Reviewing Domestic and Mineral Wastes as Soil Stabilizers

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Abstract- The mineralogical, and engineering properties of the problematic soils are well related to the problems of these soils. Extensive researches have been carried out to reduce the damages that may occur for building built on, or in problematic soils. There are numerous types of additives that mixed, added, or blended to soils to amend their poor properties. Some of these additives are conventional materials and widely used like cement, lime, chemicals, and produced materials. In the last decades, different waste materials from domestic and mineral wastes have been used to amended the problems of soils. This review paper presents different domestic and mineral wastes materials (e.g., glass cullet, plastic wastes, waste of tire, fibers, egg shell, marble dust, jarofix waste, etc.) as soil additives, where the uses of these wastes have important benefits (economic and engineering). The effects of these waste materials on soil geotechnical properties (include physical and compaction characteristics, strength and bearing ratio, and swelling and compressibility of soils) have been shown and discussed. The content used of these waste materials was studied, it looked widely varied from one research to another. This content is low in materials like waste plastics and fibers, while the content may reach more than 30% in the rest materials. The domestic and mineral wastes reduce the undesired soil properties like soil plasticity, swelling properties, and compressibility to varying degrees. While the shear strength, bearing ratio, stiffness, and compaction properties increase with the addition of these waste materials. However, some domestic and mineral wastes show more efficiency to stabilize the soils.

Keywords Domestic and mineral wastes, environment, geotechnical properties, problematic soils, soil stabilization.

1. Introduction

Authors Problematic soils are widely distributed all over the world. Different engineering problems associated with these soils. These problems are summarized by researchers, [1-7], to include high erodibility, liquefaction potential, high settlement, ground heave or collapse, low bearing capacity, migration fine particles due to movement water table, etc. The improvement of engineering soils aims to amend their geotechnical properties by increasing the soil strength and durability, decreasing the permeability and deformability, and producing more stable volume [8-12]. Such aims can be achieved using different engineering techniques include mechanical stabilization (using soil reinforcement, soil compaction, etc.), chemical stabilization (using different additives such as lime, cement dust, salts (chloride), silica fume, fly ash, geopolymers, emulsified asphalt, fuel oil, demolishing waste materials, etc.) [6, 13-18].

Day by day, the use of different materials for domestic, industry, and mining is increased. As a result, huge quantities of waste materials are accumulated. The accumulation of the generated wastes causes different major worldwide problems and threats to the environment. For these reasons, the introduction of waste materials in soil improvement techniques may help in reducing their problems, on one hand, and may have economic benefits in the field of geotechnical and construction engineering, on the other hand. A preview regarding stabilizing different engineering soils using domestic and mineral wastes such as glass cullet, plastic wastes, waste of tire, different fibers, egg shell, marble dust, Jarofix waste, and silica fume was reviewed in the present paper.

2. Domestic Wastes

2.1. Glass Cullet

Crushed glass has been evaluated as a soil stabilizer in different researches. Different soils have been stabilized with crushed glass through laboratory experimental programs. The feasibility of using crushed glass as a stabilizer to amending the geotechnical properties of soil was evaluated in 2007 [19]. It was found that the strength properties of the fine-grained soil mixed with different contents of crushed glass have been significantly increased, in some cases it was doubled. The grain size distribution of cohesive and cohesionless soils has been amended using glass cullet. This was discovered by different studies [19-21]. Two sizes' types of glass cullet have been used in these studies, silts and clays size, and sand and gravel size. The contents of the glass cullet used by studies [19-21] were ranged from 10% to 80%. In well-graded soil, glass cullet showed no effects, while the effects of glass cullet were well pronounced in poorly graded soil. These authors attributed the mentioned effects to the fact that in the poorly graded soil, the missing size fraction is filled by glass cullet.

A significant reduction in compaction's optimum water content was produced by adding more than 35% of the glass cullet [20, 22]. While the addition of glass cullet increases the maximum dry density of cohesive soils.

