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GROUND-GRANULATED-BLAST-FURNACE-SLAG AND SUGAR CANE MOLASSES INFLUENCE ON STABILIZATION OF CLAYSOIL

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ABSTRACT: For the soil stabilization, the usage of by-product of the industrial waste is feasible environmentally, socially as well as economically. Clayey soils are normally firm when they are dry and lose their stiffness as they become saturated. The decrease in strength of clay soil because of moisture leads to serious damage to structures and foundations. The objective is to propose an effective and low-cost stabilization technique for clayey soils using sugar cane molasses and Ground-Granulated-Blast-Furnace-Slag (GGBFS). GGBFS is used by the laboratory injection method to investigate stabilizer effect for the disturbed samples of clayey soil. In the past many researchers worked on GGBFS but the sugar cane molasses hasbeen discussing very few times in literature that's whywe use this one and then compare with GGBFS. Effects of sugar cane molasses and GGBFS have been evaluated by Specific gravity, Atterberg's limits, Compaction, California bearing Ratio (CBR) and unconsolidated-undrained (U-U) triaxial tests. Laboratory results revealed that by increasing the stabilizer content in the parent soil have significantly reduced the Atterbeg's limits while CBR value and shear strength of soil has increased. It has been observed in this research work that the GGBFS, quite low-cost material, has given far better results than the Sugar cane molasses.

Keywords: Stabilization; sugar cane molasses; Ground-Granulated-Blast-Furnace-Slag; GGBFS; clay soil.

INTRODUCTION

Soil is economical and laid-back material used for engineering purposes, so it is also essential to learn about the characteristics or feasibility of soil. One primary parameter is that the variation in the soil's features and engineering properties vary according to the change in the soil's region and climate(Mohd and Ved-Parkash, 2015) "Clayey soils are highly plastic soils that typically contains clay minerals such as montmorillonite that attract and absorb water", (Khurana *et al.*, 2015). Severe distresses are caused by clay soilsto various structures. "The problems associated with clay soils include heaving, settlement of soil,cracking in the building,pavements failure, channel linings, foundations of buildings and reservoir(Taye and Araya, 2015). Clay soils had caused damage to the light structures built upon it, like residential and commercial buildings, underground utilities and pavements(Zhao *et al.*, 2014).Problematic clay soils are defined by high compressibility and low strength. The main factors for improvement of soil are following shear-strength improvement of soil, potential reducing for settlement, liquefaction potential reducing, reducinghydraulic fills or saturated fine sand, hydraulic conductivity reducing etc.(Soon *et al.*, 2013). Stabilization of soil processesin whichwe improve the soilshear and strength propertieswithin the economical construction cost(Mohd and Ved-Parkash, 2015). Therefore, different techniques have been developed to solve this a problem like mechanical compaction,chemical stabilization, surcharge loading, organic compounds treatment, pre-wetting, stone dust stabilization, lime stabilization, Rice Husk Ash stabilization,cement stabilization and fly ash stabilization or many other techniques used.(Mohd and Ved-Parkash, 2015).

Soil stabilization by chemical agentsreduces the cost of Buildings and infrastructure. A chemical stabilizer is used to improve the properties of weak and low strength clay soils(Ureña Nieto, 2014) Such kind of weak soils can be referred to as problematic soils.

Chemical stabilization in pavement construction has been widely used in many parts of the world. In Ethiopia, theERA primary use of cement and lime stabilization had so far been used with gravelly soils to produce road bases. Non-traditional stabilizers that have been introduced to the country including RBI Grade 81, CON-AID, SS44/LS40, Pure Crete, Anyway Natural Soil Stabilizer and Zym-Tec Enzyme (M'Ndegwa, 2015)

Sandeep Panchal and Sharma used the bio-enzyme for the clay soil stabilization by adding the different percentages of the bio-enzyme mixed with a soil sample and observed the increase in CBR value (Panchal *et al.*, 2017).

The broad objective of this research is to investigate the suitability of sugar cane molasses and GGBFS effects on clay soil stabilization by increasing their bearing capacity and increasing shear strength. The specific objectives were investigating the response of the expansive clay soils through the application of the sugar cane molasses alone and GGBFS alone at various contents as well as to make comparisons on the effect of stabilizers on soils treated with prescribed stabilizers.

