Strengthening the clayey gravel and sand soils for Subbase course highway using different waste materials

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Abstract. The stabilization of clayey gravel and sand soil used in construction of subbase course pavement highway is one of the engineering solutions in order to increase structural capacity of underneath pavement layers. There are many sorts of soil stabilization which are classified into mechanical and chemical methods. Recently, there has been an increasing social concern about the issue of waste management, by production industrial waste and waste disposal. This project presents the study of the influence of waste ceramic dust (WCD) on strength of clayey gravel and sand materials used in construction of subbase course. The subbase collected locally was mixed with waste ceramic dust from (0 to 25%) by weight of dry soil. The target of this study is to clear that waste is often used as filling and reinforcement and for this reason California Bearing Ratio test (CBR) was conducted to research the strength of waste ceramic and plastic strip of subbase material. The application of plastic waste in various forms is one among the emerging areas of ground improvement technique and there are economic and eco-friendly advantages. A detailed analysis of their results depicts that it is often utilized in the fields effectively and economically as reinforcing materiel. Plastic strips with dimensions (12 mm × 6 mm) are mixed with soil containing the optimum proportion of ceramic dust and California bearing tests are conducted. The effect of waste plastic strip (WPS) content is 0.5% to 2% (by weight of sub base material) on the CBR of strip reinforced subbase was studied. The ratio is decided by changing its length and width. From the CBR on soil with and without plastic reinforcements, it had been found that after reinforcement the soil gained its strength appreciably. The best percent of waste ceramic dust was (20%) with waste plastic strip is (1%) which gave higher percent of CBR.

1. Introduction

The cost of extracting good quality natural materials is also increasing. Worried about it, scientists are trying to find alternative materials to stabilize the soil, and plastic waste products are one of these categories. To influence the growing problem of disposal of these substances is a problem that needs coordination and commitment on the part of all stakeholders such as government agencies, companies, the general public, and professionals. Environmental waste from technological and industrial development is increasing while natural resources are decreasing by the day. So, recycling and reuse are environmental protection and economics. In recent decades, there has been a marked increase in industrial and economic processes, which have contributed to improve the quality of life and welfare of citizens. However, every industrial production system creates by products waste materials that may affect the environment [1]. It is estimated that about thirty percentages of ceramic daily production goes to disposal of waste materials [2].
Waste disposal is a major impediment, it creates air and soil pollution. Ceramic tile dust waste additions reach 40%. Where it was found that the swelling pressure decreased by 86% and the potential for swelling decreased by 57% when adding 40% of ceramic dust. It is found that a limited research from the available literature has been done to review the consequences of waste ceramic dust on different geotechnical properties of expansive soil [3].

Today, plastic devices have revolutionized every vital sector of the economy. Consistent with recent studies, plastics can remain unchanged for 4,500 years on the earth. The use of this non-degradable product is growing rapidly, so the problem is getting rid of the plastic waste. Several million metric tons of plastic waste are produced annually. The natural materials are inherently depleting, and their quantity decreases gradually [4].

The major aim of this study is to improve the weak clayey sand and gravel subbase soil stabilized by waste ceramic dust (WCD) with addition of waste plastic strip (WPS), the second aim of this study is the study of contribution of WPS in the increasing structure capacity of the pavement layer.

2. Reuse and Resources of Waste Material
Reuse is the procedure or practice of using an item, whether for its original purpose (traditional reuse) or to achieve a special function (creative reuse or reuse of a purpose). It must be distinguished from recycling, which is the analysis of the materials used to form the raw materials to manufacture the latest products. Reuse - by taking previously-used items - not reprocessing them - saving time, money, energy and resources. From a broader economic point of view, high-quality products can be made available to people and institutions with limited means when providing jobs and businesses that contribute to the economy.

Financial motivation has historically been one of the main drivers of the reuse. This impetus in the developing world can lead to very high levels of reuse being applied, but the higher wages and consequent consumer demand for consumer products have made the reuse of low-value items in processes - such as packaging - particularly uneconomical in richer countries, which led to the suspension of many reuse programs. Current environmental awareness is gradually changing the behaviors and systems such as new packaging laws that are gradually starting to reverse the current situation [5].

3. Waste Ceramic Dust (WCD) In General
Ceramic products are produced from natural materials and these materials contain a high percentage of clay minerals. This is followed by a drying and temperature-controlled process that ranges from 700°C to 1000°C, as these minerals found in natural materials acquire the properties of burning clay.

Then broken waste ceramic tiles were obtained from internal construction and demolition sites. These tiles were broken with a hammer into small pieces. Then the smaller parts were inserted into the Los Angeles abrasion testing machine for manufacture [6].

4. Plastic Reuse
The general survey shows that 1500 bottles are dumped as garbage every second. Therefore, the disposal and dumping of the used and unwanted plastic have become a major threat for the civilized society [7].

5. Literature Review
A K Choudhary; J N Jha; and K S Gill (2010) said that in times when paved and unpaved roads perform poorly after all monsoons. Several attempts were made to illustrate the potential of HDPE reclaimed as a soil enhancer to improve the engineering properties of underground soils. Plastic bags are made of high-density polyethylene were mixed with soil. The strips obtained from plastic waste were mixed with different dimensions randomly with the soil and determined the best proportion of HDPE strips [8].

