Enhancement of Shear Strength of Sand-Slag Mixture Using Wood Sticks

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Abstract - *Sand is a granular material, composed of finely divided rock and mineral particles. In certain situations, sand is required to have extra shear strength to provide more safety, stability and support for structures. Shear strength in sand arises from friction and resistance between particles. The most common means of increasing the shear strength of sand is the cementation method and addition of slag. Some studies show that wood has also been used to improve soil strength, mostly for soft and expansive soil. However, there is limited information available on sand. Therefore, the purpose of this research is to determine whether the shear strength of a sand-slag mixture is affected by the addition of wood. The shear strength of the sand-slag-wood material was determined using a direct shear testing machine. The results showed that the shear strength of the sand-slag mixture tended to be enhanced by the presence of wood. The sand-slag mixture containing wood seemed to be stronger than the sand-slag without wood or the pure sand. The position of the wood also contributed to the improvement in shear strength. From these results, it can be concluded that wood is another potential means of enhancing the shear strength of sand-slag mixture. GGBS slag gave best shear strength when 2% slag used with sand in dry condition and 3% in wet condition. As the quantity of wood increases, and the way its arrangement changed, such as distance and direction, resulted in improvement of the shear strength of the sand-slag mixture.*

Key Words: Wood sticks, Sand- slag, GGBS slag, Shear strength, River sand.

1. INTRODUCTION

Sand is a granular material that composed of finely divided rock and mineral particles. It is defined by size, being finer than gravel and coarser than silt. Sand can also refer to a textural class of soil or soil type; that is, a soil containing more than 85 percent sand-sized particles by mass.

The composition of sand varies, depending on the local rock sources and conditions, but the most common constituent of sand in inland continental settings and non-tropical coastal settings is silica (silicon dioxide, or SiO_2), usually in the form of quartz. The second most common type of sand is calcium carbonate, for example, aragonite, which has mostly been created, over the past half billion years, by various forms of life, like coral and shellfish. For example, it is the primary form of sand apparent in areas where reefs have dominated the ecosystem for millions of years like the Caribbean.

Soil Stabilization is the alteration of soils to enhance their physical properties. Stabilization can increase the shear strength of a soil and/or control the shrink-swell properties of a soil, thus improving the load bearing capacity of a sub-grade to support pavements and foundations. Soil stabilization can be done with cement, bitumen, lime, chemical stabilization, geotextile, grouting etc. It is a method of improving soil properties by blending and mixing other materials.

1.1 Soil stabilization using slag and wood

Ground-granulated blast-furnace slag (GGBS or GGBFS) is obtained by quenching molten iron slag (a by-product of iron and steel-making) from a blast furnace in water or steam, to produce a glassy, granular product that is then dried and ground into a fine powder. It is a granular product with very limited crystal formation, is highly cementitious in nature and, ground to cement fineness, and hydrates like Portland cement. GGBS is used to make durable concrete structures in combination with ordinary Portland cement and/or other pozzolanic materials

Adding GGBS to sand had shown significant improvement in its strength properties. Shear stress or shear strength of the soil is a very important factor in reviewing the stability of the soil. Shear strength is mainly influenced by two soil shear strength parameters, namely the cohesion and friction angle. Soil shear strength is important in analyzing the stability of a slope and analysis of the subgrade bearing capacity of the foundation. Therefore, soil strength analysis and careful design are required to avoid structural failure arising from the collapse of the soil structure and prevent the undermining of the basic foundation of the structure built upon it.

There has been an increase in the use of chemicals (chemical additives) for land improvement, such as cement lime, slag and fly ash, due to the ease of use of these materials. Portland composite cement (PCC) is especially popular due to its availability on the market and the relative ease with which it can be used in the field. However, a very high shear strength indicates that soil stabilized with cement tends to be brittle and has a low tensile strength. This means the soil is less satisfactory for use as construction material which needs to be strong but ductile. In the meantime, the addition of wood has been found to improve the tensile strength of soil.

