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Utilization Waste Granulated Blast Furnace Slag to Improve the Properties of Polluted Soil with Crude Oil

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Abstract. Utilization of waste materials in the treatment of challenging polluted soils is a cost-effective and environmentally responsible strategy, as it helps to reduce disposal issues created by diverse industrial wastes. The aim of this research is to utilize waste material Ground Granulated Blast Furnace Slag (GGBFS) to enhance several engineering characteristics of polluted soil with crude oil. The engineering characteristics of clean and polluted soils with crude oil were investigated and compared to controls. Three percentages of crude oil 3%, 6%, and 9% were artificially mixed with clayey soils by weight. The effects of Ground Granulated Blast Furnace Slag on the compaction properties (OMC and MDD) and shear strength characteristics (cohesion and angle of friction) of the soil were studied. Different percentages of GGBFS (12%, and 18%) by dry weight were utilized in mixtures of soil samples for different experiments. Ultimately, bases on the experimental results, it is summarized that the use of industrial wastes, i.e. GGBFS are affected in shear strength and compaction properties. Although, they have environment-friendly behavior for the construction project purpose.

INTRODUCTION

Waste is a multiphase medium. That is, it should comprise solid, liquid, and gaseous elements. Many factors separate wastes from soil but they may compare in terms of classification. Different people, organizations and agencies have proposed different systems of classifying soil. Some of these systems derive from a regulatory, governing or management theoretical perspective while others from geotechnical aspect [1]. Pollution of soil with crude oil happened after various causes such as refineries, pipeline broken, trucks accidental and oil tanks. Extreme environmental contamination has resulted from unexpected oil spills and leaks. Oil pollution may adversely affect soil microorganisms and plants, in addition to polluted groundwater supplies for agriculture and human uses. [2]. GGBFS was used to improve durability, chloride resistance, and sulfate resistance. Aside from that, it's been utilized with lime to enhance the soil. As a result, it is very effectual in combating the extension connected with Sulphate in the soil. [3].

GGBFS is essential for improving the reuse of iron and steel industry waste in a sustainable manner by-product in a contaminated area. A fine powder called GGBFS is created by drying granulated blast furnace slag and then crushing it. [4]. GGBFS is a by-product of the iron and steel production process that is generated as a waste product. A significant amount of waste materials is produced as a result of the fast growth in iron and steel production across the world. The decomposition of GGBFS in landfills may lead to environmental hazards. Consequently, utilizing

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GGBFS waste material as an addition to soil contaminated may be a viable option that will aid in the reduction of pollution of environmental.

Furthermore, waste material may get acquainted with the soil, causing the soil to be modified. Because of this, it is necessary to conduct a thorough research, which should be adapted to local materials and circumstances, in order to consider the possibility of using GGBFS in the stabilization process of the soil [5].

It is necessary to enhance the soil in connection with the construction of the road, the pavement, and the foundation. In addition, it enhances the soil's engineering characteristics. In addition to improving bearing capacity, durability will also improve resistance to erosion as the strength of the material increases. [6]. The hydrocarbon pollution will have an impact on more than simply the soil's condition. In the case of oil-contaminated soil, however, it will also change the physical characteristics of the soil.

As a result, there will be technical difficulties throughout the building and foundation structure of the oil-contaminated site. The most common consequences of oil contamination are an excessive amount of sedimentation in tanks and the rupture of a pipeline.

The volume of clay soil changes significantly as the moisture content of the soil changes. For the stabilization of contaminated soil, several stabilization techniques were used. Soil stabilization is often accomplished via the application of chemical additions lime, slag, cement, fly ash, inorganic salts, and other chemical compounds are examples of such materials. [7,8,9]. Many authorities and investigators are lately working to reusing the wastes in environmentally and economically sustainable ways. [10,11,12]

A major emphasis of this research was of use industrial waste products, such as GGBFS, to improving of contaminated soil. To evaluate the efficiency of stabilization, compaction parameters were determined using a proctor test and compressive strength using shear strength test (direct shear). The purpose of this research was to identify the range of binder doses that would result in a substantial growth in the strength of soil that has been contaminated.

METHODOLOGY AND MATERIALS

Soil

Table 1 lists the characteristics of the soil that was used. In order to investigate the impact of crude oil on soil mechanical characteristics, the soil sample was treated in many ways. It was utilized a clayey silt soil that had 42.9 percent clay, 50 percent silt, and 7.1 percent sand, as shown in Figure 1 to conduct our experiments. The distribution of sieve analytical results was identified in order to determine the gradation of the soil. The reading of sieves is based on ASTM D-422 standard specifications. The soil utilized in this study was brown colored, low plasticity clay soil (CL), which was taken from a borrow pit that was 1 m below the natural ground level, and it was used for the experimental work.

