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Effect of Brick Dust on Soil and Strength Improvement with the use of Plastic Waste

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Abstract

In the age of rapid development, massive civil engineering structures are being built on top of the soil. Soil properties varies from one location to the other. Many of them show problematic behavior such as swelling, poor drainage, low strength that can lead to catastrophic failure of the structure built above it. This paper focuses on the effect of brick dust and plastic waste as a alternative way to improve soil properties. The study performed were Atterberg's limit, Compaction properties and unconfined compressive strength (UCS). Soil has been tested with addition of brick dust in ratio of 10%, to 50% by weight. Plastic waste is added on each brick dust ratios of 30%, 40% and 50% in the amount of 0.25%, 0.5% and 1% to test the compressive behavior of soil at different curing periods. It is concluded that the addition improves the soil behaviour by decreasing its plasticity index, increases the compaction index and also improves the geotechnical parameters.

Keywords

Soil stabilization, Brick Dust, PET plastic,Atterberg's, UCS

1. Introduction

Soil stabilization is the process of enhancing the engineering characteristics and performance of soil for various use case. Soil stabilization consists of a number of various techniques to enhance the engineering properties of soil. Additives such as cement, lime or other chemical compounds are used either by allowing it to interact with the undisturbed soil through seeping through the soil voids or is physically mixed with the natural soil to create a homogeneous soil [1]. Various research over the past decades have found soil stabilization to be one of the best in mitigating the expansive behavior of soil. The use of pozzolanic compound to stabilize the soil has been studied by many researchers. Lime, cement, fly ash, rice husk ash, etc. have shown a substantial increase in the strength and stability of the soil [4, 9, 13, 14]. But the cost of the cement, lime and availability of fly ash and rice husk has increased the overall cost of stabilization of soil [4]. Hence a need for sustainable compound has risen.

Brick dust is a waste material found in the brick kilns and is easily available at a very low cost. Brick dust is made up of silica (55%), iron oxide (8%), aluminum oxide (15%), calcium oxide (7%), magnesium oxide (2%) and sulfur trioxide (1%)[3]. Based on its availability and its inherent chemical properties extensive research has been carried out to find the optimum ratio for mixing and finding improvement in the properties. Rheological properties of brick dust has shown it to be superior in terms of mortar- brick bond strength when cement was replaced by it [10]. The replacement of cement by brick dust has also shown reduction in the deterioration effect of alkali-silica reaction in mortar [15]. Replacement of cement by brick dust in concrete by up to 25% has shown greater thermal resistance and sufficient strength gain [3].

A study performed a number of tests on clayey soil by replacing soil with 10%, 20% and 30% percentage of brick kiln dust and with 0.5%, 0.75% and 1% coir fiber by weight of soil sample. The result of the tests showed that the addition of brick kiln dust resulted in increase of CBR value. The combination of coir fiber and brick kiln dust resulted in CBR value to increase continuously. The tests concluded with optimum value of brick kiln dust and coir fiber to be 30% and 10% respectively. The study also found when subgrade is stabilized with 30% brick kiln dust and 1% coir fiber, the subgrade thickness is reduced by 40% [7].

Al-Baidhani and Al-Taie (2020)[2] in their experiment, replaced the highly plastic soils with brick dust by 10%, 20% and 30% by dry weight of the soil. A number of linear shrinkage and unconfined compression were then carried out to find the quantitative variation of the effect of replacing the soil with the brick dust. The experiment concluded that the critical behavior of highly plastic soil can be controlled by mixing with 20% or 30% of brick dust. The effect of curing on the undrained shear strength of the soil specimen mixed with brick dust was also carried and showed significant improvement after curing period of seven days.

Growing use of plastic has turned into a massive problem in terms of waste management. The ease of availability and versatile use of plastic has made it one of the most popular material for rapid change in human lifestyle. Thus an alternative to the management is needed [16].

Over the last six decades, the manufacturing and use of plastic bottle have increased drastically across the globe. This has made environmental impact around the world [12]. The author in their paper suggests to use the plastic waste especially plastic bottle as a way to stabilize the soil. The study conducted by the author conducted experiments to examine the effect of plastic bottle strips on the clayey soil by replacing the soil with 0.1%, 0.2%, 0.3% and 0.4% of the dry weight of the soil and compared the resulted with the non-stabilized soil. California bearing test, compaction test and Atterberg's test was performed on the soil mix. The result showed that up to 0.3% replacement by plastic waste, there was increase in the CBR value and then the value dropped for further increase in the percentage.

Mallikarjuna and Mani [8], on their paper used plastic pieces from plastic chairs and made them into strips. The plastic strips were added to the black cotton soil in percentage of 2, 4, 6 and 8 and modified proctor test was carried out. The author found that till 4% replacement the MDD increased and further addition of plastic decreased the maximum dry density. The optimum moisture content of the soil mix decreased throughout the replacement. The CBR value reached a peak at 4% replacement and decreased on further addition of the plastic waste. Similar study conducted by Neopaney et al., in 2012 [11] also found increase in the CBR value of the soil specimen. The CBR value of unreinforced soil increased to a maximum of 1.7 times compared to the reinforced soil sample. The study also found that the size of the strip affected the CBR value of the soil mix and suggests further study to be carried out.

