Exploring the shear strength characteristics and CBR value of an expansive soil by using brick dust and coir fiber

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Abstract. Expansive soil is a term generally applied to any soil or rock material that has a potential for shrinking or swelling under changing moisture conditions. Expansive soils are widely found in many parts of Pakistan. This research aims to investigate the effect of brick dust and coir fiber on the stabilization of expansive soils. A sample of clayey soil was obtained from Nandipur Gujranwala, Punjab, Pakistan, which is expansive soil in nature. California Bearing Ratio (CBR) and direct shear tests were performed for the evaluation of shear strength and CBR value. Direct shear tests were performed at different percentages of brick dust to find an optimum percentage. Brick dust is used in intervals of 10% ,20%, 25%, 30% and coir fiber is used in interval of 0.3%, 0.6%, 0.9%, 1.2%, and 1.5%. The optimum value of brick dust (25%) was used, and the percentage of coir fiber was varied to find an optimum value of coir fiber. The results show that at the optimum value of brick dust, the cohesion value is lowest, and the friction angle is highest. Varying coir fiber percentage, cohesion, and friction angle both increases, and the CBR value also increases at an optimum value of 1.2% of coir fiber.

Keywords: Shear Strength, Brick Dust, Coir Fiber, CBR, Direct Shear.

1. Introduction

Nowadays, due to sustainable constructions, there has been a great consideration for soil reinforcement with various types of natural fibers. In highway and building construction, the layer of soil on which construction is being performed is most important. The success or failure of the foundation and pavement depends upon the underlying soil. A major challenge in geotechnical engineering is the improvement of expansive clays on which buildings are built. The soil stabilization technique is used to improve the performance and engineering properties of soil.

An important characteristic of clayey soil is that it swells when its moisture content is allowed to increase [1]. Therefore, the optimization of such clay soil is important for safety and to further prevent damage to the structure. Additives such as lime and cement have been added to soil with fibers [2-5]. Kumar et al. [6] used brick dust blended with varying percentages of lime as a stabilizing additive for the stabilization of black cotton soil. The results show that the combination of brick dust and lime produces maximum improvement in soil strength as compared to individual additive. Although, fiber-binder soil composites enhance the soil strength drastically, they may show an undesirable brittle behavior of fiber-soil mixtures.

Therefore, the concept of soil stabilization with different natural and synthetic fibers has gained widespread attention. Many researchers have reported different varieties of additive materials used on the subject of soil stabilization, the most common methods of soil stabilization of clay soils are plant saps, animal dung, and natural oils stabilization [7]. Li and Zornberg [8], [9] studied the shear strength behavior of soils reinforced with weak fibers and reported that the fiber increases the peak shear strength of the soil. Lakshmi et al. [10] performed soaked CBR and unconfined compression (UCC) tests to increase the soil strength by adding non-woven coconut coir fiber. The experimental tests depicted that UCC strength and soaked CBR value increase with the addition of fibers in soil. Lone [11] studied the effect of natural fibers blended with fly ash for soil stabilization. The results of research depicted that the CBR value of soil increases with the addition of fibers and fly ash. Pokale et al. [12] studied the effect of admixture of 30% brick dust on the soil shear strength. Neha and Trivedi [13] performed experimental work for the stabilization of clayey soil with brick dust. It was reported that the soil properties improved with the addition of brunt brick dust. Khan and Sonthwal [14] performed the experimental study using fibers and brick dust. It was concluded that varying percentage of brick dust increases the soil strength.

It is evidential from earlier studies that, for the stabilization of soil different modifications procedures are used such as lime, fly ash, rice husk, cement, geogrids, geomembranes, etc. In this study, the effect of coir fiber in conjunction with brick dust on clay soil for enhancing the strength of the soil is investigated. The behavior of unreinforced and reinforced samples was observed.

2. Materials and methodology

2.1. Soil

Many areas of Pakistan such as Nandipur, Narowal, and Layyah contains expansive clayey soil. In this research, problematic expansive clayey soil was collected from Nandipur and used for further analysis. Nandipur is an industrial town located near Gujranwala, Punjab, Pakistan. The clayey soil in Nandipur is weak in shear strength and has swelling problems, which cause the failure of building and foundations. Table 1 shows the properties of soil used in the experimental work.