The effects of glass cullet on shear strength parameters in coarse-grained soils have been studied by researchers as [23-24]. These researchers recorded an increase in the internal friction of silty sand and sandy silt, while no significant effects on the internal friction of the mixture of sand-gravel mixtures and sand were noted.

The effect of the glass cullet on Atterberg limits of the cohesive soils was stated by references [25-27] . The final conclusion of these authors showed that the increase of glass cullet reduces the Atterberg limits.

2.2. Plastic Wastes

One of the important materials that found everywhere is plastic. The properties of this material made it one of the widely used materials in daily life applications. As a result, the generation of plastic waste increased and, therefore, caused a threat to the environment. According to [28], the expected global demand for plastic in the year 2020 may exceed 300 million tons. Unfortunately, only a fraction of the waste of plastic materials is recycled. For example, about one-third of the plastic waste was recycled in Europe in the year 2014 [29]. For this reason, the introduction of plastic waste in soil stabilization techniques may help in reducing its problems.

As a reinforcement to granular soil, the polyethylene terephthalate fiber (from the waste of plastic bottles) has been used by reference [30]. They distributed the mention fibers in a random way to improve fine sand. The plastic fibers used have a length of 3.6 cm, while the content of these fibers reached up to 0.9% (of the dry weight of the soil). The authors noted that both the compressive and the tensile strengths of the cemented sand (up to 7% cement content) were significantly improved by adding the fiber reinforcement.

The engineering behavior of the silty sand soil improved by waste plastic has been studied by [31]. In addition to soil improvement economical solutions, their study aimed to face a waste disposal problem. In this study, strips of plastic bottles have been prepared in the squares form of 1.5 cm length and contents of (0.2, 0.4, 0.6, 0.8)%. They were found that the behavior of soil reinforced with plastic waste is like that reinforced with fibers. They, also, found that the optimum content of strips of plastic bottles is 0.4% at which the maximum compaction density and soil shear strength reach its maximum value. While the bearing ratio still increased as the content of plastic waste increase.

Reference [32] used the waste of plastic bottles and other plastic to improve the properties of expansive type soil called black cotton soil. They considered these materials as friendly environmental and economical. The percentages of plastic waste are by the dry weight of soil and varied from 0.5% to 1.5%. It was found that the performance of expansive soil mixed with plastic wastes is better than that for soil alone. They also noted that the soil-plastic mixture has good elastic characteristics in comparison to the soil without admixture.

A new form of plastic waste has been recently produced by in 2020 [5]. These authors used the waste of water bottles to produce a powder form of plastic, then they used the product to improve the geotechnical properties of fine sand. The content of the powder used was 0.5% to 2%. The internal friction of the sand found to be increased from 35 degrees to 40 degrees. The finding of this paper proved that the powder plastic is an effective stabilizer for poor sand and this encounters the waste disposal problem and gives an economic solution for the improvement of poor soil.

Based on the review shown, the plastic wastes materials are used in different forms as an additive to improve poor soils' geotechnical soil properties. These forms are the fiber form, stirp form, and powder form. The content of these forms used in soil stabilization is shown in Fig.1.

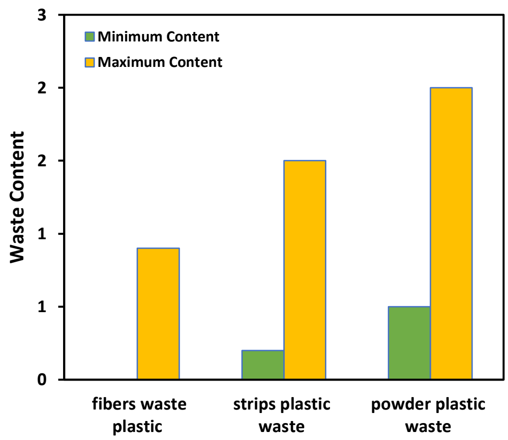

Fig. 1. Different forms of plastic wastes.