TABLE 1. Soil characteristics.

Properties	Characterization
Sand content 0.0075%-4.75 mm%	7.1
Clay and Silt contents <0.0075mm%	92.9
Color	brown
Specific gravity	2.662
USC	low plasticity clay - CL
Liquid limit %	35
Plastic limit %	21
Plasticity index %	13

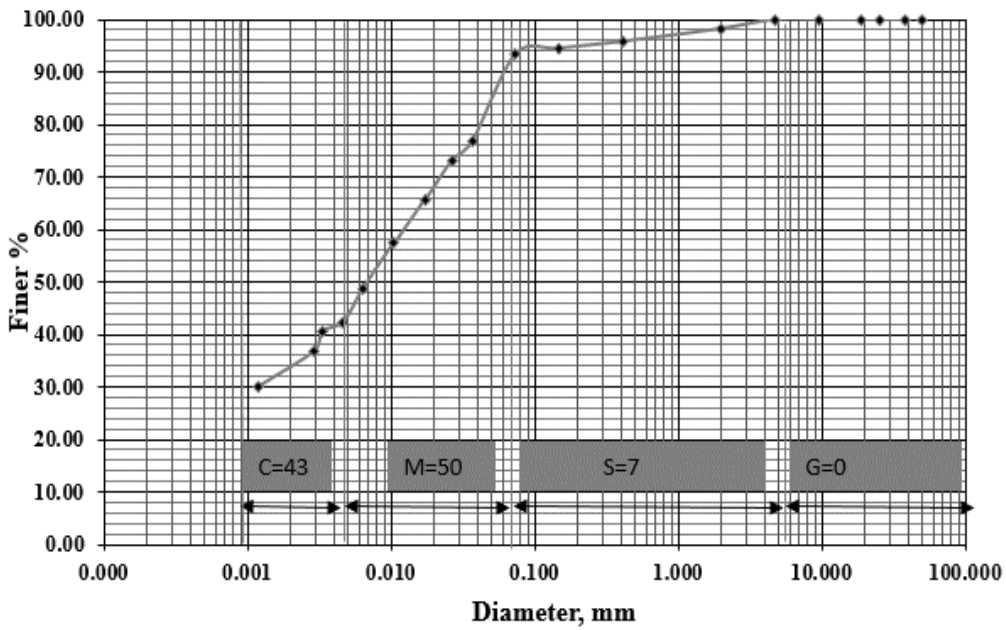

FIGURE 1. Demonstrate the sieve size analysis of a soil sample [13].

The Crude oil

The crude oil utilized has a specific gravity of 0.851 at 25.0°C and an American Petroleum Institute (API) gravity of 23.261 at 25.0°C, according to the API. Table 2 shows the characteristics of crude oil.

TABLE 2. Crude oil characteristics [10].

The sample	Flash Point ⁰C	Density (g/cm3) @ 25⁰C	⁰API	Viscosity (Cp)
Kar Refinery	52.9	0.850	23.260	18.21

Slag (GGBFS)

The GGBFS, which is made by crushing granulated blast furnace slag, is used to restore damaged soil that has been contaminated with light crude oil. When it comes to GGBFS, it is made up of a variety of metals that vary depending on the components utilized in the manufacturing procedure. When the slag is granulated, it has a chance to cool down before reaching temperatures of above 800 degrees. Granulation is a technique that may be used in which molten materials are granulated. GGBFS is restricted to the use of jet streams of water or air under pressure for cooling and slag fragmentation purposes. The chemical characteristics of GGBFS are shown in Table 3 of this document.

TABLE 3. Slag's chemical composition (GGBFS).

Components	Accumulation
Fe_2O_3	23.930
Al_2O_3	3.020
CaO	5.830
MgO	0.757
SiO_2	60.689
SO_3	1.556

Procedure

This experiment used artificial mixing of contaminated soil samples with crude oil at concentrations of 0 percent, 3 percent, 6 percent, and 9 percent of the dry weight of the soil samples to create polluted soil samples. To avoid oil evaporation during the ageing process, the samples stored in plastic containers for two weeks before being used. GGBFS was added to soil samples in proportions of 12 percent and 18 percent, respectively, after the homogeneity of contaminated soil had been achieved, according to the mix design shown in Table 4. The necessary water was also added and mixed with the combination for one day before conducting the specificized test; after that, it was transferred back to thick plastic containers to prevent water evaporation and arrangement with the pollutants during the test. Following the delivery of the samples, an ASTM D698 compaction test was carried out on them.

