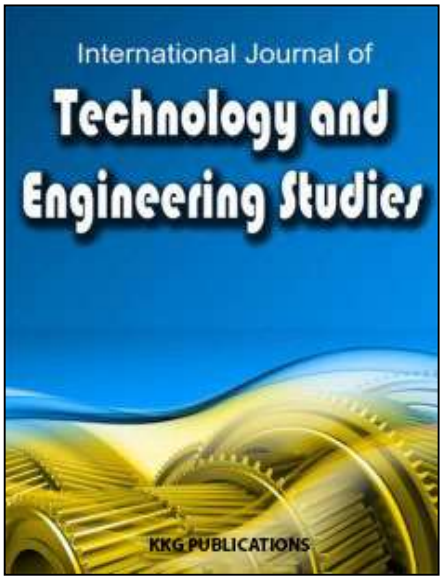

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GEO ENVIRONMENTAL UTILIZATION OF IRON-FILING WITH CEMENT IN SOIL STABILIZATION

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Abstract. This paper presents the use of iron filing materials mixed with cement to improve the shear strength of clayey soils. Two types of expensive clayey soils known to have low shear strength were obtained and mixed with iron filing-cement mixtures at different percentages: 2%, 4%, 6%, 8%, and 10% by dry weight of the soil. The ratio of iron filing to cement used was 2:1. Direct Shear tests were conducted on all samples to determine the shear strength of the soils. The tests were conducted after 2 and 7 days from the curing time. It was found that the addition of 10% of the iron filing-cement mix will significantly increase the shear strength parameters of the two types of clay. The shear strength increases by 79% and 162% when soil one and soil two are mixed with 10% of iron filing-cement mixture, respectively. It was also observed that the shear strength increased slightly throughout the curing time from 2 to 7 days. The research result implies that this material can be used in soil stabilization and further reduce the impact of this material on the environment.

INTRODUCTION

Soil stabilization is an engineering technique used to encounter many problems associated with some types of soils especially weak soils. It is used to reduce or eliminate defects in soils such as expansion, compressibility and settlement, as well as for improving its shear strength. Soil stabilization or soil improvement can be achieved either mechanically such as by compacting and densifying the soils or by the addition of some materials to the soil.

There are good number of studies in the literature indicating that there are many materials that have been used as soil stabilizing agent. An old and well known approach of soil stabilization is to use lime or lime with cement [1], [2], [3]. Recent studies showed that the addition of wheat husk to the clay soil increased the shear strength and reduced the expansion of the soil [4]. Also, a study on the use of fly ash with the expansive soils has been investigated. The investigation concluded that the addition of fly ash will result in a significant reduction in swelling pressure of the soil [5]. Many experimental researches have been conducted on different soils to study the effect of randomly distributed natural or synthetic fibers on the engineering mechanical properties of soils. The researches revealed that the use of fibers with soil will increase shear strength and improve its engineering physical properties. It also changes the failure mechanism and the soil behaves more ductile than brittle [6], [7], [8], [9], [10], [11].

With the huge increase of the solid wastes all over the globe, the geo environmental engineers started thinking of using these solid wastes in soil stabilization. Combined industrial waste with lime was mixed with soil and the results showed that this mix can be used as soil stabilization material [12]. Rubber tires were recommended in highway construction [13].

Sand showed an increase in its shear strength when mixed with shredded waste tires and it could be used effectively as backfill materials [14], [15]. The uses of these wastes in geotechnical applications will reduce the pollutions and disposing areas as well as improving the engineering properties of soils.

Iron-filing is a new waste material that may have potential uses to stabilize the weak soil. Iron filing is produced in a huge amount due to extensive use of steel in construction industry. Iron filings are very small pieces of iron that look like a powder and are mostly a by-product of the grinding, filing, or milling of iron products. This material can be utilized and used in different engineering applications, one of which is soil stabilization. Little research is reported in the literature regarding the utilization of iron-filing to stabilize the soil. A recent research investigated the potential use of iron filing as a new soil stabilizing agent. The investigation concluded that the use of iron-filing and iron filing-cement mixtures can decrease the swell potential and swelling pressure of expansive soils and increase the unconfined compressive strength of clayey soils [16], [17], [18, [19].