2.3. Waste of Tire

One of the major waste worldwide problems that increase day by day is the problem of tire waste. This problem is related directly to the increase in cars number. As a result, huge quantities of scrap tires are accumulated [33]. Reference [34] stated that there are more than 270 million waste tires accumulated in the US, while there are approximately 180 million in the European Union [35].

Almost, the tire waste is dumped, stockpiled, or landfill. Unfortunately, none of these processes represent a long-term solution, as that the environment may be damaged [36]. For this reason, the introduction of scrap tires in soil stabilization techniques may reduce its problems.

Different investigations have been carried out to evaluate the suitability of tire waste for soil stabilization. The effect of rubber (scrap tires) has been studied by studies as [37]. Different dosages ranged from 1% to 5%, have been used to stabilize the soil. The effect of 10mm length "tire rubber fiber" on the shear strength parameters of soil was studied. An increase in soil strength was noted at the fiber content of 2%, above this content the strength of the soil was decreased.

Two types of subbase materials reinforced with different wastes, include waste tire rubber, have been studied by [38]. The first gravel subbase material reinforced with waste tire rubber and waste plastics, while the second one is subbase material consists a fly ash subbase material reinforced with the same waste materials used in the first subbase type. They were observed that the first and second subbase type tested for bearing ratio and shear test show the optimum properties at 5% and 6% waste tire rubber, respectively.

The applicability of the "ground shredded rubber tire (GSRT)" in stabilizing sand soil has been studied in 2018 [39]. These authors noted a decrease in the dry density of the fine sand due to adding "ground shredded rubber tire (GSRT)", while the soil's angle of internal friction was increased in both loose state and dense state. The drainage characteristics of the soil, coefficient of permeability, was, also, increased when the rubber tire was added. The usage of a rubber tire in the geotechnical application is a wise choice to achieve sustainable development.

Reference [40] examined the improvement of the clay soil mixed with waste tire rubber, (4 to 5) mm in length. The shredded tire has a thickness of 2mm to 3mm. The content of waste's shredded, in percentages, ranging from (3 to 9) with an increment of 1%. They were noted that the use of waste tire

Reference [11] presented an assessment of granulated tire rubber (GTR) as an additive in stabilization of soil. It was found that the granulated tire rubber is effective in mitigation of the swelling of soil.

As shown, there are different forms of waste of tires used in geotechnical applications. These forms can be summarized in fiber scrap tire rubber, shredded rubber tire, and granulated tire rubber. Different content of these materials was applied as shown in Fig. 2. It is appearing that the amount used of tire rubber is lesser in a form of fiber, while higher content of tire rubber has been used in its granulated form. As a conclusion, high quantities of waste tires can be applied in soil stabilization, and this can reduce the threats of these wastes to the environment.

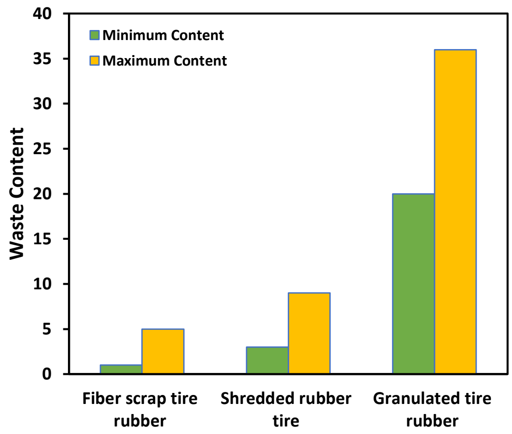

Fig. 2. Different forms of waste of tires

2.4. Different Fibers

Reference [41] explored the effects of recycled polyester-fiber, from polyethylene bottles, in combination with nano-silica as a stabilizer to amend the properties of soft cohesive soil. 0.1% and 0.5% combinations of fiber were mixed with the soil as well as 0.5% and 1% combinations of nano-silica were added to soft soil. The results showed that an increase in the shear strength and a decrease in failure strain was recorded. The shear strength parameters and elastic modulus of soil were increased due to the interlocking-force between the surface of the fiber and particles of the fiber. This interlocking was increased with an increase in the nano-silica content.

