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Unconfined Compressive Strength Evaluation of Natural Expansive Soil with the Substitution of Combined Industrial Byproducts

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Abstract : The black cotton soils which show very high shear strength in a dry state but rapidly lose their strength on wetting are known as collapsible soils. Such rapid and massive loss of strength produces severe distress leading to 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 is an industrial byproduct and is being produced in large quantities globally poses an environmental hazard. Therefore, it is of the utmost need to look for some sustainable solution for its disposal. The present study focused on the mitigation of the collapse potential of black cotton soil through a physio-chemical process. The soil is sensitive to wetting, warranting its stabilization. Waste marble dust (WMD) and Ground Granulated Blast Furnace Slag (GGBFS) in varying percentages was used as an admixture. The study's optimization process showed that geotechnical parameters of black cotton soil improved substantially by adding waste marble dust. Plasticity was reduced while Unconfined Compressive Strength (UCS) significantly increased. This study appraises the safe disposal of hazardous waste safely and turns these into suitable material for engineering purposes.

I. Introduction

For construction purposes on the in situ soil, the basic necessity is that the soil must have high strength characteristics. If the locally available soil does not have high strength then options available are:-

1. Modify the design.
2. Replace the locally available soil.
3. Avoid the site for construction purpose.

All these above mentioned options are time consuming, highly expensive and sometimes not feasible according to the situations prevailing. The soil is said not to be feasible for various engineering practices if accordingly it has low bearing capacity, soil has low CBR value, soil is prone to liquification, has high swelling and shrinkage characteristics, has low UCS value etc. Also due to ever increasing population there is scarcity of land and also some sites are prone to landslides. So, now locally available soil has to be modified with some operations on it so that its strength increases up to a desirable limit and now further construction can be done. These operations which are done on the locally available soil to make it fit for the construction is called soil stabilization.

1.1 Soil Stabilization

Any method which is done on the locally available soil to improve its engineering properties and strength is called soil stabilisation. Improvement can be done physically, chemically, biologcally, mechanically etc. This all can be done by compaction, reinforcement with fibres, introducing sand drains, addition of chemicals etc. Also, one of the problem arising nowdays is of waste disposal. Engineers have to deal with this problem of waste disposal and one of the solution available is to use these wastes for the stabilisation of soil. This benefits as:-

1. Cost is reduced by using waste material as soil stabilizer.
2. Problem of waste disposal is solved and is eco-friendly.

Abdul Waheed et. Al. [1] works on the Soil Improvement Using Waste Marble Dust for Sustainable Development. The soils which show very high shear strength in a dry state but rapidly lose their strength on wetting are known as collapsible soils. Such rapid and massive loss of strength produces severe distress leading to extensive cracking and differential settlements, instability of building foundations, and even collapse of structures built on these soils. Waste marble dust is an industrial byproduct and is being produced in large quantities globally poses an environmental hazard. Therefore, it is of the utmost need to look for some sustainable solution for its disposal. The present study focused on the mitigation of the collapse potential of CL-ML soil through a physio-chemical process. The soil is sensitive to wetting, warranting its stabilization. Waste marble dust (WMD) in varying percentages was used as an admixture. Tozsin, G. et. Al [2] studied on Using marble wastes as a soil amendment for acidic soil neutralization. One of the most important factors limiting plant growth is soil pH. The objective of this study is to determine the effectiveness of marble waste applications on neutralization of soil acidity. Marble quarry waste (MQW) and marble cutting waste (MCW) were applied to an acid soil at different rates and their effectiveness on neutralization was evaluated by a laboratory incubation test. The results showed that soil pH increased from 4.71 to 6.36 and 6.84 by applications of MCW and MQW, respectively. It was suggested that MQW and MCW could be used as soil amendments for the neutralization of acid soils and thus the negative impact of marble wastes on the environment could be reduced.