Table 1. Properties of Soil

Natural Moisture Content	21.9%
Specific Gravity	2.81
Liquid Limit	46.93 %
Plastic Limit	25.56 %
ASSTHO Classification	A-7-6(14)
USCS Classification.	CL (Sandy Lean Clay)

2.2. Brick dust

Brick dust is a local waste material generated through the burning of bricks with the soil. It is red in color and fine texture in nature. Due to the burning of soil bricks, it becomes hardened; when the set-up covering is removed, the powder in the form of brick dust is obtained. Brick dust is easily available at any brick kiln, provides additional strength to soil, makes it strong in shear strength, and increases the bearing capacity. It has a great ability to reduce the swelling potential for highly expansive clay soils.

2.3. Coir fiber

Coir fiber is a natural waste material of coconut husk, having the characteristics of a hard structural fiber. The use of these materials in soil reduces the pavement thickness, So the materials cost also decreases. Coir fiber increases the tensile strength of soil, so it reduced the cracking of soil which occurs due to long-term loading on the soil. Coir fiber twisting and curling without any breaking enhanced the plasticity of pavement. In this study, coir fibers were purchased from a local market. For experimentation purposes, its diameter varied from 0.2 to 0.3 mm. Further, the coir fiber was cut into pieces of 30 mm length and mixed with soil taking a percentage of 0.30%, 0.60%, 0.9%, and 1.2%.

2.4. Methodology

The current study was carried out in two stages. At the first stage, a series of laboratory direct shear strength tests were performed on clay soil samples with the addition of brick dust. Brick dust is replaced with the soil in proportions of 0%, 10%, 20%, 25%, and 30%. The optimum percentage of brick dust was selected through this testing.

In the second stage, the soil with the optimized brick dust was further mixed with coir fiber in proportions of 0%, 0.3%, 0.6%, 0.9%, and 1.2%. Modified proctor compaction tests were performed for the determination of optimum moisture content (OMC) and maximum dry density (MDD). direct shear strength test (DST) and California bearing ratio (CBR) tests were also performed on prescribed proportions of coir fiber. The CBR tests were performed on soaked samples which were immersed in water for 96 hours before testing.

3. Results and Discussion

3.1. Direct shear test

For evaluation of the shear strength behavior of soil, a series of direct shear tests was performed after treating the soil with brick dust. Soil samples were prepared by varying percentages of brick dust at 0%, 10%, 20%, 25%, and 30%. Fig. ***1*** and Fig. ***2*** show that as the percentage of brick dust increases in the soil the value of cohesion decreases but the angle of internal friction increases up to 25% brick dust addition. On further addition of brick dust after 25% the value of cohesion increases but angle of internal friction decreases which indicates that the optimum value of brick dust in the soil is 25%. The amount of brick dust was fixed 25% (optimum value) and varying percentages of coir fiber from 0%, 0.3%, 0.6%, 0.9% and 1.2 % with 0.3 % interval were added for further trails. Fig. ***3*** and Figure ***4*** show that as the percentage of coir fiber increases the value of cohesion and angle of internal friction increases up to the percentage of 1.2%, on further addition of coir fiber cohesion and angle of internal friction start to decrease.