Reference [42] studied the effect of using the natural fibers for reinforcing the cohesive silt subgrade to improve the strength of pavements. Different fibers types have been used in their study. These are jute, water hyacinth, and coir fibers. The working life of these fibers was increased by using chemicals with nano-particles of ferric-hydroxide and aluminum-hydroxide. The results approved that the possibility of using chemically treated fibers in improving the strength of materials of road embankment.

Reference [43] investigated the fiber of bush mango mixed with lime to stabilize the weak clay. They used fiber of bush mango contents (0.25, 0.5, 0.75, 1.0)% and (2.5, 5, 7.5, 10)% lime content. The compaction properties of the soil increase with increasing the content of bush mango. This is also found for unconfined shear strength results. While the values of soil plasticity index decrease with increase the bush mango content.

2.5. Egg Shell

The potential of egg-shell powder to stabilize the fine-grained soil was assessed by many researchers [44-46]. This improvement method is eco-friendly and economical to decrease the problems of disposal of the wastes. Reference [44] used the mixture of egg-shell powder and stone dust (SD) as a replacement to traditional additives' materials. They used different contents of ESP (2, 4, 6, 8, 12, 16, and 20) %, and stone dust (10, 20, and 30) %. These materials were added (by weight of samples) to improve the CBR of the soil. It was found that the value CBR maximized from 3.9 to 7.9 with increasing the content of ESP ((from 2 to 20) %). In another research, [45], the lime was substituted with powder of egg-shell in improvement of a soft soil. The substitution contents were ranged from 0.5% to 2% (with an increment of 0.5%). It was found that the substitution of 25% of the lime improved the shear strength to its better value. The effect of egg-shell ash of the shear strength of lime-stabilized soil was studied by in 2017 [46]. They were found that addition of the different contents (0.5, 1, and 2%) of egg-shell ash increases the shear strength and mitigates the plasticity of stabilized soil. The 2% content of egg-shell ash considered as an optimum value.

As shown, the eco-friendly waste material (egg-shell) is used in two forms as an additive to improve the geotechnical soil properties. These forms are the powder form and ash form. The content of these forms used in soil stabilization is shown in Fig. 3.

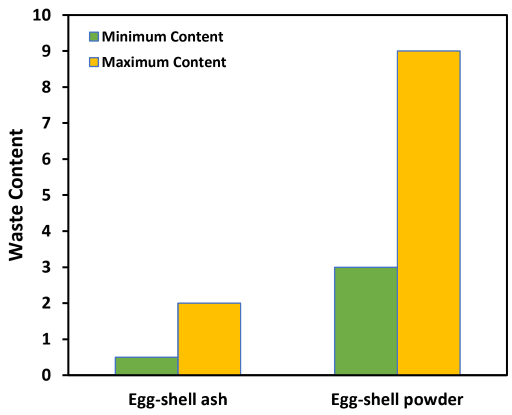

Fig. 3. Different forms of Egg-shell

3. Mineral Wastes

3.1. Marble Dust

The marble industry considers as one of the important of the mining sectors. Due to the growing demand for marble, the marble mining sector is gradually developed and the capacity of marble production is increased. Consequently, the marble's waste amounts increased and caused significant problems [47]. For these reasons, the introducing of marble waste in soil improvement techniques may help in reducing its problems.