Sabat, A.K. and Nanda [3] studied the Effect of marble dust on strength and durability of Rice husk ash stabilised expansive soil. It presents the results of a laboratory study undertaken to investigate the effect of Marble dusts on strength and durability of an expansive soil stabilized with optimum percentage of Rice Husk ash (RHA). The optimum percentage of RHA was found out be 10% based on Unconfined Compressive Strength (UCS) tests. Marble dust was added to RHA stabilized expansive soil up to 30%, by dry weight of the soil, at an increment of 5%. Compaction tests, UCS tests, Soaked California Bearing Ratio (CBR) tests, Swelling pressure tests and Durability tests were conducted on these samples after 7 days of curing. Yilmaz, F. and Yurdakul, [4] works on the Evaluation of Marble Dust for Soil Stabilization. It Usage of marble dust was investigated for soil stabilization in the scope of utilization of waste material. Geotechnical properties, such as compaction, Atterberg limits, unconfined compressive strength of the mixtures and changes of these properties with the marble dust ratio were determined. From the test results it is seen that marble dust increases the mechanical properties of soil and application of dust wastes for soil stabilization will be an efficient practice in terms of solid waste management.

PriyankaShaka et al (2016) [5] Based on IS classification, red soil is classified as Clayey sand and the black cotton soil as highly compressible clay. Laboratory testing showed that decrease in liquid limit and plasticity index was observed with the increase in dosages of Terrazyme. Also, the Terrazyme dosage of 200ml/0.75m3 of dry soil garnered the best result. Further increase in the dosage does not alter the plasticity characteristics of soils substantially. CBR Value of the soil sample was increased by 2.75%. 3.345%. 3.47% and 3.56% by application of the bio-enzyme with a dosage of 200ml/0.75m3. With further increase in the dosage of the enzyme, no substantial increase was recorded.

Lacuoture and Gonzalez (1995) [6] conducted a comprehensive study of the TerraZyme soil stabilizer product and its effectiveness on sub-base and sub-grade soils. The reactions of the soils treated with the enzyme was observed and recorded and compared to the untreated control samples. The variation in properties was observed over a short period only and it was found that in cohesive soils there was no major variation in properties during the early days but the soil showed improved performance progressively.

Isaac et al (2003) [7] studied effectiveness of Terrazyme on lateritic and clay type soil collected from Kerala. The reactions of the soils treated with enzyme were recoded for 8 weeks. The CBR value increased in all soil type in the range of 136 to 1800 percent that of the original value by addition of Terrazyme, which proved its suitability as a stabilizing agent. Terrazyme is useful for clay soil and sand but is less significant to silty soils; clayey and sandy soils had increase in CBR by 700 percent.

Swathy M Muraleedharan1, Niranjana (2015) [8] conducted laboratory tests on clay of high plasticity treated with Terrazyme. The effect of enzyme on soil in terms of Plasticity Index, Compaction, Unconfined Compressive Strength (UCC), and California Bearing Ratio (CBR) were studied. The dosage of bio-enzyme added to the soil was 0ml, 0.1ml, 0.2ml, 0.3ml and 0.4ml per kg soil on bio stabilized soil .The soil properties showed improvement in stabilizing with enzyme dosage of 0.2ml/kg. The treated soil was observed to be having lesser plasticity index values. For the optimum dosage, the MDD of the up to 6% and OMC decreases up to 19%. At the optimum dosage, there was an increase of 351%in the UCC strength and 352% in CBR value 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.

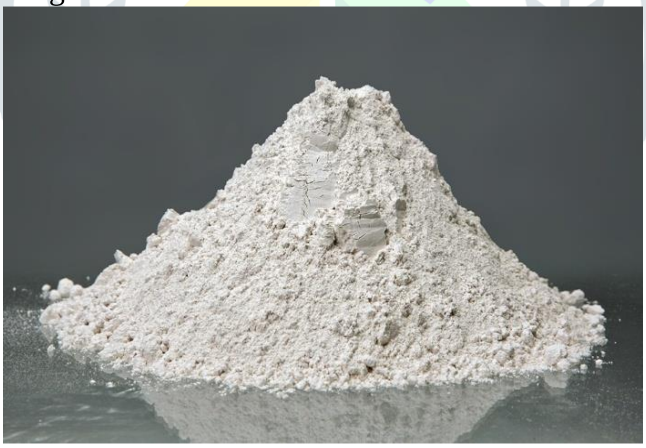

Fig 2.1: Ground Granulated Blast Furnace Slag Cement

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%

2.3 Unconfined Compression Test

Modified proctor test was conducted according to IS: 2720 (Part 10)-1991. It is a modification to the tri axial test in which unconfined pressure is kept as zero. The soil specimen is placed unconfined compression test machine. The dial gauge and proving ring are set to zero. The compressive load is applied to the specimen by turning handle. As the handle is turned, the upper plate moves downward causes compression. The compressive force is determined from ring reading and the axial strain is found from the dial gauge reading. Force divided with area gives the stress value.