Sabat (2012) [9] said that stabilized soil mixed with waste ceramics. Locally available clay soil was mixed with ceramic dust with dose of 0 to 30% with an increase of fifty. The effect of ceramic powder on the atterberg limits, engineering properties, unconfined compressive strength and swelling pressure in clay soils was investigated. From the results of the tests, it was found that the fluid limit decreased from 62% to 35%, the plastic limit decreased from 30 to twenty, and the PI decreased from 32 to fifteen. The compression properties have also been improved. Maximum dry density increases from 15.6 kN /
m³ to 18.1 kN / m³, and optimum moisture content decreased from 20.4% to 17.6%. The CBR soaked value has raised from 1.6% to 4% [9].

Prasad et al. (2014) [10] studied that the impact of tile waste on mud soil was assessed. Locally available clay soil mixes with waste tiles from 0 to 30%, up 10%. The liquid limit and the plastic limit have been reduced regardless of the quota addition of waste tiles. MDD accounted for 20% of tile waste and OMC was decreasing with increasing of tile waste percentage. Soaked CBR was increased with increased percentage of tile waste being added. The CBR value increased by 105% compared to untreated soil when 20% of tile waste was mixed. There was 48% and a decrease in soil swelling pressure compared to untreated soil when adding 20% of tile waste. From the above analysis, it was found that up to twenty tiles waste are often used to reinforce the sub-layer of clay soil from a flexible pavement while saving significantly the construction cost [10].

Patil and Neeralagi (2017) [11] said that soil stability is an effective way to improve soil properties. The biggest goal of any stabilization technique is used to increase soil strength, rigidity and build ability. Plastic-like shopping bags are used to fortify the soil to improve the various properties of the soil. Soil stabilization applications improves the natural foundation of the soil for building highways and airports. Meanwhile, the plastic bottle strips and bag strips are used for stability [11].

Saberian et al., (2019) [12] investigated that one of the most important environmental issues devastating around the world. Therefore, the use of waste materials in civil projects such as subbase stabilization applications would greatly reduce the consumption of quarry-based virgin materials, reduce disposal of landfills, and reduce greenhouse emissions [12].

6. Waste Ceramic Dust (WCD)

In this study, then broken waste ceramic tiles were obtained from disposal landfill sites. These tiles were broken with a hammer into small pieces. Then the smaller parts were inserted into the Los Angeles abrasion testing machine for manufacture. As the name implies, Waste Ceramic Dust is irregular broken pieces which have been ground in the Los Angeles machine for 100% smooth powder (Passing No200 sieve=100%). WCD was collected from building debris or surplus upon completion of buildings. Waste Ceramic Dust was added to the soil at different percentage by the weight of soil; five samples with 5%, 10%, 15%, 20%, and 25% of WCD were examined in order to find optimum WCD percent that improves the soil engineering properties and soil strength especially. Figure 1. illustrates sample of WCD materials,

![Sample of WCD material](image)

**Figure 1.** Sample of WCD material.

7. Waste Plastic Strips (WPS)

Plastic strips are waste plastic cups or bottles they waste from water manufactories or houses. They are cut by using ordinary cutting scissors into slices with dimensions (12 mmx8mm) to be used for the purpose of stabilization with soil installed by (WCD), they are added directly to the soil. Waste plastic strips were obtained as waste plastic strips added to the soil at various proportions by the weight
of soil, four samples with WPS of 0.25%, 0.5%, 0.75%, and 1% are tested in order to find optimum WPS percent that improves subbases soil strength.

Figure 2. Sample of WPS material.

8. Experimental Work
After evaluating the engineering properties of the used materials in this study such as subbase, WCD and WPS, mixing of subbase soil only is carried out. Table 1 indicates sieve analysis for Natural Subbase while table 2 presents sieve analysis for ceramic waste materials.

| Sieve size     | weight sieve empty | Remaining weight with sieve | Passing ratio | Specification (class B) |
|----------------|--------------------|-----------------------------|---------------|-------------------------|
| 1inch          | 1069               | 1427                        | 92.8          | 75-95                   |
| 3/8 inch       | 955                | 1782                        | 73.1          | 40-75                   |
| No.4(4.75mm)   | 796                | 1471                        | 59.6          | 30-60                   |
| No.8(2.36mm)   | 701                | 1441                        | 44.8          | 21-47                   |
| No.50(0.3mm)   | 583                | 1911                        | 18.2          | 14-28                   |
| No.200(0.075mm)| 514                | 1101                        | 6.5           | 5-15                    |

| Sieve size     | weight sieve empty | Remaining weight with sieve(try1) | Remaining weight with sieve(try2) | Passing ratio(try1) | Passing ratio(try2) |
|----------------|--------------------|-----------------------------------|-----------------------------------|---------------------|---------------------|
| 1inch          | —                  | —                                 | —                                 | 100                 | 100                 |
| 3/8 inch       | —                  | —                                 | —                                 | 100                 | 100                 |
| No.4(4.75mm)   | 1209               | —                                 | —                                 | 100                 | 100                 |
| No.8(2.36mm)   | 971                | 1133                             | 1137                             | 83                  | 83                  |
| No.50(0.3mm)   | 583                | 931                              | 830                              | 58                  | 57                  |
| No.200(0.075mm)| 530                | 1017                             | 1046                             | 9.5                 | 9                   |