The main objective of this study is to investigate the effect of iron-filing material mixed with cement on the shear strength and shear strength parameters –angle of internal friction and cohesion- of clayey soils. To achieve the objective of this

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investigation, two types of clayey soil will be selected and used in this study. The clayey soils will be mixed with iron filing-cement mixture at different percentages and tested using standard Direct Shear test. The ratio of iron filing to cement in the mix is 2:1. It was decided to use five different percentages of the mixture with soil from 0.0% to 10% with 2% increment. Additionally, the effect of curing time will be investigated. The prepared specimens were tested at three time intervals after 1, 2, and 7 days from the preparation time. The testing program will be fully conducted in soil testing laboratory.

MATERIALS AND METHOD

Two types of clayey soils were selected in this research. The selection was based on clay fraction and percentages of fine particles in the soil. The initial physical properties of the clay soils such as Gs, cohesion, angle of internal friction, plasticity indices, maximum dry unit weight and optimum water content were determined in accordance with American Society for Testing and materials (ASTM) standard procedures. The initial physical properties of the used soils are shown in table 1.

TABLE 1
SOIL PHYSICAL PROPERTIES

	Soil 1	Soil 2
Grain size distribution		
Clay, %	68	31
Silt, %	18	33
Sand, %	11	36
Atterburg's limits		
LL, %	64	29
PL, %	29	14
PI, %	35	15
Compaction	12.9	15.7
γd,max	51	21
wop		
Gs	2.67	2.65
Classification	CH	CL

The used soil in this investigation passed through U.S. standard sieve # 4 and the iron filing passed through sieve # 40. The soil was mixed with iron filing at five different percentages mainly 2%, 4%, 6%, 8%, and 10% by the dry weight of the soil. Specimen from each type of soil was prepared in the direct shear standard mold at 95% relative compaction and optimum water content. The iron filing to cement ratio is 2:1. Specimens were sealed with plastic bag to prevent any moisture content loss and tested at 1, 2, and 7 days from the preparation time. Standard Direct Shear test was used to study the effect of iron filing mixture on the shear strength parameters of clayey soil. In this test the prepared specimen is sheared in the standard shearing box at predetermined shearing rate. Both vertical and horizontal displacement will be measured as well as the shearing force under normal load (stress). Three specimens are needed for this test. The horizontal strain vs shearing force will be plotted for each normal load. The maximum shearing force under each normal stress will be found and plotted to find the shear strength parameter cohesion and angle of internal friction.

RESULTS AND DISCUSSION

A. The Effect of Iron Filing-Cement Mixture on the Angle of Internal Friction and Cohesion of the Soils

The effect of iron filing-cement mixture on the angle of internal friction is shown in Fig. 1. This figure implies clearly that the addition of iron filing-cement mixture to the soil will affect the value of angle of internal friction. The increase of iron filing mixture percentages in the soil will result in a higher value of angle of internal friction. However, it was noticed that soil 2 was affected more than soil 1 by the addition of the mixture and the reason behind that can be explained that soil 2 has more sand than soil 1. This extra amount of sand when mixed with iron filing will result in a higher friction between the sand and the iron filing during shearing stage resulted in a higher value of angle of internal friction. The angle of internal friction increased from 16 degree to 30 degree and from 27 degree to 49 degree when the iron filing cement percentages increased from 0.0% to 10% for soil 1 and soil 2, respectively.

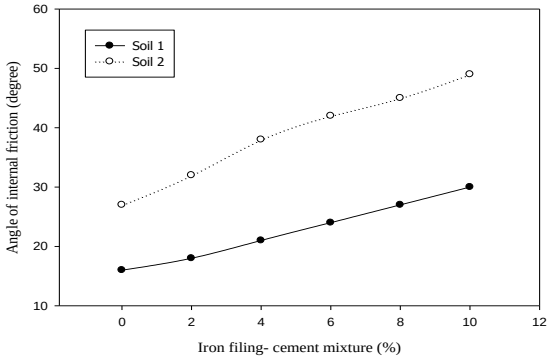

Fig. 1. The effect of iron filing-cement mixture on the angle of internal friction of the soils

The effect of the iron filing-cement mixture on the cohesion of the two soils is shown in Fig 2. The figure shows interesting results due to the addition of iron filing-cement mixture. The cohesion of the two soils increased significantly with the increase in the percentages of this mixture. Soil 2 has a high percentage of sand and as a result possesses a low value of cohesion. However, the addition of the mixture to soil 2 resulted in a significant increase in the cohesion and the cohesion increased from 17 kN/m^2 to 55 kN/m^2 when the percentages of the mixture reached 10% in the soil. The large increase in the cohesion can be explained due to the fact that the sand in the soil with the existence of the iron filing bonded with the cement and became stronger material. This strong material is due to the cementation between iron filing-cement mixture and sand that became more stabilized and showed higher cohesion. Soil 1 also behaves in the same trend and the cohesion increased with increase in the percentage of the mix in the soil. The cohesion of soil 1 has higher clay content.