The addition of wood to soil was usually studied in cohesive soils. There are not many researchers conducted on addition of wood to sand. For this addition of slag to sand was found to be better alternative in order to make a well graded condition. Addition of Wooden sticks can improve soil strength, mostly for soft and expansive soil but there is only limited information about wood addition on sand. When Additives alone are added, it tends to make soil brittle with low tensile strength. Addition of wood sticks improves tensile strength, which improves shear strength of soil. Application of wood to this sand-slag mixture seemed to provide more frictional resistance also and thus improvement in shear strength of soil. The shear strength of the sand-slag-wood material can be determined using a direct shear testing machine.

This study intent to test the effect on soil shear strength of adding wood to sand containing various percentages of slag. The aim of this study is to determine whether the addition of wood to slag-stabilized sand is a viable alternative for improving soil shear strength. Moreover, the application of wood may be a more sustainable solution for soil stabilization.

1.2 Objective and scope of the study

The main objective of this experiment is to determine whether the addition of wood to slag-added sand is a viable alternative for improving the shear strength of soil. Hence direct shear test was carried out to test the shear strength of soil with addition of wood sticks. The tests were carried out at dry and wet conditions. The suitable amount of slag percentage to be added was found using testing with different percentage of slag such as 1,2 and 3%. The optimum value was selected and added wood sticks. The configuration of wood sticks, whether horizontal or vertical and the spacing between the wood sticks that would give optimum shear stress were tested.

2. MATERIAL USED

2.1 Sand

The sand chosen for the study was a river sand, that shown in figure1, is obtained from Kadalundi river side near Nooradi, Malappuram. The sand was air dried for conducting all the laboratory tests. The grain size distribution was found using IS: 2720-part 4.

Fig -1: River sand from Kadalundi river

2.2 Slag

Slag is an addictive which is widely used in structural engineering. The addition of slag to soil is a recent interest of the researchers. The slag used in this experiment is ground granulated blast furnace slag (GGBS), and was obtained from quenching molten iron slag (a by-product of iron and steel-making) from a blast furnace in water or steam, to produce a glassy, granular product that is then dried and ground into a fine powder. GGSB contains chemical compounds including CaO, SiO_2, Al_2O_3, and MgO. Figure 2 shows the GGBS slag used for the study. Table 1 shows the chemical contents in GGBS Slag.

Fig -2: GGBS Slag

2.3 Wood

The wood employed in this experiment was aspen timber. Since the experiment only needed a small quantity of wood, and considering the limited length of wood that can be accommodated by the small direct shear machine, it was decided to use the wood from 'Redheads' matches. The wood was prepared by removing the tip of the matches which contain the chemical mixture that forms the heads. The initial moisture content of the wood was 12% with a specific gravity of 0.36. Figure 3 shows the matches used in experimental study.

Fig -3: Match sticks

3. METHODOLOGY

The materials such as sand, slag and wood sticks are collected prior to the experiment. The engineering properties of sand was found using sieve analysis, specific gravity test, relative density test, permeability tests and direct shear test. The direct shear test was done both dry and wet conditions. Test was conducted for 50,100 and 150 KPa loads. The optimum amount of water found based on cementation property of GGBS slag. Then adding 1%, 2%, 3% and 4% slag with sand test was again conducted in both dry and wet states. The optimum value is selected and added wood sticks in vertical and horizontal alignment to find the best configuration. Vertical configuration seemed to give more shear strength. The spacing between the wood sticks changed and tested for its effect on shear stress using direct shear test.

Fig -4: Sand-slag mixture in dry condition

Figure 4 shows the Sand-slag mixture in dry condition and figure 5 shows the mixture of sand and slag in wet condition that is used in the study.

Table -1: Chemical content of GGBS slag

Calcium oxide (CaO)	30–50%
Silica (Amorphous CaO)	35–40%
Aluminium oxide (Al_2O_3)	5–< 5%
Sulphur (S)	15%

Fig -5: Sand-slag mixture in wet condition

3.1 Sand-slag mixture

The direct shear test was used to obtain the failure stresses for each composite and the failure data was then used to calculate cohesion and friction angle. Direct shear tests series were conducted to examine the shear strength of the sand composite, starting with the pure sand specimen, progressing to the sand containing various percentages of slag, with wet and dry condition and finally to the sand-slag mixture with added wood. The moisture content needed for wetting was about 5% of water. The percentages of slag introduced to the sand specimens were 1%, 2%,3% and 4%. The direct shear test was run based on IS 2720 part 13–1986. Prior to shear testing, the sample was loaded into and compacted in a 60mm x 60mm shear box layer by layer according to its density. Three normal stresses of 50, 100 and 150 kPa were applied in each series of tests for all samples.

