containing of hot slag may result into formation of vitrified slag. The granulated blast furnace slag is a result of water during quenching process, while, the use of air in the process of quenching may result into information of Granulated slag. Expanded slag is formed under certain conditions; stream produced during cooling of hot slag will give rise to expanded slag.

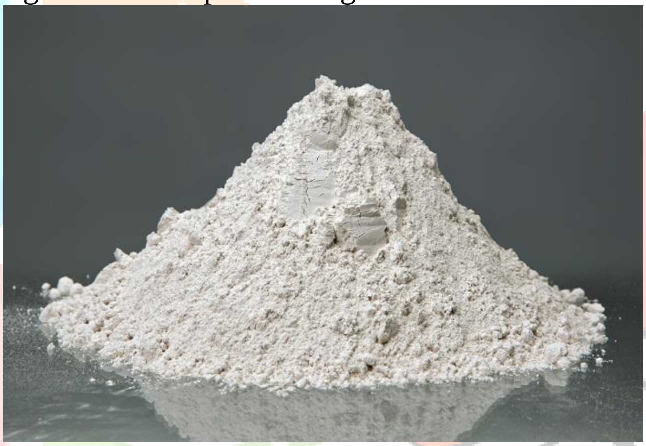

Fig 2.1: Ground Granulated Blast Furnace Slag Cement

Table 2.2: Physical Properties Of GGBFS

Sr. No	Properties	GGBFS (value)
1	Liquid Limit (LL)	40.73%
2	Plastic Limit (PL)	Non plastic
3	Plasticity Index (PI)	Non plastic
4	Specific gravity (G)	2.77

2.3 Waste Marble Powder (WMP):

Marbles dust produced from cutting and grinding of marble has very fine particle size, non plastic and almost well graded. The use of traditional techniques to stabilize the soil faces problems like high cost and environment issues. The improvement of soil by marble dust is the alternative solution .The soil stabilized by marble dust can be utilized in the construction of canal lining, pavement structures and foundations. This work aims to reduce the expansion of expansive soils by using marble powder and notice the change in index properties of soil samples with increasing percentage of marble powder

Fig 2.2: Waste Marble Powder

Table 2.3: Chemical Composition of WMP

Sr. No	Content	Percentage
1	$CaCO_3$	51 to 56%
2	$MgCO_3$	42 to 45%
3	Mix Oxides	01 to 03%
4	SiO_2	0.5 to 2.5%
5	Loss on Ignition	41 o 44%

2.4 Specific Gravity

The ratio of a given volume of a material to the equal volume of displaced liquid is defined as specific gravity. In geotechnical field specific gravity plays an important role. Specific gravity test was conducted according to IS: 2720 (Part 3): Sec 1-1980. About 50 kg of soil was taken for conducting the specific gravity test. Take the empty weight of the pycnometer and report it as W1. Soil was filled in pycnometer. Weigh the pycnometer and report the weight as W2. After that Bottle was filled with distilled water and placed on sand bath to remove air bubbles. After sometime take out the pycnometer from the sand bath and kept cooling fill the pycnometer up to the mark. Weigh the pycnometer (soil and water) and report it as W3. After that fil the water up to the mark. Take the pycnometer and water weight and report it as W4. Now the specific gravity of the soil is calibrated as for the formula.

Figure 2.3 Pycnometer Used For Specific Gravity Test

2.5 Liquid Limit

Liquid limit test was conducted according to IS: 2720 (part5)-1985. The Soil which is passing through 425-micron sieve was used to conducted the test. About 200 gm of soil is taken in a tray. Some amount of water was mixed to the soil. Soil paste was taken into the casagrande apparatus. By the help of groove a cut was made in middle of the soil. The groove divides the soil paste into two parts along the diameter. After that handle of the device was turned. After the some turns the two parts will join together. Take some amount into container for knowing the moisture content. Note down the corresponding blows. Repeat the test two to three times. Draw a graph between blows vs moisture content. Measure the moisture content corresponding to 25 blows. It is reported as liquid of the soil.

Figure 2.4 LL test on admixed BC soil specimen

2.6 Plastic Limit Test

For determination of plastic limit of a soil, sieved through 425 IS sieve. About 30 gm of soil is taken, is mixed thoroughly with distilled water. Take 10 gm of water mixed soil into hand and form a ball. Now the ball was rolled against glass plate with fingers. The ball shape turns into thread shape.do the process until the thread is of size 3 mm size. The rate of rolling was about 80 to 90 strokes per minute. Take the soil into the container to know the moisture content. The water content at which soil thread showing cracks that moisture content was known as plastic limit of the soil.