(Soon *et al.,* 2013) had worked on artificially prepared expansive soil by GGBFS and GGBFS-Cementstabilizers. GGBFS and GGBFS-Cement were intercalary in proportions of 5 to 25 percent at 5 percent associate increment. It had been telling that the stabilizers belittled the overall quantity of swell wherever because the swell rate wasnoted that to be enhanced. (Sharma and Sivapullaiah, 2016) had utilized the effect of GGBFS on UCS of clay soilat different intervals of the curing (7,14and 28) days. Concluded that the development of the strength although it depends on proportion of GGBFS, the impact of this activity was less prominent. By increasing the content of GGBFS the initial tangent modulus values also increased. (Sabat and Pati, 2014) had utilized the influence ofcompaction delayedby adding the GGBFS and cement stabilizers in soil on black cotton soilstrength characteristics. Concluded thatthe strength of the soil decreases by the delay in compaction. (Celik and Nalbantoglu, 2013)had investigated the influence of GGBFS on PI, SP and L, and SPof lime stabilized sulphate-bearingclaysoil. Theyconcluded that by mixing the GGBFS the ettringite mineral growth was prevented, which resulted in areduction of the SP, LS,andPIof lime stabilized clay soil.Osinubi told about compaction delaying effect on black cotton with GGBFS and cement characteristics of strength.It was found that delay in compaction decreases the stabilizer strength.

Sabat and S. Pati (Sabat and Pati, 2014)had investigated the results of lime sludge and Sugar Cane syrup on, UCS, MDD, CBR, and OMC of clay soil to review its value effectiveness in strengthening the soil of flexible pavement in the region of clay soils. Mahendran and N. P. Vignesh (Mahendran and Vignesh, 2016) verified that sugar cane syrup is often an efficient soil stabilizer. M'Ndegwa (M'Ndegwa, 2011)suggested that the clay soil stabilization `with syrup accumulated the values of CBR and load-bearing ability of the soil. Also, molasses decreases the tendencies of clay soil. Sugar cane molasses could be viscous byproduct of the process of sugar cane into sugar. In Yaltopya sugar production quantity was 21.7 million tons within the year of 2010; but, in 2016 this quantity went to be accumulated to fifty-one million tons (Kamski, 2016) due the sugar demand Increasedthe generation of cane molasses material also raised that constitutes concerning 30 minutes - 40 you look after sugar volume. molasses contains an adhesive and a few inorganic mineralsthat render it not fit for human uses. syrup might cause environmental pollution if spills don't seem to be properly cleaned. It may also cause pollution if anindustrial plants or spills liquid waste enter the watercourse. If we have a tendency to use this waste for the stabilization of the clay soil forestall the environmental pollution.

MATERIALS AND METHODS

Soil*:* Clayey soilsamples were collected from clayey deposits of Taxila Punjab Pakistan regions. The soil samples were collected from the depth of 1 to 1.5ft below from the ground surface in a disturbed state. During the soil sample taking avoids from the grabbing and vegetation. Then dried these samples or pulverizing by using the wooden mallet. Then these processed samples were used for the various experimental investigation.

Ground-granulated-blast-furnace-slag(GGBFS): GGBFS is a byproduct of the steel and iron industry having oxides similar to that of cement but in varies percentages. It is generally obtained in three shaped one is air cooled, foamed shaped and in granulated shaped. The use of byproduct materials for stabilization has environmental and economic benefits. (Das *et al.,* 2007) GGBFS material is used in the current work to stabilize clay soil. For the replacement of Portland cement GGBFS can be used ranging from 35%-70% by mass. GGBFS was purchase from Lahore iron industry on 11 April 2018.

Molasses: Sugar cane Molasses is a terribly sugar cane process by-product with thick dark brown liquid (Saric, 2016) it is additionally known as treacle. It may cause pollution if manufactured or spills effluents enter in watercourse streams. Some agents of clarification and evaporator are added into the sugar processing like Sulphur dioxide and lime or others during the sugar juice crystallization which reacts with the clay soil to change the clay soil properties most probably. (M'Ndegwa, 2011). During the stabilization by molasses of the clay soil the two main reaction are carried out flocculation-agglomeration and cation exchange.

During sugar process, some materials are additionally added into the method as clarification agents and evaporator decadents. These materials embrace Sulphur dioxide and limewith others throughout juice of sugar crystallization, those components stay in molasses and are then enclosed within the ingredients of natural syrup.(M'Ndegwa, 2011)

Dark brown strap syrup sample was purchased from city sugar manufactory molasses storage tanker on 06 March 2018.

Sampling method: The soil sample which pore structure and bulk density doses not preserve after taking the sample called disturbed soil sample. Samples of soil were collected in Disturbed statefrom the site of HMC Taxila.

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Laboratory Testing: The testing procedures involved mixing the soil with the stabilizer before compacting the soil into the molds. Four specimens were created for each soil treated with different percentage of stabilizers. The first specimen was compacted immediately after completion of mixing. Each specimen was covered with plastic bags to prevent moisture content loss before testing.
Following tests were carried out:

Sieve Analysis: After removing any unusually big particles like stonethansieve analysis testwas performed. According to the ASTM standard D422.

Atterberg's Limit Tests: Theatterberg's limit test like liquid limit (LL) and plastic limit (PL) tests performed to determine water content for change in states according to ASTM designation D4318.