The shear strength of dry sand slag mixture is done using different loading conditions such as 50 kPa, 100 kPa and 150 kPa. 1%, 2% and 3% slag are added with sand and tested in each loading conditions. The optimum value in dry condition was obtained when 2% slag was added to sand to make the mixture as shown in chart 1. From chart 2 it can be seen that the maximum shear stress obtained is 1.023 Kg/cm^2.

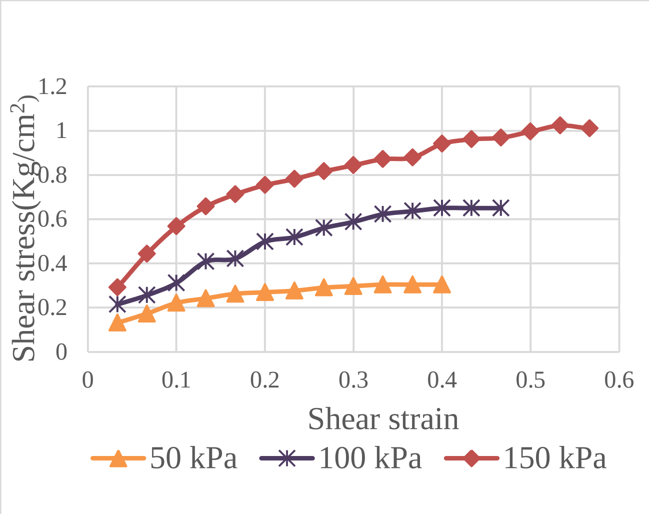

Chart -1: Shear stress vs shear strain graph of 2% slag-sand dry mixture

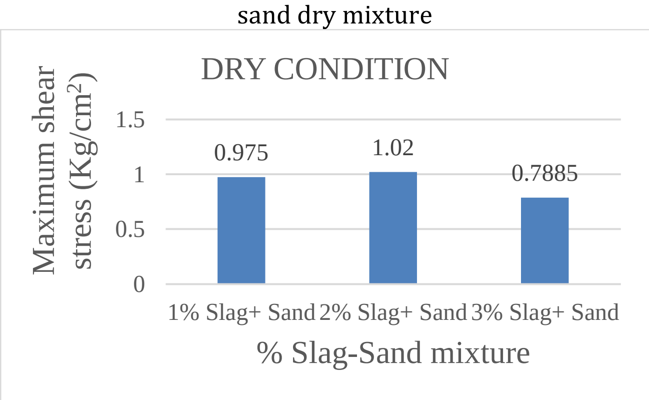

Chart -2: Comparison of Maximum shear stress of sand-slag mixture in dry condition

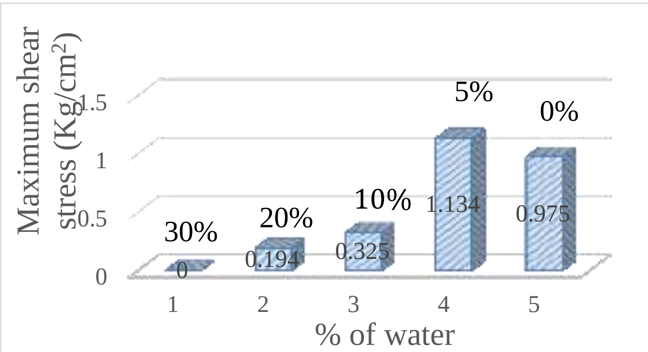

Chart -3: Maximum shear stress v/s Percentage of water content graph

The optimum water content needed for wet condition is found by testing the sand-slag mixture, using direct shear tests with various percentage of water such as 30%, 20%, 10%, 5% etc. When 30% water was added, it was of slurry form and sheared quickly. On using 20% water content, the paste or mix was loose. Thus, the value of direct shear test result was lesser than the without water condition. When 10% water is provided for testing, the mixture was still in a loose condition, yet readings were available in loading conditions. On further decreasing the water content, the optimum water content was found to be 5%. Therefore, 5% water content is adopted for further testing in wet condition as results obtained from chart 3. The test is conducted using 5% water, that is 8.285 ml water with 1%, 2%, 3% and 4% slags, using 50, 100 and150 kPa loads.