Figure 2.5 PL test on admixed soil specimen

2.7 Swell Index Test

Expansive soils are known to have great swelling ability because of the presence of swelling dominant clay minerals such as the montmorillonite group. It shows the swelling pressure results of black cotton soil for different dosage of Enzyme. The swelling pressure for untreated soil is 180 kN/m2, as addition of enzymes (Terazyme) with different dosage lowers the swelling pressure to 160, and 40, kN/m2 for 7 days and 30 days curing period. This implies that as enzyme is added the lesser the swelling pressure of the compacted soil and hence the more stable the material is. After adding the enzyme, it is also consistent that swelling potential decreases with the amount of stabilizer.

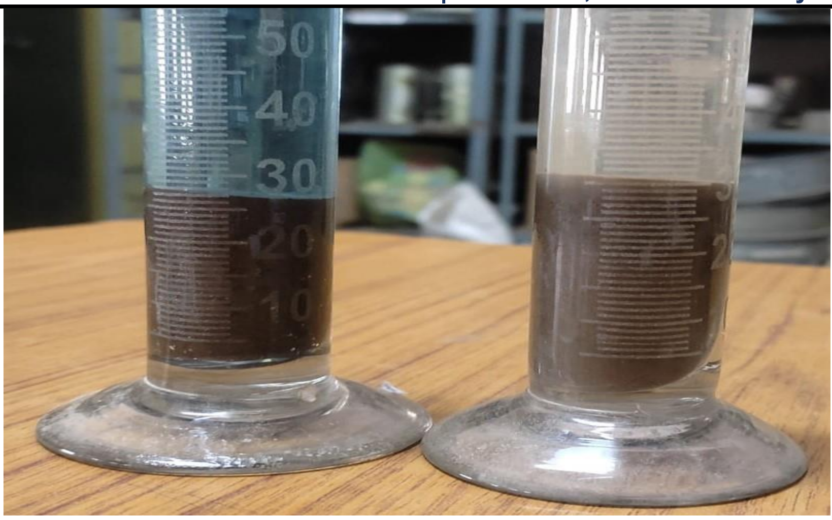

Figure 2.6 Swell index test on admixed soil specimen

3 Experimental Study

The tests were performed according to relevant ASTM and AASHTO Standards; the standard designations are referred to, where applicable.

3.1 **Specific Gravity Test**

From the Table 3.1 shows the values of specific gravity for admixed BC the soil. A close examination of Table 3.1 reveals that the observed value of specific gravity of admixed soil was on nearly equal to BC soil. As per IS (1498-1970), the recommended value of specific gravity is within 2.20 to 2.50. Therfore,the values of specific gravity found in Table 3.1 for admixed soil samples are within the permissible limits.

Table 3.1 Sp. Gravity Test based on admixed BC soil.

Sr. no	**Sp. Gravity Test w.r.t admixed soil**	**Sp. Gravity**
1	BC100MG0	2.10
2	BC95MG05	2.27
3	BC90MG10	2.22
4	BC85MG15	2.35
5	BC80MG20	2.35
6	BC75MG25	2.32
7	BC70MG30	2.50

3.2 Shrinkage Limit Test

Shrinkage Limit Test was carried out as per IS:2720 (Part 5)-1985. Table 3.2 shows the observed values of shrinkage limit corresponding to the replacement of admixture in BC soil. A close examination of Table 3.2 reveals that value of shrinkage limit was found to be nearly equal for all admixed soil specimen. Table 3.2 reveals addition of admixture in BC soil does not get any changes in the sample.

Table 3.2 variation in shrinkage limit based on admixed BC soil

Sr. no	**Shrinkage Limit Test w.r.t admixed soil**	**Shrinkage limit (%)**
1	BC100MG0	8.2
2	BC95MG05	13.3
3	BC90MG10	13.3
4	BC85MG15	13.2
5	BC80MG20	14.9
6	BC75MG25	16.7
7	BC70MG30	15