Specific Gravity: Thistest was performed to determine effect of adding GGBFS and Molassesto soil particles. Each specimen was mixed with GGBFS and Molasses at different treatment. The pycnometer test is the appropriate method to determining specific gravity of the soil. According to ASTM standards D-854.

RESULTS AND DISCUSSION

Specific Gravity: The figure 1 curve of the GGBFS shows that the clay soil specific gravity decreases with an increase in the percentage of the GGBFS in the clay soil but very slowly. While molasses content up to an 8% increase, the specific gravity decreases rapidly as compared to GGBFS. Molasses is more effective at 8% if we increase the content of molasses specific gravity of the clay soil decreases because of moisture content increases in weak soil particles bonds.

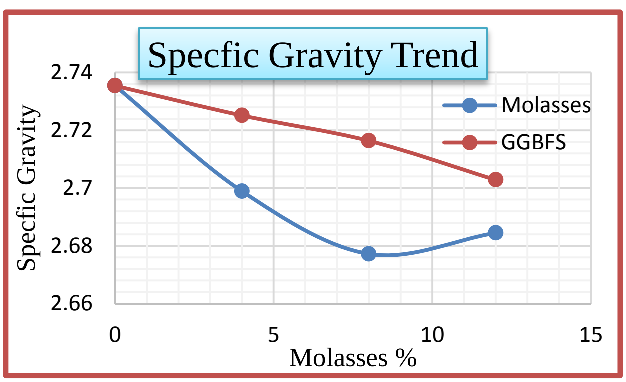

Figure-1 Molasses and GGBFS % versus Specific Gravity.

Plastic index (P-I): The plastic index (P-I) is an effective factor to control the swelling effect of the clay soil.(Celik and Nalbantoglu, 2013)In figure-2 the curve tells the PI of the clay soil decreases with an increase in the percentage of the GGBFS. By adding GGBFS into the soil plasticity index reduces and consequently decrease in the soil swell potential values. But when molasses content increases up to 8% the specific gravity decreases if more increase then the plastic index of the clay soil also increases. When molasses added in the clay soil bonds between the soil particles become stronger and soil converting to granular soil but when we increase the molasses content more than 8% the moisture content increase and reduce the bond strength.

Modified Proctor Test: This test was performed on the clay soil with or without the stabilizer to find the clay soil moisture and dry density relationships at different content of the molasses and GGBFS according to the ASTM standard D698

California Bearing Ratio (CBR)test: This test is a penetration test performed on the soil for evaluation of the penetration resistance and mechanical strength according to the ASTM designation D 1883-07 at Soil sample with various amounts of molasses and GGBFS. The rate of the penetration was 1.25 mm per minute. For four days the samples were soaked before performing the experiment.

Unconsolidated-Undrained(U-U) triaxle test: To examine the behavior of the strength of stabilized soil in detail, four soil samples were treated with different percentage of molasses and four for the GGBFS were tested for unconsolidated-undrained (U-U) triaxle tests to determine short term strength improvement of soil. The laboratory test was very important because it allowed assessment of the suitability of soil stabilized as material for dam embankment construction to be carried out.

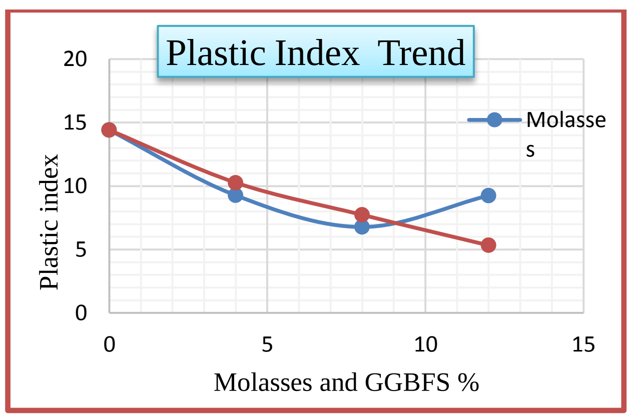

Figure-2 Molasses and GGBFS % versus Plastic Index (P-I).

California Bearing Ratio (CBR): In figure -3 the molasses curve shows that the CBR value of the soil increases by mixing the molasses content in the clay soil up to 8% due to the presence of magnesium and calcium cations which decreases the pH of the soil by weaker monovalent ions of sodium displaced from the clay soil. The molasses increased the stability of the soil by the attraction of electrostatic particles and flocculation. That's why the stronger bond formed between the soil particles and increase in the CBR value up to 11%. But when we increase the molasses content the CBR value decrease. The reason is that the soil particles are coated by molasses and its thickness also increased. That's why it increased the distance between the particles and weak the bonding. The GGBFS curve shows that the CBR value of the soil increases up to 18% by mixing the 4% and 8% GGBFS content in the clay soil. With the high content of the stabilizer, the reaction of pozzolanic does not carry out .(Sharma and Sivapullaiah, 2016).