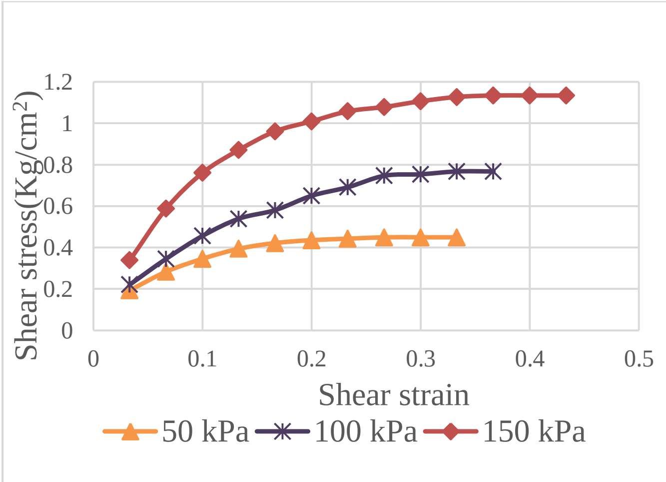

Chart -4: Shear stress vs shear strain graph of 3% slag-sand wet mixture

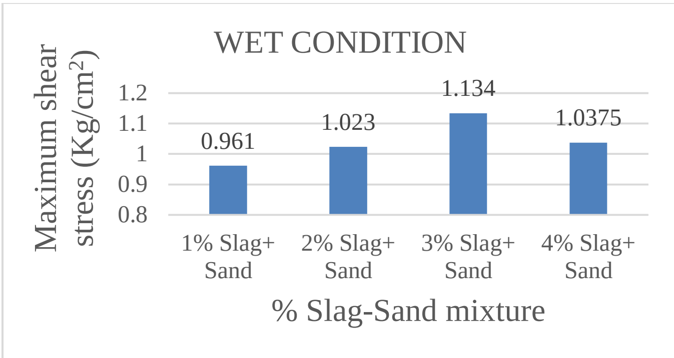

Chart -5: Shear stress vs shear strain graph of 3% slag-sand wet mixture

Chart 4 shows the 3% slag with sand mixture in wet condition. The maximum shear stress was obtained when 3% slag -sand mixture is tested in wet condition as obtained from chart 5. This mixture is used for further tests that include addition of wood sticks in various configurations.

3.2 Application of Wood Sticks to Sand-Slag Mixture in Wet Condition: with Horizontal Configuration

In wet condition, the 3% slag- sand mixture is used and the direction provided is horizontal configuration. The spacing in between vertical direction is varied, 12mm and 8 mm. The figure 6 shows provision of wood sticks in horizontal direction in 3% sand -slag mixture.

Fig -6: Alignment of wood in horizontal direction

3.3 Application of Wood Sticks to Sand-Slag Mixture in Wet Condition: with Vertical Configuration

In wet condition, the 3% slag-sand mixture is used and the direction provided is vertical configuration. The load applied were 50, 100 and150 kpa. The spacing in between vertical direction is varied, 12mm and 8 mm to find the relationship of spacing with shear stress.