Reference [48] utilized a waste of marble in stabilizing swelling clays (consist of Kaolinite and bentonite clays). The ratios at which the marble dust has been added were ranged from (10% to 30%, by soil dry weight). The results obtained from this study show decreasing in the swelling potential and optimum moisture content, while the compressive strength and the dry unit weight increase with increasing the content of the marble dust. SEM images present a morphological change when clay specimen is treated with marble-dust, as a result, more compact structure display in SEM images with fewer pores.

Marble-dust was used as a stabilizer and additive material in the work of reference [49]. These authors stabilized different cohesive soil using (5, 10, and 15)% of marble dust. The soils used are low and high plastic soils. The results attained from this investigation included both consolidation index and welling index. The marble dust reduced both mentioned indices due to reducing the voids of the soil specimens, as a result, the consolidation settlement of the cohesive soil reduced.

The utilizing of marble dust for high plastic silt stabilization has been investigated by in 2017 [50]. Geotechnical properties, such as compaction, unconfined compressive strength, and Atterberg limits, were obtained. The percentages of stabilizer were ranged from a 5% to 40% (with 5% increment). The results presented that an improvement in compaction properties was noted with increasing the marble dust ratio that mixed with plastic silt.

Reference [51] treated a swelling soil using the marble-dust. A number of laboratory tests conducted on swelling soil (black cotton soil) mixed with various contents (from 5% to 20%. With 5% increment) of marble-dust (MD). The results presented an improvement in the maximum density (MDD) and a reduction of optimum-moisture-content (OMC) with an increase of marble-dust percentage. The shear strength of the samples of black cotton soil was raised with increasing the marble dust content (up to 15%). However, after this marble content, the increasing strength's trend was reduced.

Reference [52] amended the load-bearing capacity of cohesive soil using marble dust. The different percentages of marble-dust were 5%, 10%, 15%, and 20%. These percentages have been added with (2.5%, 5%, 7.5%, and 10%) of sodium-silicate to improve the cohesive soil. It was noted that the optimum ratio of marble dust and sodium-silicate is 15% and 10%, respectively. At these contents, the behavior of the high plastic clay changes to silt soil behavior due to reducing the plasticity of the soil.

Reference [11] reviewed the use of marble-dust in stabilizing the "husk ash stabilized soil". The stabilized expansive soil exhibited a considerable reduction in swelling pressure. Such reduction is noted for all marble contents. The important note of their review is the using of 25% of marble dust reduces the swelling pressure of "husk ash stabilized soil" to zero.

Reference [53] presented a review that included many materials used as a stabilizer for expansive soil such as stone dust. They noted that the stabilization of swelling soil using stone-wastes amends the geotechnical characteristics of swelling soil.

As a summary, by reviewing different works of literature it can see that the marble dust content was varied widely from one reference to another. Fig. 4 presents different works of literature for different marble contents.

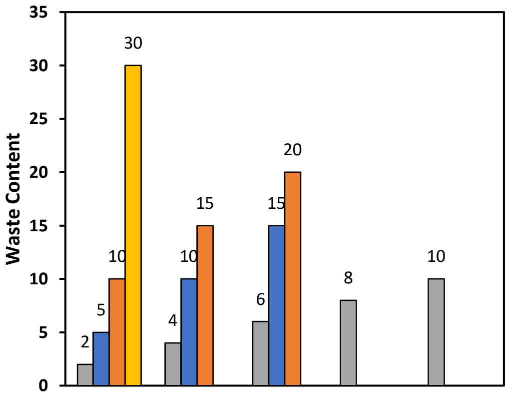

Fig. 4. Different contents of marble dust.

3.2. Jarofix Waste

Jarofix is a type of waste materials, it is produced as a result of zinc ore extraction. This waste material was used as a soil stabilizer. According to [54], the Cochin marine clay has been stabilized using Jarofix waste. A series of experiments carried out to investigate the effect of this waste on the strength properties of Cochin marine soil. Six content of Jarofix was adopted for the experimental triaxial test, the maximum value of the waste was 3%. According to the failure envelops and stress-strain curves, the shear strength soil parameters and young modulus values determined for different Jarofix percentages and under different curing periods. The results of the study showed that Jarofix waste is successful in improving the shear strength of Cochin marine soil. This waste material showed higher efficiency in improving soil under curing conditions.