TABLE 4. Mixture of additional waste materials.

Mix description	Oil (%)	GGBFS (%)	soil (%)
Soil	0	0	100
Soil with 3% oil	3	0	97
Soil with 6% oil	6	0	94
Soil with 9% oil	9	0	91
Soil with 12% GGBFS	0	12	88
Soil with 3% oil+12% GGBFS	3	12	85
Soil with 6% oil+12% GGBFS	6	12	82
Soil with 9% oil+12% GGBFS	9	12	79
Soil with18% GGBFS	0	18	82
Soil with 3% oil+18% GGBFS	3	18	79
Soil with 6% oil+18% GGBFS	6	18	76
Soil with 9% oil+18% GGBFS	9	18	73

All of the samples were prepared with the MDD and the corresponding OMC. Supplemental tests were performed for adding to these, including shear strength test (direct shear), which was carried out in accord with ASTM D3080 utilizing the ShearTrac II system known as (Geocomp), as presented in Figure 2. In the Erbil Construction Laboratory, all testing had been completed (ECL). In order to apply shear stress on the polluted soil, continuous vertical loading was applied. Specimen mold had a thickness of 25.4mm and a diameter of 63 mm. The specimen was specifically placed into the shear box with the bottom porous stone and aligning pins in place, and varied stresses of 100, 200, and 300 kPa were applied to the specimen at various locations. To guarantee that the oil does not drain out of the earth, this procedure was followed.

FIGURE 2. Demonstrate the ShearTracII Trak [13].

OUTCOMES AND DISCUSSION

Compaction test

Figures 3 and 4 show the outcomes of the compaction test and the consequences of this decision. In the compaction test, the optimum moisture content is an essential element to consider. It is important to determine the OMC in demand to obtain the MDD. In order to understand this phenomenon, it is required to increase the crude oil concentration of contaminated samples while decreasing the optimum water content. According to certain theories, the capillary effect is the underlying reason of this tendency. [8,9,15]. In general, the spaces between soil particles may be thought of as a capillary conduit, which causes the amount of water in the soil to rise as the distance between them increases. While the compaction weight is being applied to the soil, the gaps between the grains get smaller and thinner, increasing the capillary tension in the soil.

The findings provide an explanation for the impact of GGBFS on both clean and contaminated soil. In the laboratory, 12 mixes were used to demonstrate that increased GGBFS decreases OMC while increasing GGBFS increases OMC. However, when a percentage of GGBFS content is added, the optimum moisture content decreases. In the control mixture (soil + 0 percent oil), as shown in Figure 3, the greatest value of OMC was detected at the highest concentration. Many researchers, including those mentioned above, have verified the findings of this study. [9].

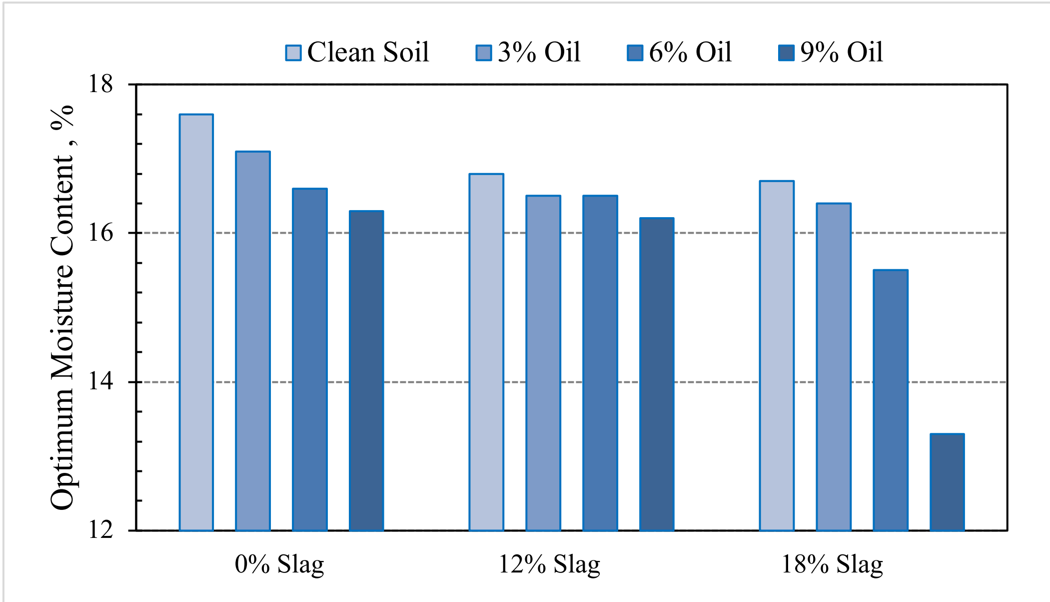

FIGURE 3. Show the effect of GGBFS on OMC.