Unconsolidated-Undrained Triaxial Test: The figure-4 shows that molasses curve of unconsolidated-undrained (U-U) compression strength of the clay soil increase up to 380 kPa by mixing the molasses content in the clay soil up to 8% due to the presence of magnesium and calcium cations but when to increase the molasses content the U-U compressive strength value decreased. The reason is that the soil particles are coated by molasses and its thickness also increased. The figure-4 shows that GGBFS curve of Unconsolidated-Undrained (U-U) compression strength of the clay soil increase up to 400 kPa by mixing the GGBFS content in the clay soil up to 8% due to reaction of pozzolanic of silica with calcium in the consequences cementitious compounds formed the as calcium–aluminate–hydrates (C–A–H), calcium–silicate–hydrates (C–S–H),) and. calcium aluminum-silicate–hydrates (C–A–S–H) that's why the compressive strength of soil increased. The reaction of the pozzolanic did not occur after a certain level of an increase in stabilizer and decreases the strength of the soil.

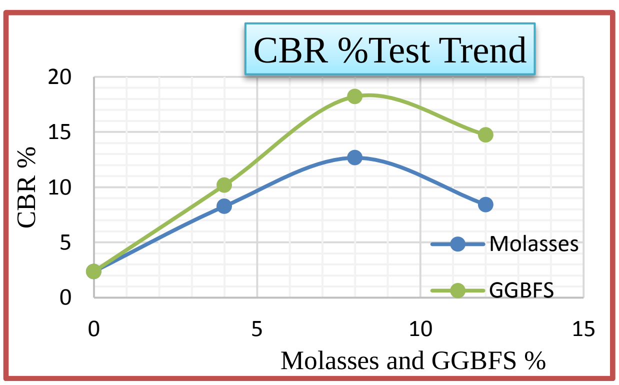

Figure-3 Molasses and GGBFS % versus CBR%

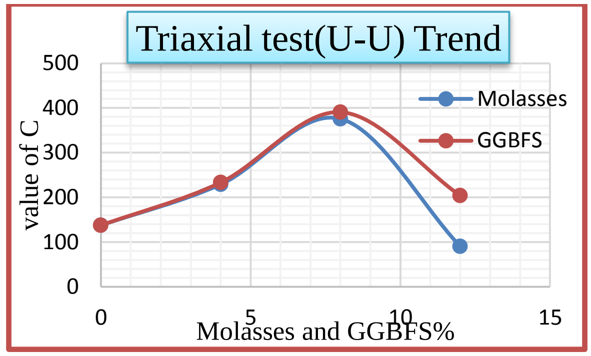

Figure-4 Unconsolidated-undrained compressive strength.

Conclusion: It can be observed from this research work that increasing the molasses content decreases the expansion characteristics of soil. Similarly increasing the GGBFS content decreases the expansion characteristics of soil up to certain extent. From the results, it is concluded that with the increase in content of molasses from 0% to 8% will reduce the expansion of soil and improve its stability. But when we increase the molasses content more than 8% the moisture content increase reduces the bond strength of the soil particles. Use of molasses for controlling the expansion of soils is an economical solution. Use of GGBFS for controlling the expansion of soils is more economical solution although it provides more better results(Sharma & Sivapullaiah, 2016) but they are not properly collected in Pakistan and also after addition in more than 8% it's strength start decreasing because fine particles will start to replace the soil.

Recommendations: This research finding can be reinforced by soil sample of clay soil are collecting from other potential sites and checking their adequacy to be stabilized using each of the above-mentioned stabilizers working on the same lines. Stabilizers other than the above mentioned can be used to propose a better, effective and low-cost stabilization the technique for Taxila and other potential sites, e.g. marble powder, sand mixing, pieces of plastic bottles. While working on the sample from potential sites for expansion, another useful testing should also to be carried out like swell potential testing to get a more reliable data for evaluating the parent sample as well as for finalizing the most efficient stabilization technique. This research may be extended to investigate the influence of the mixture of both types of additives in different percentages used in this exercise. This research has been carried out on A-6 soil. Based on the same guidelines, the work should be continued to propose the low-cost stabilization techniques for A-7soils as well.

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Table-1: Performance Results:

Soil sample	Percentage	Specific Gravity	Plasticity Index	CBR % value	Shear strength(c)
Without stabilizer	**0%**	2.73	14.4	2.37	137.49
With	**4%**	2.69	9.13	8.27	229
Molasses	**8%**	2.67	6.77	12.66	375.98
Stabilizer	**12%**	2.68	9.25	8.42	90.12
With	**4%**	2.74	10.26	10.19	233.23
GGBFS	**8%**	2.71	7.73	18.21	390.64
Stabilizer	**12%**	2.7	5.53	14.74	203.8