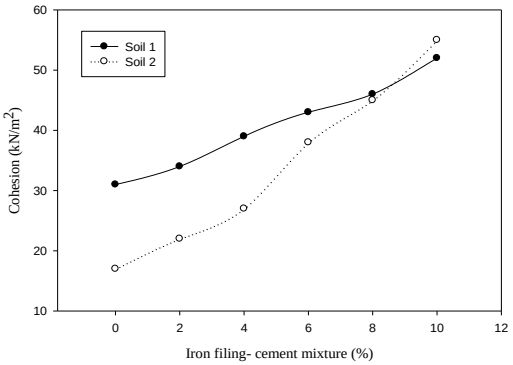

Fig. 2. The effect of iron filing-cement mixture on the cohesion of the soils

Figure 2 showed a higher cohesion at 0.0% of the mixture than soil 2. However soil 2 showed a higher cohesion than soil 1 at 10% addition of the mixture to the soil.

The Effect of Iron Filing-Cement Mixture on the Shear Strength of the Soils

Fig. 3 summarizes the effect of the iron filing-cement mixture on the shear strength of the two soils. The shear strength of the soil is calculated from the angle of internal friction, cohesion and the normal load obtained from the direct shear test. It is obvious from this figure that the addition of iron filing-cement mixture will increase the shear strength of the two soils. The shear strength increased more in sand 2 than soil 1 due to the addition of the mixture. The percentages in shear strength increase at each percent of the mixture for soil 1 and soil 2 as shown in Fig. 4. The shear strength increased as high as 79% when the percentage of the mixture reached 10% in soil 1.

The effect is more significant in soil 2. The percent in shear strength increased from 25% to 162% when the percentages of iron filing mixture increased in soil 2 from 2% to 10% respectively. Also it is clear that the percentages in shear strength increased with increasing of the percentages of iron filing-cement mixture in the soil. Also, soil 2 experienced more increase in shear strength than soil 1.

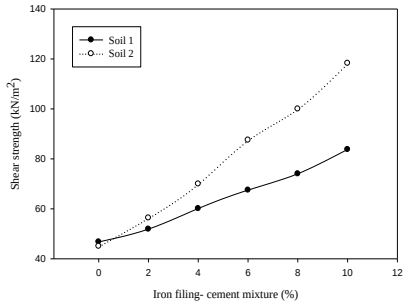

Fig. 3. The effect of iron filing-cement mixture on the shear strength of the soils

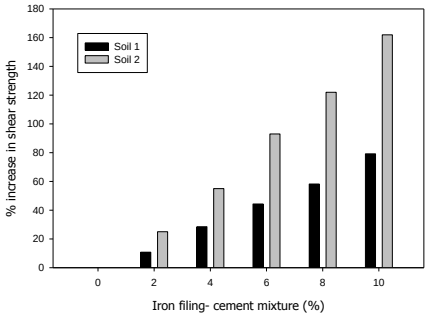

Fig. 4. Percent increase in shear strength for soil 1 and soil 2 when mixed with iron filing-cement mixture

The Effect of Iron Filing-Cement Mixture on the Failure Mechanism of the Soil

Fig. 5 and Fig. 6 depict the failure mechanism of soil 1 and soil 2 respectively due to the addition of iron filing-cement mixture to the soil. It is clear from these two figures that there is a change in the mechanism of failure behavior of the soils due to the addition of the mixture. As the percentage of the mix increases in the soils, both soils tend to behave more brittle and fail at lower displacement. Soil 1, due to a high percentage of clay, behaves as ductile material. This is very clear in Fig. at 0.0% of the mix. Then after the percentages of the mix increased in the soil, the soil gradually changed its failure mechanism from ductile to brittle and started this behavior relatively at 8.0% of the mix. The brittle behavior is very clear for soil 1 at 10% of the iron filing–cement mixture.