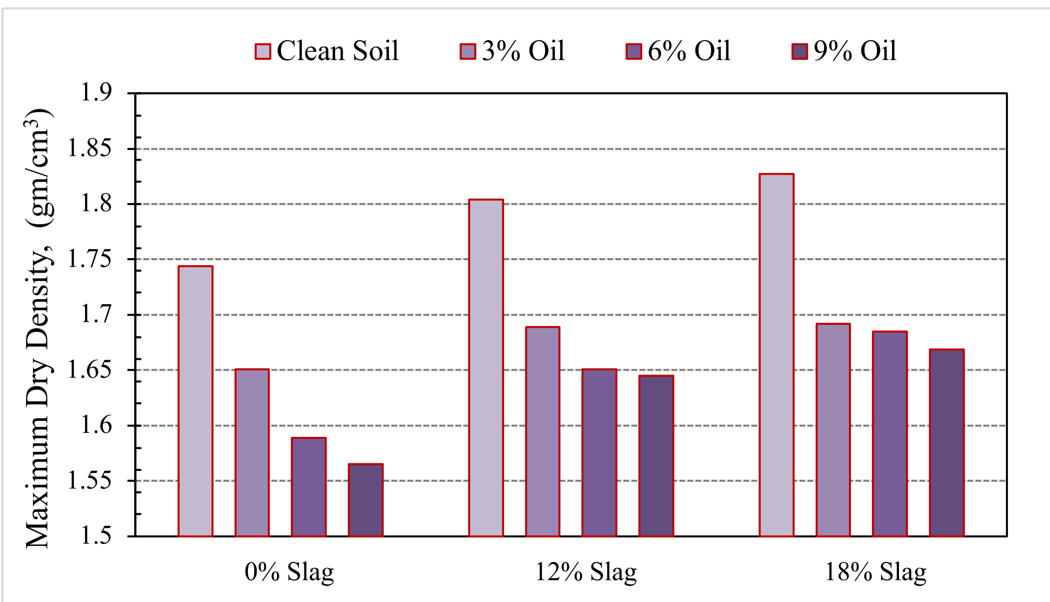

FIGURE 4. Show the effect of GGBFS on MDD.

Figure 4 shows the effect of crude oil and GGBFS on the MDD of soil samples. After adding the GGBFS, maximum dry density increased. The MDD was reduced when crude oil content increased, the maximum value observed in [(soil + 0 percent oil) with 12 percent GGBFS] and [(soil + 0 percent oil) with 12 percent GGBFS]. Many researchers' findings on MDD are encouraging, and this is reflected in their findings. The results show that adding GGBFS to mixes may result in an increase in MDD. The MDD developed for the soil relates the density of soil particles to the composition of cementitious material and crystals, as determined by the MDD developed for the soil. The formation of these crystals is directly proportional to the curing period and occurs shortly after the addition of the mixture. The development of connections between particles and crystals of the mixture culminates in the combining of soil particles, which is an encouragement to the increase in strength of the mixture. [9,13,16] described thus, as GGBFS content rose, the maximum dry density increased and the optimum moisture content decreased.

Shear Strength Test (direct shear)

Figures 5 and 6 illustration the results of the shear parameters, which were determined via experimental work. The addition of GGBFS to both clean and contaminated soil samples resulted in an increase in cohesion. While GGBFS is included in mixtures, it has a important effect on the outcome of cohesion. This variation is due to the viscous characteristics of the soil contaminants, which aid in bringing the different soil particles closer together, resulting in a more compact configuration of the particles. The results are agreement with. [9,13,14,15,16]. An increase in the angle of internal friction is usually seen when crude oil is applied to the soil sample. Results are close to being gathered due to the change in the proportion of GGBFS.