This article presents the experimental evaluation of effect of brick dust and subsequent addition of plastic waste on the engineering properties of soil and also the effect of curing on the soil mix.

2. Materials

2.1 Soil

For the study, the black cotton soft soil was acquired from Magargaun ,Lalitpur from the excavation pit of single basement residential building at a depth of around ten feet. The acquired soil was air dried for seven days and crushed to fine particles using a mallet. The soil was sieved through 425um IS sieve and stored in a dry container and dry location. According to the Unified soil classification system, soil is classified as CH (Inorganic clay of plasticity, fat clays) and A-7-6 in AASHTO system. The particle size distribution of soil sample is shown in Figure 1. The index and engineering properties of soil are shown in Table 1.

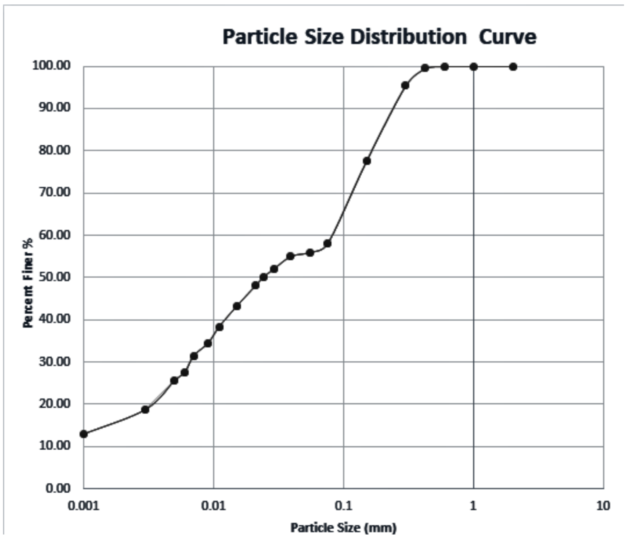

Figure 1: Particle Size Distribution

2.2 Brick dust

The brick dust for the experiment was acquired from the kiln located at Tathali, Bhaktapur. The brick dust was then allowed to air dried, pulverized and passed through 425um IS sieve. The collected brick dust is stored in dry place (Figure 2).

2.3 Plastic waste

PET (polyethylene-terephthalate) waste plastic bottle were collected locally and was cleaned and dried. Then the bottle was stripped and cut into small flakes of size less than 3 mm (Figure 3). Accordingly, three different percentage of 0.25%, 0.5% and 1% by weight of soil mix was used. The size adopted was based on the experiments by Lozada et. al [5].

Figure 2: Brick dust

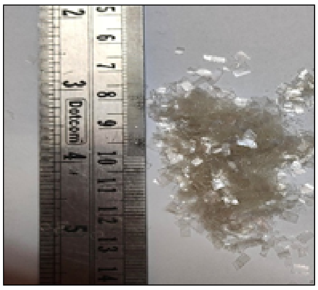

Figure 3: Plastic waste flakes

Table 1: Index and Engineering properties of Soil

SN	Properties of soil	Values
1	Specific Gravity of soil (G)	2.51
2	Maximum Dry Density (MDD) kN/m^3	13.78
3	Optimum moisture content (OMC) %	29.21
4	Liquid Limit %	54%
5	Plastic Limit %	27.45%
6	Plasticity Index %	26.55%
7	Classification	CH
		A-7-6
8	Specific Gravity of Brick dust	2.62

3. Methodology

In this study we are conducting Atterberg's limit test, standard proctor test for the determination of dry density and moisture content. Unconfined compressive test is also conducted to see the strength variation of the soil mix. The proportion of brick dust (BD) used in the test varies from 10, 15, 20, 25, 30, 40 and 50 percentage by dry weight of the natural soil. Then the 30, 40 and 50 percentage of brick dust is further mixed with 0.25, 0.5 and 1% of plastic flakes (PW) to see the unconfined compressive strength. The Atterberg's limits is carried out based on IS: 2720 (Part V):1985, Standard proctor test is carried out based on IS: 2720 (Part 7):1980, and unconfined compressive strength test is carried out based on IS 2720 part X: 1991. The UCS sample are covered with plastic to keep the moisture intact and see the effect of curing of 7 days.

4. Analysis and Results

4.1 Atterberg's Limit

Figure 4 presents the results obtained. The plasticity index is reduced to a greater amount with the addition of brick dust.