Figure 3 shows result of Proctor test for natural subbase soil materials to determine optimum water content.
CBR mix design method was used to get the optimum WCD content and evaluate the strength of the mixtures in laboratory and other engineering properties of the mixture. A subbase soil about 5000 gm is mixed with different percent of WCD (5%,10%,15%,20%,25%) and mixed with optimum moisture content, the mixture is then placed in CBR mold at five layers, each layer is compacted using 56 blows, after compaction, each mold is weighted, then soaked in water for four days, After soaking, each mold is tested in CBR test in order to find optimum WCD content which is reached a maximum CBR value. After evaluating optimum WCD content, subbase soil is mixed with the optimum WCD content and different percent of WPS (0.25%, 0.5%, 0.75%, 1%) at optimum moisture content and the same above stapes which are repeated in order to determine the optimum WPS which improves the soil strength and maximum CBR value. Figure 4 and 5 illustrates Result of CBR test for Subbase materials stabilized by waste ceramic and CBR test results for Subbase materials stabilized by waste ceramic and waste plastic strip, respectively.

Figure 4. Results of CBR test for Subbase materials stabilized by waste ceramic.
Figure 5. CBR test results for Subbase materials stabilized by waste ceramic and waste plastic strip.

As mentioned before, subbase soil is chosen for this study, engineering properties such as the optimum moisture content and maxes. dry density was tested. Atterberg limits are also examined at the optimum moisture content and CBR value was determined according to ASTM D 1883/AASHTO T 193-93. Table 3 indicates engineering of natural subbase course materials.

| Test description        | Result       | Specification Limits (SCRB,2003) |
|-------------------------|--------------|----------------------------------|
| Liquid limit            | 22.1         | 25%                              |
| Plastic limit           | 4.2          |                                   |
| Plasticity index        | 17.9         | 6%                                |
| Max.dry density         | 2.2 gm/cm³   |                                   |
| Optimum water content   | 9.8          |                                   |
| CBR                     | 29.5052%     |                                   |
| Soil type               | (A-2-6)      |                                   |
| Passing No200 sieve     | 6.5          |                                   |

9. Effect of WCD Material on Soil Characteristics
As mentioned in pervious chapter, the WCD material was added to the soil in five different percents. After the CBR test for all molds, the optimum WCD content was 20 % which represents a maximum percent of WCD that improves the soil strength. Other engineering properties such as the optimum moisture content and max dry density were also tested. The result is shown in figure 6: CBR value was improved, according to ASTM 01883/AASHTO T 193, the load reading at 5 mm is 8.934, CBR value is 86.738%, as a result, the soil strength was increased at 20% WCD.
10. Effect of WPS Material on Soil Characteristics

After reaching the optimum WCD content and test soil mixture properties, the WPS material was added to the mixture in four different percent. After the CBR test for all molds, the optimum WPS content was 1% which represents a maximum percent of WPS that improves the soil strength. Other engineering properties such as optimum moisture content and max dry density were also tested. The result is shown in figure 7: CBR value was improved, according to ASTM 01883/AASHTO T 193, CBR value is 103.010%, as a result, the soil strength was increased at 20% WCD and 1% WPS.

11. Testing Results and Discussion

Based on laboratory test results, the CBR value of the treated samples increase with increase of WCD until (20%) percent and specific percent of WPS(1%), this behavior can be justified by the increase of strength of the treated soil due to chemical bond produced by reaction of WCD with components of soil, The increase in the bonding strength with the addition of the increase, which leads to the increase in strength, and thus the increase in the strength of CBR values. The results exhibited that plasticity index of the soil treated with WCD is decrease at optimum WCD content, on the other hand, plasticity index of soil treated with 1% WPS is increase at optimum WPS content, result shown in figure 8.
Figure 8. CBR test results with (20%WCD) and (1%WPS) additives.

12. Conclusions

The main conclusions have been drawn can be listed below:

1. Soil strength as it was evaluated by California bearing resistance (CBR) are increased with increase of WCD percent until 20%. Also, stabilized soil strength are increased with increase of WPS.

2. The existence of WCD and WPS in the subbase soil mixture is considered as an eco-friendly material and it can improve soil strength.

3. Regarding the CBR test, the process of using WCD is enhanced by WPS as 20% from weight of soil and 1% of WPS.

4. From the economic analysis, it was found that up to 20% ceramic dust is often used to strengthen the flexible pavement with a significant saving in the construction cost.

5. Plastic parts reduce the maximum dry weight of the soil and the optimum moisture content. The difference in the optimum water content, the maximum dry weight with the linear plastic cutting content, and the shape of the compression curves is almost the same as those of the unsupported samples.

13. References

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