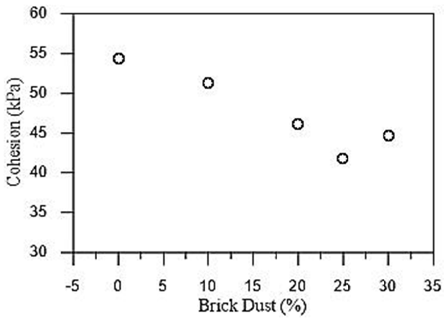

Fig. 1. Effect of brick dust on cohesion value

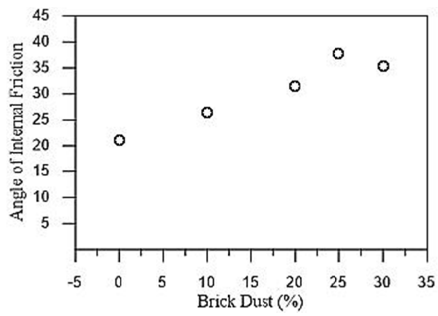

Fig. 2. Effect of brick dust on angle of internal friction

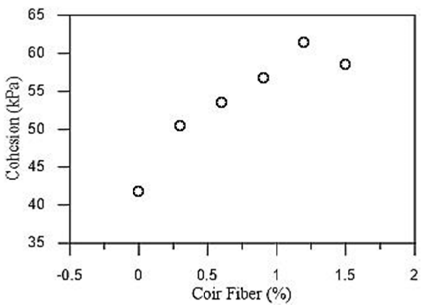

Fig. 3. Effect of coir fiber on cohesion value

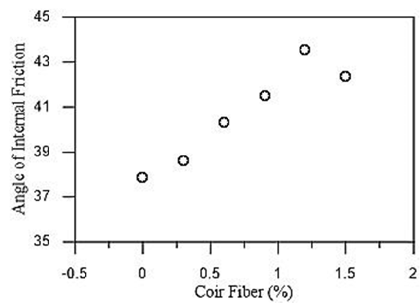

Figure 4. Effect of coir fiber on angle of internal friction

3.2. Modified proctor test

Modified proctors' tests were performed on clayey soil samples by taking the optimum value of brick dust and varying percentages of coir fiber from 0%, 0.3%, 0.6%, 0.9%, and 1.2 % with a 0.3% interval.

On 25% brick dust addition, the optimum moisture content decreases from 20.07% to 16.07% but maximum dry density increases from 1.87 g/m^3 to 2.18 g/m^3. On the other hand, Fig. ***5*** showed that after the addition of varying percentages of coir fiber 0%, 0.3%, 0.6%, 0.9%, 1.2% and 1.5% with a 25% brick dust (optimum value) the value of optimum moisture content increases from 16.07% to 17.64% but maximum dry density decreases from 2.18 g/m^3 to 1.83 g/m^3. So, with the addition of coir fiber maximum dry density increases significantly with less optimum moisture content.

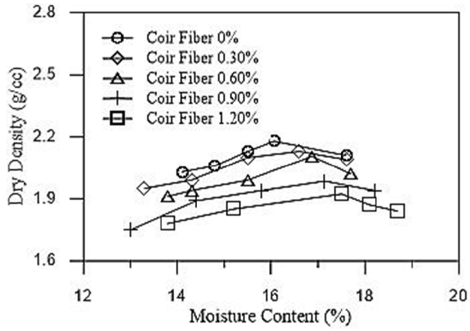

Fig. 5. Effect of coir fiber on moisture content and dry density

3.3. California bearing ratio test

Soaked California bearing ratio test was performed on clayey soil samples by taking the optimum value of brick dust and varying percentages of Coir fiber from 0%, 0.3%, 0.6%, 0.9%, and 1.2% with a 0.3% interval. From Fig. ***6***, it was observed that as the percentage of brick dust increases up to 25%, the CBR value increases from 35.7% to 44% and after taking 25% B.D constant and varying percentages of coir fiber i.e., 0.3%, 0.6%, 0.9%, 1.2%, and 1.5%, it was observed that CBR value increases from 44% to 59.9% up to 1.2% coir fiber. So optimum value of C.F is 1.2 % where 59.9 CBR is achieved. Therefore, an increase in the percentage of coir fiber increases the CBR value, higher the CBR means higher the bearing capacity and more the soil stable.

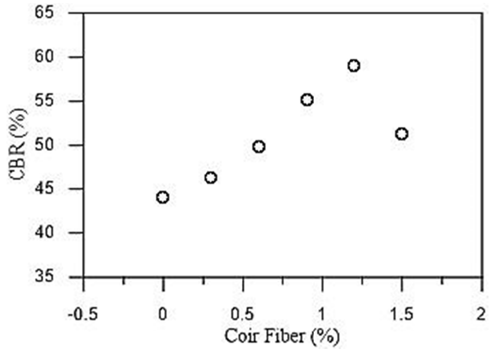

Fig. 6. Effect of coir fiber on CBR value

4. Conclusions and recommendations

In this paper, the optimum value of brick dust and coir fiber was evaluated for the stabilization of locally expansive clayey soil. Following observations were made after performing a series of tests.

- Soil is classified as CL according to USCS and A-7- 6(14) according to the ASSTHO classification system, it is poor as a subgrade, as the G.I value is 14. Soil has 97% of silt and clay content.
- The addition of brick dust in soil decreases the cohesion of soil and increases the angle of internal friction. As the percentage of brick dust increases the angle of internal friction increases and the maximum increases up to 25% brick dust, which is the optimum value of brick dust. At 25% of brick dust, the maximum value of shear strength increases.
- After the addition of 1.2%, coir fiber with 25% brick dust the soil cohesion increases up to 46.7% and the angle of internal friction increases up to 15%.
- The CBR value increased by 23% with the addition of 25% brick dust. On further addition of 1.2% coir fiber with 25% brick dust, the CBR value increases by 65%.

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