3.3. Silica Fume

Silica fume can be defined as a byproduct material of the ferrosilicon industry [55]. This by- product waste is a pozzolanic material, it has a spherical-particles in shape and softer than the particles of by 100 time [56]. The use of this waste material in civil engineering applications provides an important solution to the disposal problems of this industrial byproduct waste. In geotechnical application, silica fume has been used in soil stabilization.

The mixtures of fly ash/silica fume with the cohesive soil have been prepared as in [57] to be used as a filling material to improve the poorly graded sand. The experimental test comprised the injection of the mentioned mixture into a cylindrical soil specimen. It was found that the grouting of the mixture with 10% to 20 % silica fume is capable to reduce the soil permeability and increase the shear strength of the soil.

The effect of mixing silica fume to amended the geotechnical properties of clay has been investigated by different researches [58-59]. These researchers noted a decrease in the values of soil swelling pressure and its permeability as a result of adding the silica fume. It was also noted an increase in soil shear The content of this material as in [59] was ranged from 10% to 50%. Additional investigation showed that a drop in the compressibility, swelling, and in the expansion of dryness cracks can be obtained as a result of silica fume addition.

The suitability of silica fume as an improvement material stabilize the clay has been examined in 2017 [60]. Series percentages of the amount of silica fume were added. The results in compacted soil samples showed that silica fume reduces the desiccation cracks' development on their surface. The silica fume found to improve the compaction properties of the compacted soil.

The combination of silica fume and fiber was carried out in 2019 [61]. These authors improve the strength values of the soil by adding the produced combined. They also improve the freeze-thaw of the low plastic clay (kaolinite) and its durability. They were recorded that the particles of silica fume react with the soil and as a result, the CSH gel products were formed. The formation of the component causes filling to the soil's voids and this produces an increase in soil strength. However, the content of silica fume combined in this study ranged from 2.5% to 10% by dry weight of the soil. The results approved that the properties of the modified clay for stress-strain behavior changes and shifts from ductile to brittle.

4. Conclusion

Jarofix Day by day, the use of different materials for domestic, industry, and mining is increased. As a result, huge quantities of waste materials are accumulated. The accumulation of generated wastes causes different major worldwide problems and threats to the environment. For this reason, the introduction of these waste materials in soil improvement techniques may help in reducing their problems, on one hand, and may have economic benefits in the field of geotechnical and construction engineering, on the other hand. This review is regarding the stabilization of different engineering soils using domestic and mineral wastes such as glass cullet, plastic wastes, waste of tire, different fibers, eggshell, marble dust, Jarofix waste, and silica fume.

Based on the reviewed references, it is appearing that the domestic and mineral wastes are used in different forms as additives to improve poor soils' geotechnical properties. These forms are the fiber form (e.g. fiber of scrap tire rubber, polyester-fiber (from polyethylene bottles), polyethylene terephthalate fiber, the fiber of bush mango, the fiber of jute, the fiber of water hyacinth, and coir fibers), strip form (e.g. waste plastic bottle materials), granulated form (e.g. waste of tire rubber), ash form (as in eggshell), and powder or dust form (as in marble dust and Jarofix waste) The form of the used waste mainly depends on the nature of the waste material itself and the purpose of using it. On the other hand, the contents used of these wastes' materials are varied widely from one material to another and from form to form.

High contents of waste materials in the granulated form are used in the stabilization of soils (up to 80%). While very low contents of waste materials are used in form of strip and fiber (less than 1%). Also, low contents up to 2% of waste materials are used in form of powder and ash in soils' stabilization. Finally, in general, it was proved that the properties and behavior of modified soils change clearly with the application of different waste materials (from domestic and mining).

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