Figure 2.3 UCS Figure

3 Experimental Study

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

3.1 Unconfined Compressive Strength

The effect of addition of GGBFS and Waste Marble Powder to the black cotton soil sample on their UCS Value along with the different percentage of OMC And MDD Value obtained by SPCT Test. It exhibit that the UCS Of the black cotton soil sample increase with the replacement of different percentage of admixture at a certain limit.

3.1.1 UCS test based for 0 days

The USC testing was conducted. The block of different combination of Black Cotton soil, waste Marble Powder and Ground Granulated Blast Furnace Slag admixtures prepared. The percentage of GGBFS and Waste Marble Powder in the combination of Black cotton soil was varying from 0% to 25%. The block of 50mm diameter was prepared having length 150mm. The testing was conducted on Universal Testing machine. The testing was conducted at 0 days. The results are shown on below table. The readings were recorded for every 0.5mm deformation. It has been observed that, the stress induced in the material was increasing as increase in the strain. The details information can be seen in below graph. The graph shown below, shows as percentage combination of GGBHS+WMP increases in the block the stress induced was also increases. Higher the percentage combination higher is the UCS. The minimum UCS induced can be seen for pure black cotton soil while maximum induced stress seen for 25% admixtures for 0 days of curing. The maximum induced UCS observed of 0 days of curing is 66.24 MPa, 70.88 MPa, 75.84 MPa, 81.15 MPa, 86.83 MPa, and 92.91 MPa for combination of 0%, 5%, 10%, 15%, 20% and 25% admixtures respectively.

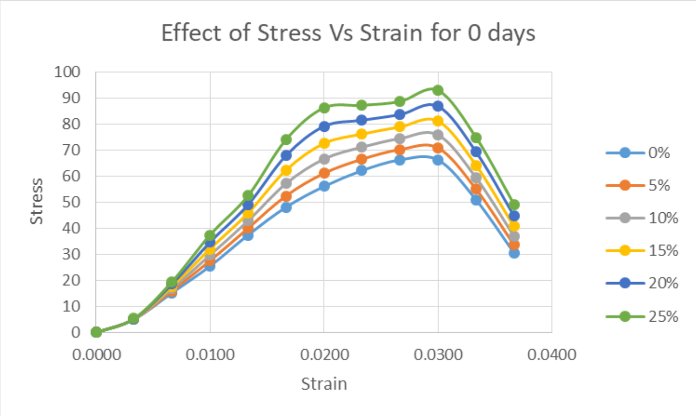

Figure 1: Stress Strain Data of UCS Test of 0 days for different percentage of admixtures

3.1.2 UCS test based for 3 days

The USC tests were carried out. The block was made by mixing various amounts of ground-granulated blast furnace slag, discarded marble powder, and black cotton soil. Between 0% and 25% of the mixture of Black cotton soil contained GGBFS and Waste Marble Powder. A 150mm-long block with a 50mm diameter was created. On a Universal Testing machine, the testing was done. Three days after the cure, the testing was carried out. The results are displayed in the table below. Every 0.5mm of deformation resulted in the readings being recorded. It was found that when the strain increased, the stress that the material underwent increased. The graph below shows the specific information. The graph below demonstrates how stress induction increased as the proportion combination of GGBHS+WMP increased in the block. The UCS is higher the higher the percentage combination. Pure black cotton soil exhibits the least amount of UCS generated stress, whereas 25% admixtures during 3 days of curing exhibit the greatest amount of induced stress. For combinations of 0%, 5%, 10%, 15%, 20%, and 25% admixtures, respectively, the highest induced UCS recorded after 3 days of curing is 96.81 MPa, 103.59 MPa, 110.84 MPa, 118.60 MPa, 126.90 MPa, and 135.78 MPa.