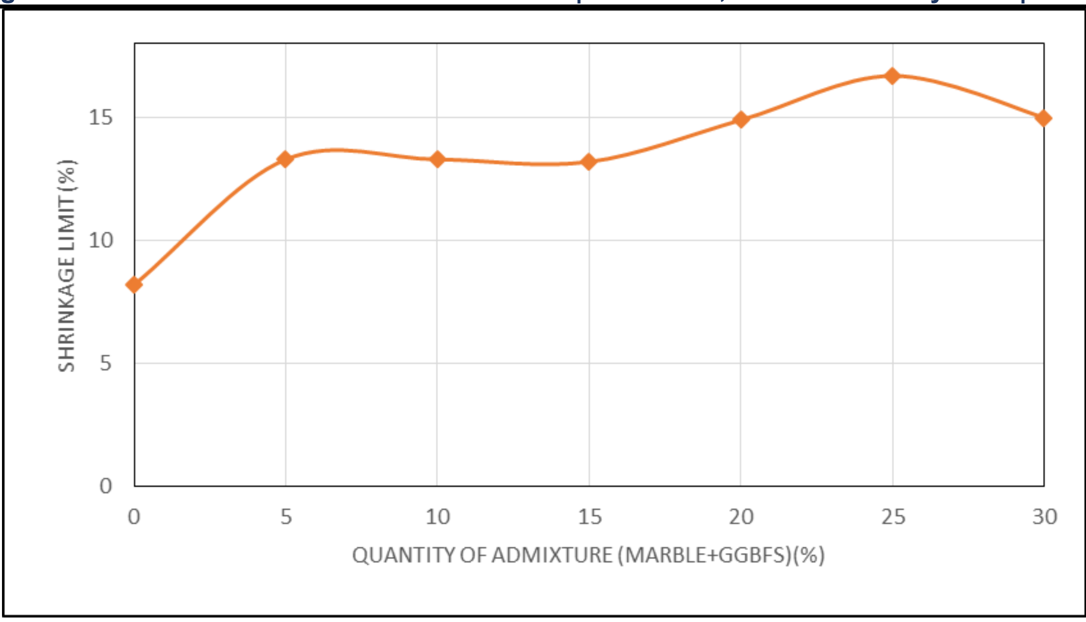

Figure 3.2 Graph on Shrinkage Limit V/S Quantity of Admixtur

3.3 Plasticity Index

Plastic Limit Test was carried out as per IS:2720 (Part 5)-1985.Table 3.3 shows the observed values of Plastic limit corresponding to replacement of admixture in BC soil and w.r.t their plasticity index. Table 3.3 shows that the observed value of plasticity index of admixed BC soil was found to be decrease. A reduction in the plasticity index is often used to determine the effectiveness of (GGBFS+ WMP) treatment on BC soil.

Table 3.3 variation in plasticity index based on admixed BC soil

Sr no	Test on admixed soil	Plastic limit (%)	Plasticity index (%)
1	BC100MG0	30.947	41.71
2	BC95MG05	29.443	38.15
3	BC90MG10	28.434	35.59
4	BC85MG15	26.966	31.03
5	BC80MG20	22.527	28.47
6	BC75MG25	24.557	20.44
7	BC70MG30	23.737	21.26