Mix proportion	Liquid limit (%)	Plastic limit (%)	Plasticity index (%)
Natural soil (NS)	54	27.45	26.55
NS+10%BD	50.98	26.52	24.46
NS+15%BD	47.77	24.04	23.73
NS+20%BD	43.75	20.47	23.28
NS+25%BD	39.9	18.96	20.94
NS+30%BD	36.04	16.78	19.26
NS+40%BD	34.36	15.76	18.6
NS+50%BD	30.9	12.37	18.53

Figure 4: Atterberg's Limit

4.2 Standard Proctor

The maximum dry density of the soil and the optimum moisture content with varying ratio of brick dust were were determined. According to Figure 5, it is observed from the compaction curves that when the percentage of brick dust increases, the dry density increases and the optimum humidity content decreases.

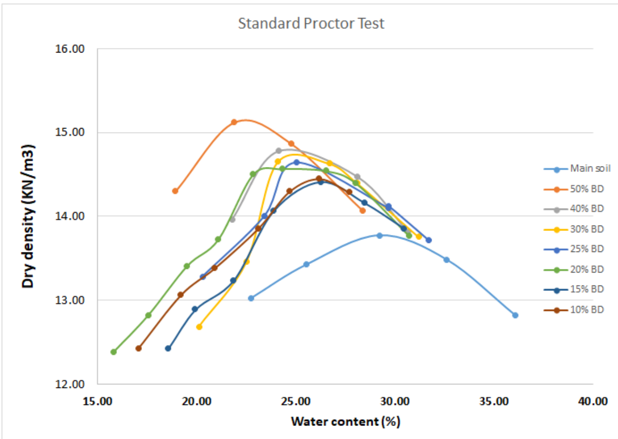

Figure 5: Standard Proctor Test

4.3 Unconfined Compression Test

The test result confirmed the value of unconfined compressive strength of the natural soil to be 114.48 Kpa. The addition of Brick dust on the soil sample in all mix proportion increased the value of unconfined compressive strength and the change was more prominent in soil mixed with 40% BD and 0.25% PW and attained a value of 737 kpa after curing period of 7 days. In all the mix proportion curing period increased the unconfined compressive strength. This is due to the ongoing hydration reaction within the soil mix which was aided by the curing method applied. In all the soil mix proportion the addition of plastic waste in the amount of 0.25% by weight increased the strength while remaining 0.5% and 1% plastic waste addition decreased the strength when compared to no addition of plastic waste to the mix. The lowest strength in all mix proportion was due to the 1% addition of plastic waste which can be due to the excess amount of plastic particles clumping together and forming void inside the specimen [6]. Also the surface of the PET plastic is smooth and thus there is loss of friction between different layers of soil in the soil mix sample.

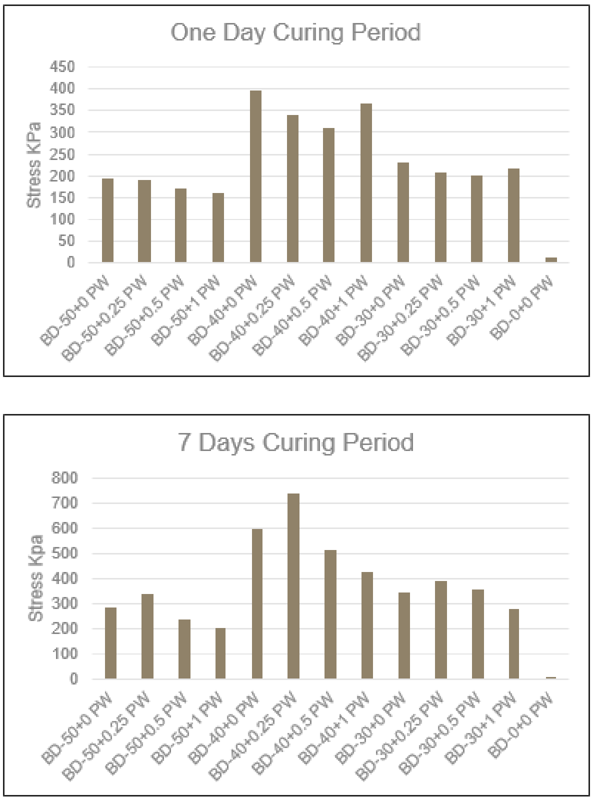

Figure 6: Unconfined Compression Test

5. Conclusion

- The maximum dry density of the soil increases with the increase in the content of brick waste dust. The highest dry density was attained at 50% brick dust replacement.
- Liquid limit, plastic limit, and plasticity index of natural and stabilized soils decreased with the increment of the percentage of brick dust to its highest ratio of 50%.
- The addition of brick dust up to ratio of 50% improved the soil and shifted the CH group to be in the CL group
- The UCS of the stabilized soil was greater than the UCS of the natural soil sample. The best result was obtained with the mix of 40% Brick dust with 0.25% Plastic waste.
- In every mix, 0.25% PW showed highest strength gain compared to the soil mix with no plastic waste.
- Further tests on varying soil properties can be done to get a bigger data set and which can be further used to validate the work and develop relation.

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