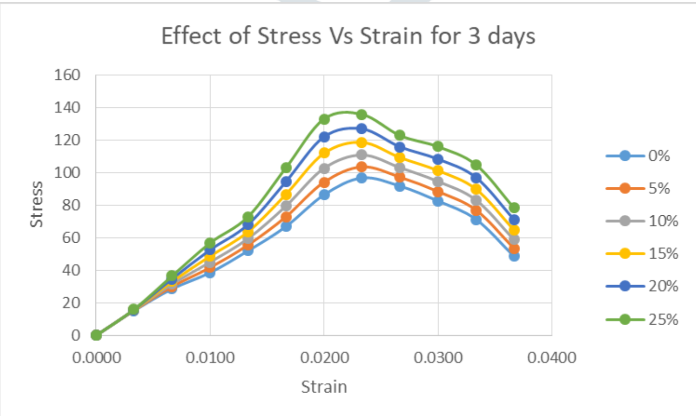

Figure 2: Stress Strain Data of UCS Test of 3 days for different percentage of admixtures

3.1.3 UCS test based for 7 days

The USC testing was carried out. A block of various Black Cotton soil, waste Marble Powder, and Ground Granulated Blast Furnace Slag admixtures was made. The percentage of GGBFS and Waste Marble Powder in the Black cotton soil mixture ranged from 0% to 25%. A block with a diameter of 50mm and a length of 150mm was constructed. The testing was carried out on a Universal Testing Machine. The testing was performed after 7 days of cure. The findings are presented in the table below. Every 0.5mm deformation resulted in a reading. It was discovered that when the strain increased, the stress created in the material increased. The specifics are shown in the graph below. The graph below demonstrates that as the proportion combination of GGBHS+WMP in the block grows, so does the stress caused. The larger the percentage combination, the higher the UCS. The least amount of UCS is caused by pure black cotton soil, whereas the most amount of stress is induced by 25% admixtures after 7 days of curing. For combinations of 0%, 5%, 10%, 15%, 20%, and 25% admixtures, the highest induced UCS recorded after 7 days of curing is 101.91 MPa, 109.04 MPa, 116.67 MPa, 125.51 MPa, 136.80 MPa, and 149.11 MPa, respectively.

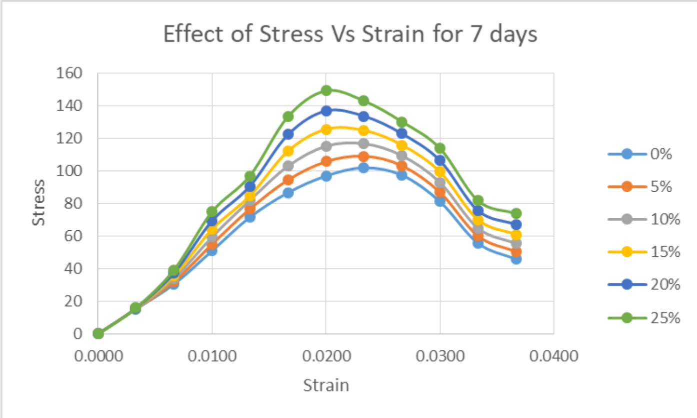

Figure 3: Stress Strain Data of UCS Test of 7 days for different percentage of admixtures

3.1.4 UCS test based for 14 days

The USC examinations were conducted. Blocks containing various combinations of Black Cotton soil, discarded Marble Powder, and Ground Granulated Blast Furnace Slag were fabricated. The percentage of GGBFS and Waste Marble Powder in the Black cotton soil mixture varied between 0% and 25%. The 150mm long block with a 50mm diameter was prepared. The testing was performed using a Universal Testing device. Testing was performed 14 days after cure. The results are displayed in the table below. Each deformation of 0.5 mm was accompanied with a readout. It has been shown that, as strain increases, so does the stress created in the material. The information is depicted in the graph below. As demonstrated in the graph below, as the percentage of GGBHS+WMP in the block grows, so does the stress caused. The UCS increases as the proportion combination increases. Pure black cotton soil induces the least UCS, but 25% admixtures produce the greatest stress after 14 days of curing. 14 days after curing, the highest induced UCS is 117.20 MPa, 125.40 MPa, 134.18 MPa, 153.62 MPa, and 164.64 MPa for combinations of 0%, 5%, 10%, 15%, 20%, and 25% admixtures, respectively.