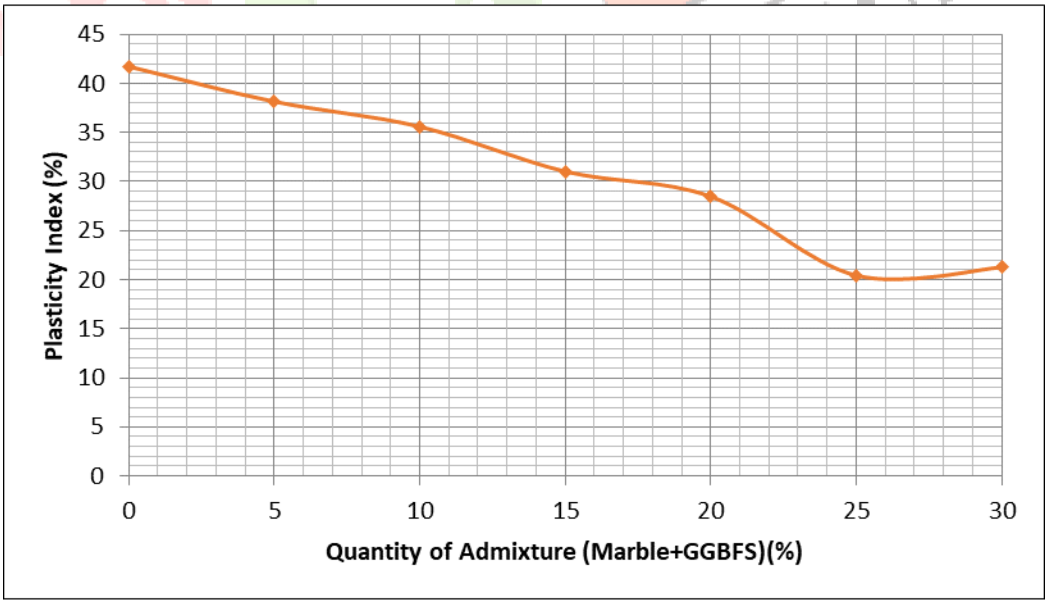

Fig 3.3 Graph on Plasticity index V/S Quantity of Admixture

3.4 Free swell index

As per ASTM D4546 Test Method C has been performed for determining swell %. The results are listed in the table 3.4 It is identified that as the percentage of GGBFS+WMP is increasing the differential free swell index values are decreasing. Table 3.4 shows that radially decrease in percentage of swelling index. The percentage of additives from 0 to 20% shows drastic change in reduction of swell index after that it shows zero expansion in admixed BC soil.It is possible to get a negative value of swell index, its called ashydrocollapse. As per ASTM D4546 Test Method C sample disturbance of non-expansive or even expansive soil can produce negative values as well.

Table 3.4 variation in swelling index w.r.t admixed BC soil

Free Swell Index	Swelling Index (%)	Degree Of Expansion
BC100MG0	33.33	Moderate
BC95MG05	23.68	Low
BC90MG10	18.52	Very Low
BC85MG15	17.26	Very Low
BC80MG20	16	Very Low
BC75MG25	0	No Expansion
BC70MG30	-4.16	No Expansion

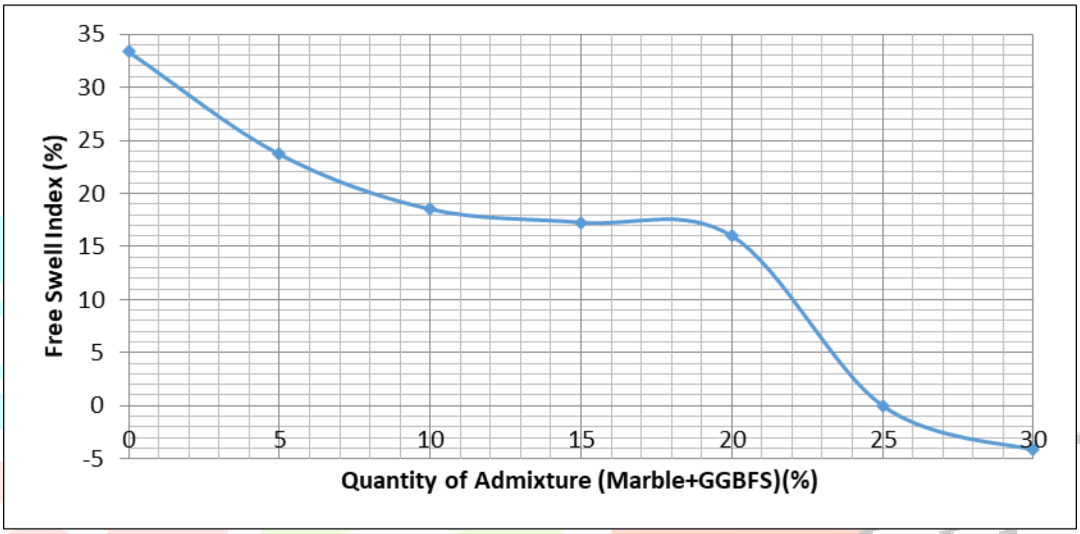

Fig 3.4 Variation In Swelling Index By Treated BC Soil.

4. Conclusion

From the above study, the following conclusions are drawn based on the performance of the admixed Black Cotton Soil:

1. From the combination of GGBFS and WMP used in BC soil the different properties of soil are find outs.
2. Sp. Gravity was found to be in the range of 2.1 to 2.5. It is increasing as the percentage combination of GGBFS and WMP increases in black cotton soil.
3. The shrinkage limit has been tested. It was found to be in the range of 8.2% to 15%. It is increasing as the percentage combination of GGBFS and WMP increases in black cotton soil.
4. The plastic limit and plasticity index has been tested. It was found that, the range of plastic limit is 23.73% to 30.94% and plasticity index in the range of 21.26% to 41.71%. It is decreasing as the percentage combination of GGBFS and WMP increases in black cotton soil.
5. The swelling index has been tested. It was found that, swelling index in the range of 33.33% to -4.16%. It is decreasing as the percentage combination of GGBFS and WMP increases in black cotton soil.

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