Fig -7: Alignment of wood in vertical direction with12 mm spacing

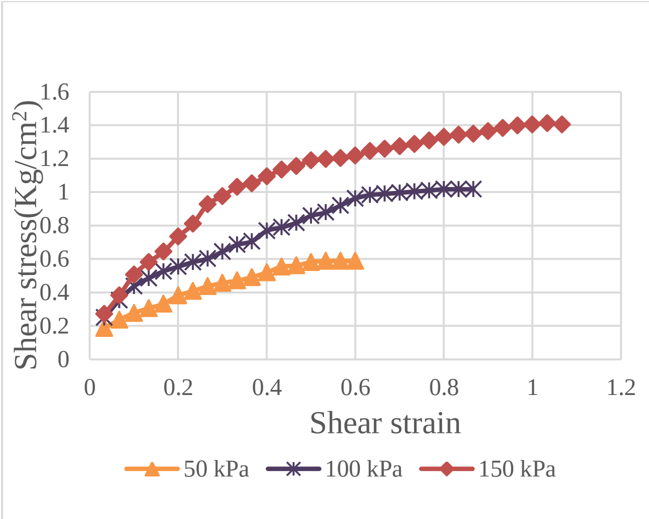

Chart -6: Shear stress vs shear strain graph of 3% slag-sand wet mixture with wood sticks in vertical direction with spacing 12 mm

The arrangement of wood sticks provided in vertical direction with 12 mm spacing between the wood sticks is done as shown in figure 7. Here 4x4 arrangements with 16 wood sticks of 20 mm length and 2 mm width is provided. The maximum shear stress obtained was 1.404 Kg/cm^2 at 150 kPa.

The arrangement of wood sticks provided in vertical direction with 8.3 mm spacing between the wood sticks is done as shown in figure 8, given below. Here 5x5 arrangements is done with 25 wood sticks of 20 mm length and 2 mm width.

Fig -8: Alignment of wood in vertical direction with 8 mm spacing

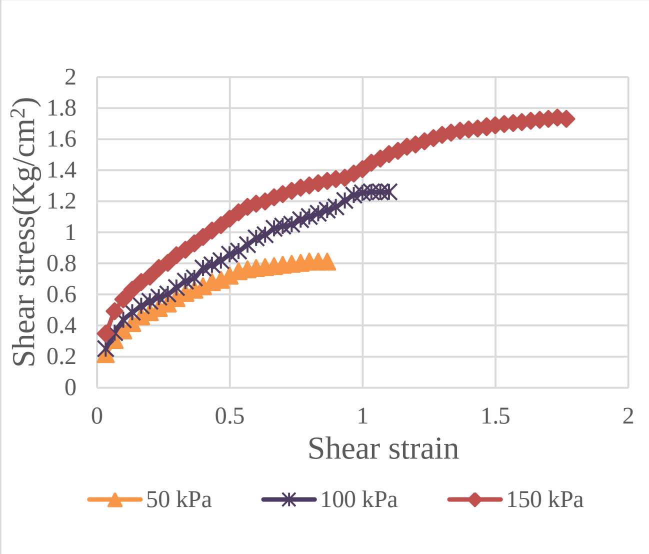

Chart -7: Shear stress vs shear strain graph of 3% slag-sand wet mixture with wood sticks in vertical direction with spacing 8 mm

Chart 7 shows that the maximum shear stress obtained was 1.729 Kg/cm² at 150 kPa with 8 mm spacing and the angle of internal friction obtained is 21°.

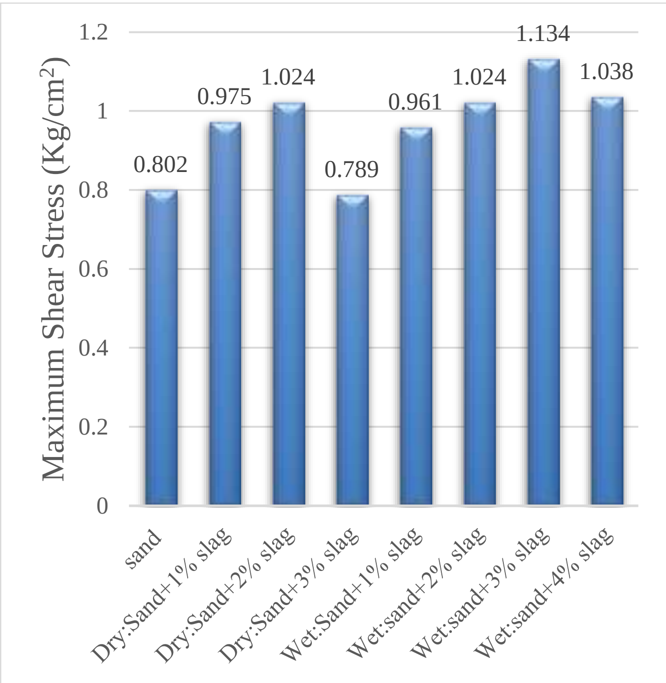

Chart -8: Comparison of Various Sand-Slag Mixtures with Maximum Shear Stresses

From the chart 8, it can be concluded that 2% slag gives maximum shear strength in dry condition, where as 3% slag provide maximum shear stress in wet condition.