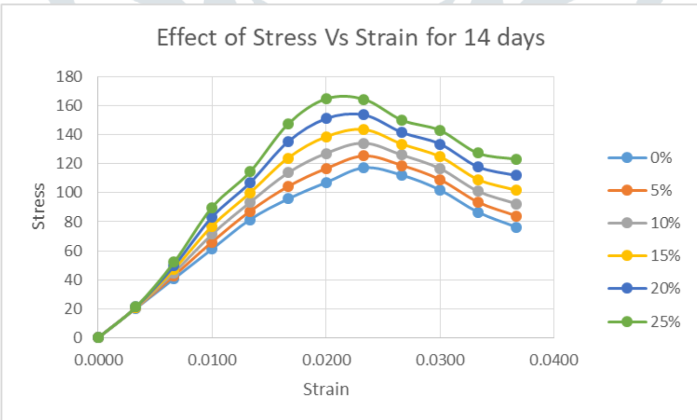

Figure 4: Stress Strain Data of UCS Test of 14 days for different percentage of admixtures

3.1.5 UCS test based for 28 days

The tests for USC were done. Mixtures of Black Cotton soil, waste marble powder, and ground granulated blast furnace slag were used to make the block. The amount of GGBFS and Waste Marble Powder in the Black cotton soil mixture ranged from 0% to 25%. The 150mm-long block with a 50mm-wide hole was made. Universal Testing machine was used to do the tests. At 28 days after curing, the tests were done. The results are in the table below. For every 0.5mm of deformation, a reading was taken. It has been seen that as the strain went up, the stress in the material went up as well. The information is shown in the graph below. The graph below shows that as the percentage of GGBHS+WMP in a block goes up, so does the stress that it causes. The UCS goes up as the percentage combination goes up. The least UCS is caused by pure black cotton soil, and the most UCS is caused by 25% admixtures after 28 days of curing. After 28 days of curing, the maximum induced UCS is

127.39 MPa, 136.31 MPa, 145.85 MPa, 156.06 MPa, 166.98 MPa, and 178.68 MPa, respectively, for combinations of 0%, 5%, 10%, 15%, 20%, and 25% admixtures.

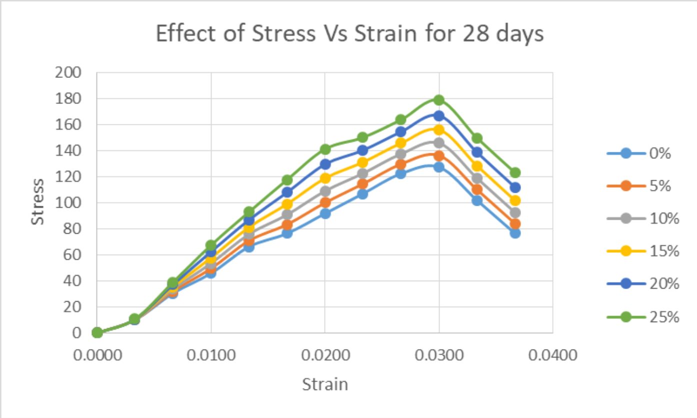

Figure 5: Stress Strain Data of UCS Test of 28 days for different percentage of admixtures

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 Sp. Gravity was found to be nearly same for different replacement levels

2.Liquid Limit, plastic limit and plasticity index of BC soil decreased with the addition of GGBFS and WMP. The addition of GGBFS causes flocculation of clay particles and increases the number of coarser particles which helps in reducing the Atterberg limits.

3.The variation in GGBFS and WMP content shown maximum UCS value at the replacement level of 5% and 10%. Unconfined compressive strength of admixed soil specimen increased by 35.71% with the increase in WMP content and GGBFS and found maximum UCS value at proportions 5 and 10 percent of GGBFS+WMP in equal proportion.

4.The maximum unsoaked CBR and UCS value obtained after stabilization with GGBFS and WMP was increased significantly as the replacement level increased.

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