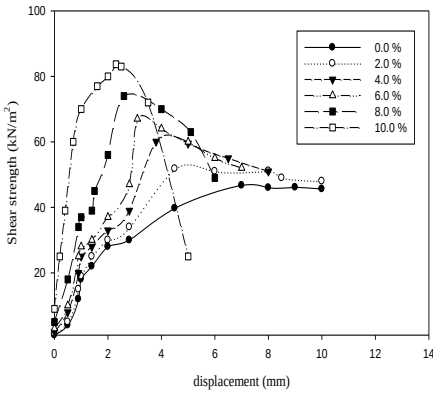

Fig. 5. The effect of the iron filing–cement mixture on the shear stress-displacement behavior of soil 1

However, Fig. 6 showed that soil 2 experienced a brittle behavior at low percentages of the mix in the soil. Soil 2 behaves like a brittle material at 6% and this behavior is obvious when the percentage of the mix reaches 8.0% and 10%.

Also, it was noticed that both soils possess a peak strength with increasing the percentages of the mix in the soils especially at 6% or higher.

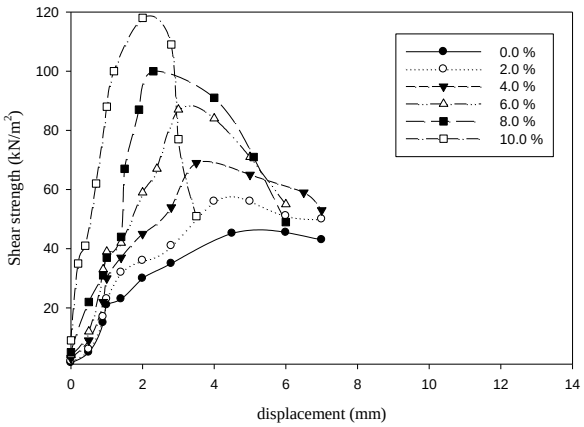

Fig. 6 The effect of the iron filing–cement mixture on the shear stress-displacement behavior of soil 2

The Effect of Curing Time on Shear Strength of the Soil mixed with Iron Filing-Cement Mixture

The effect of curing time on the shear strength of the soil mixed with iron filing-cement mixture has been investigated. The effect of curing time was investigated at three time intervals and five different percentages of the mixture. Fig. 7 and Fig. 8 depict the effect of curing time on shear strength for soil 1 and soil 2 at 2 and 7 days respectively.

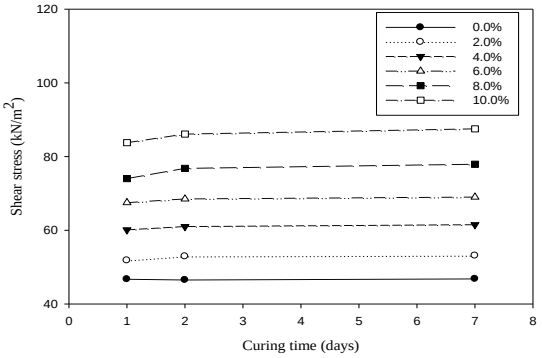

Fig. 7 The effect of curing time on the shear strength of the soil 1 at different percentages of iron filing-cement mixture

It is clear from these two figures that the curing time has no effect on shear strength of the soil at lower percentages of iron filing-cement mixture (2%, 4% and 6%). However the curing time has a small effect on the shear strength values of the two soils at higher percentages of the mixture. It was noticed that there is a slight effect of curing time for both soils at high percentages of iron filing mixture mainly 8% and 10%. At these two specific percentages, the shear strength showed a slight increase in shear strength due to curing time or after two days of curing time.

CONCLUSION AND RECOMMENDATIONS

A geo environmental application of new material was investigated in this research for potential engineering application. Iron filing-cement mixture was added and mixed with two clayey soils at 5 different percentages by dry weight of the soils. The addition of this material showed that the iron filing when mixed with cement can be effectively used as new stabilizing material. This will minimize the problems associated with the huge production of iron filing and solve many problems of weak soils. It was found that 10% of the addition of 10% of iron filing-cement mix to the soil will increase significantly the shear strength of the soil. This application is more effective with soil containing high percentages of sand. Additionally, the investigation revealed that curing time has no or slight effect on shear strength properties of the soil. Further research should be conducted on the use of this material for potential use with pavement materials and to be added to soils used as a base material.

Declaration of Conflicting Interests

There are no conflicts of interest associated with this research work.

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— This article does not have any appendix. —