Chart 9 gives the comparison of various arrangement of wood to sand-slag mixtures with maximum shear stresses.

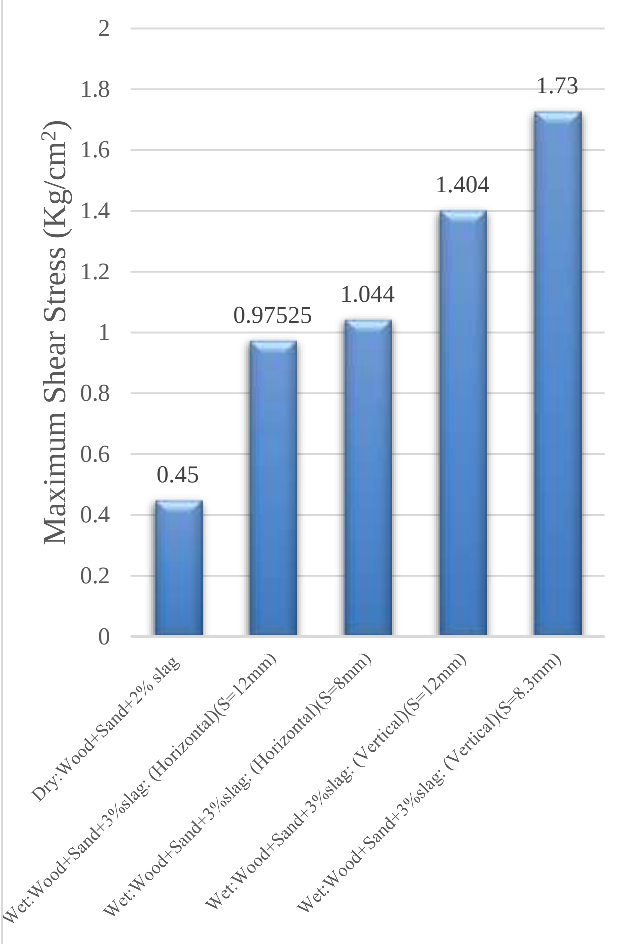

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Chart -9: Comparison of Various Arrangement of Wood to Sand-Slag Mixtures with Maximum Shear Stresses

From experiment results, it can be found that the maximum shear stress was obtained when 3% slag-sand mixture was used in vertical configuration of wood addition with 8.3 mm spacing. As spacing decreases, shear stress increases. Also, greater the quantity of wood, the shear stress is also great.

3. CONCLUSIONS

A series of direct shear tests were applied to sand-slag and wood mixtures. The percentages of slag added to the sand were 1%, 2% and 3%, 4% and the results showed good potential for the application of wood or slag. Based on the preliminary tests, the amount of wood introduced to the sample was calculated as a percentage based on the top surface area of wood and sand sample. The wood was then placed in a position vertical to the shear direction, as this configuration seemed to provide the optimum result. In this experiment, by adding wood into sand-slag mixtures, the shear strength of the mixtures increases significantly.

❖ Wood appears to improve the shear strength performance of sand-slag mixture by various degrees, from 0.802 to about 1.73, when normal stresses of 50 kPa, 100 kPa and 150 kPa are applied. ❖ Optimum water content for wet condition was obtained when 5% water was used. ❖ The greatest improvement in shear strength occurred when 150 kPa of normal stress was applied to the mixture. ❖ The highest shear strength was seen in the sand mixture containing 3% slag under all normal stresses applied in wet condition. ❖ The highest shear strength 2% in dry condition. ❖ Wet condition is more preferable than dry condition to achieve more shear stress. ❖ As spacing decreases the shear strength increases. ❖ As the quantity of wood increases, shear stress also increases.

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