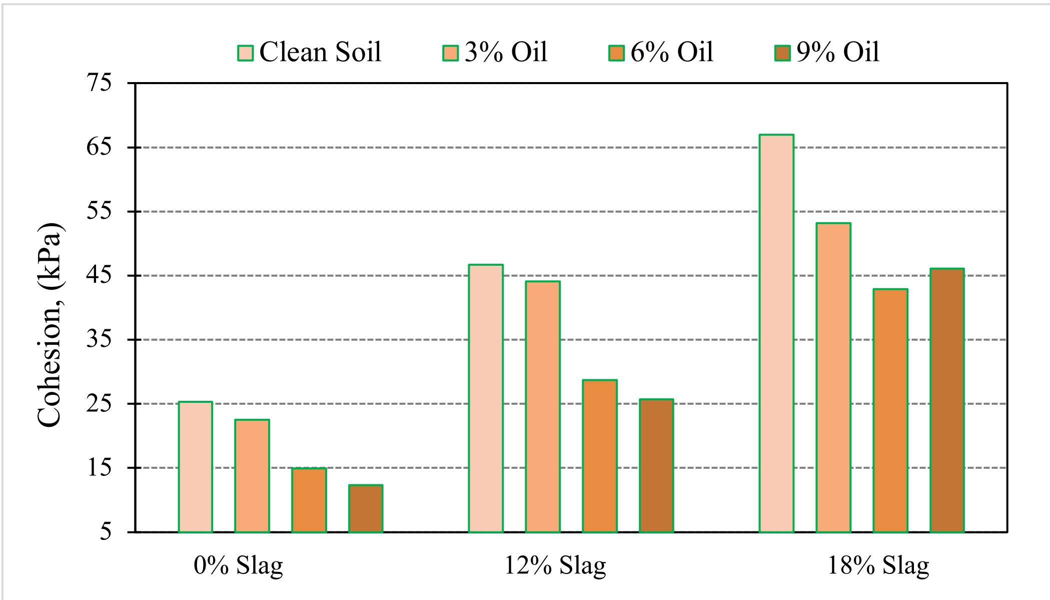

FIGURE 5. Show the effect of GGBFS on OMC.

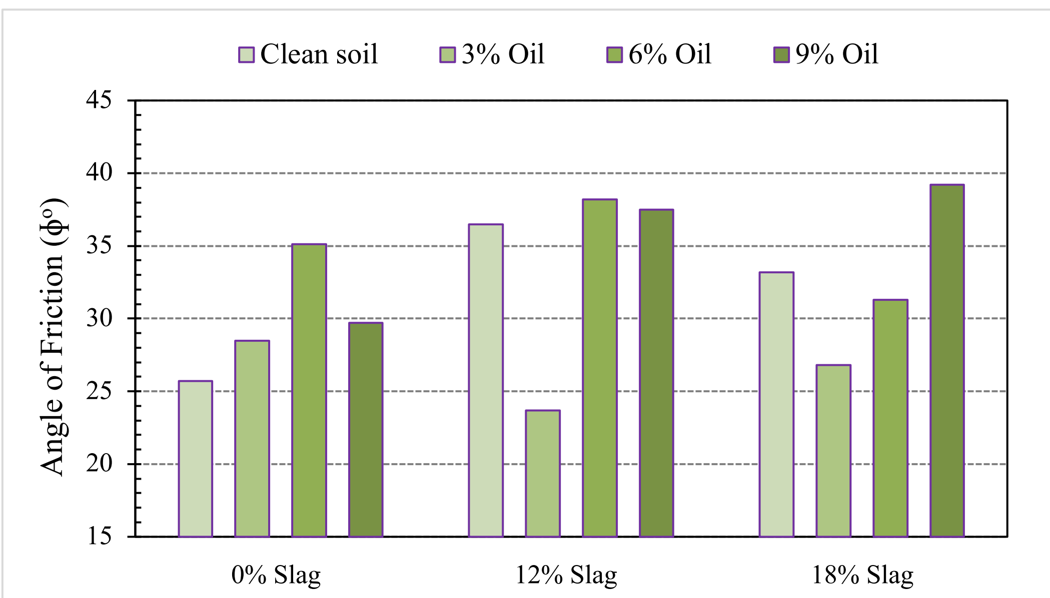

FIGURE 6. Show the effect of GGBFS on OMC.

CONCLUSIONS

This study explores crude oil contamination of the soil. To improve polluted soil, the mineral admixture is applied. Samples are subjected to compaction and direct shear inspection. Key properties of soils were described in this investigation. The result for soil products is seen as follows:

1. Determined dry unit weight and dry density decreased as a result of increased crude oil absorption by soil.
2. This mineral also improved the shear strength parameters and compactions of clay soils, which was an added benefit.
3. However, the utilization of industrial waste materials in highway and embankment construction may help to lower the inclusive cost of the project while also being environmentally beneficial.

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