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Improvement of swelling clay properties using hay fibers

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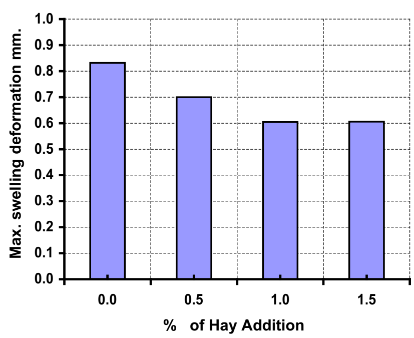
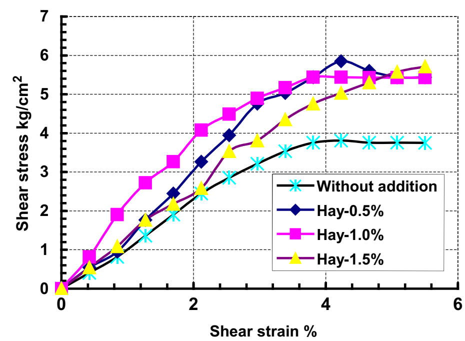
HIGHLIGHTS

- ▶ Swelling clay is mixed with hay fibers to improve its characteristics.
- ▶ The shrinkage limit decreases with the increasing of hay ratio till 1% hay ratio.
- ▶ The unconfined compression strength decreases with the increasing of hay ratio.
- ▶ The tensile strength of the air dried hay–clay mixture increases by 30% with hay ratio addition of 1% by weight.
- ▶ The swelling potential decreases by 20% with hay ratio equal to 1%.

GRAPHICAL ABSTRACT

Improvement of swelling clay properties using hay fibbers. The hay fibbers decreases the swelling potential and increases both the shear strength and the tensile strength of the air dried samples.





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ABSTRACT

For soil stabilization, lime, fly ash, and different chemicals additives were used to improve the swelling characteristics of the clayey soil. In the present study, the hay of wheat is added to a type of clayey swelling soil to improve and stabilize its characteristics. Old houses in Egyptian villages were built with clay mixed with hay as a cementious agent between clay particles. The hay ratio used in the present study was 0.5%, 1% and 1.5% by weight of the clayey soil. The soil used in the study represents a type of swelling clayey soil. Index, strength and swelling properties tests are carried out on the clay–hay mixture. The results showed that the shear strength increases with the increase of hay ratio till approximately 1% hay addition. The indirect tensile strength for air dried samples increased as well. The deformation due to the swelling potential also decreased to about 20%.

1. Introduction

Swelling clays are found in many parts of the world, particularly in arid and semi-arid areas. Swelling clays are detected in Australia, Canada, China, Jordan, Saudi Arabia, India, South Africa, Sudan, Egypt, and the United States. The expansive soil term is used for soils that have potential shrinkage and swelling property under changing water content.

Swelling soils in Egypt are found in different areas such as Madinat Nasr, Sina, Assiut, the New Valley, and Sohag [3]. Although a considerable progress had been made to overcome this problem but no definite theoretical analysis has been established. This may be due to the complex interaction of the soil-cations minerals with water. In cases where the surface layer only is found as expansive clay, it can be replaced with clean sand or admixture of gravelly sand. Sometimes, a protective procedure should be applied to prevent the access of the free water to the soil i.e., constructing the

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foundation at depths not subjected to the changes in the water table. However in embankment construction, if the soil of the embankment was a swelling soil, it must be treated with some additions before construction. Egyptians used hay in houses, by adding it to the clay pastel. They built their houses from pastels of clay mixed with hay in their wet state and left it until getting dry. This efficient method contributed to the stability of the houses they built. For economic purposes, the construction of highways necessitates using the local soil in the field. This problem may be overcome by converting or improving the swelling properties of soil using appropriate additives. Lime is one of the most common and successful soil stabilizers. Some chemical additives are used with lime, and are found to be useful in accelerating the interaction between lime and soil. These chemical additives are not widespread due to their high cost. Stabilizing of swelling soil by lime requires months to react and reach equilibrium state with soil.

The main objective of this research is studying the effect of hay addition to an expansive soil, on its strength and swelling properties. Hay is cheap and is found all over the world. Hay is added to an expansive clayey soil from Sohag province in Egypt as a percentage of soil by weight.

Extensive studies have been carried out on the stabilization of expansive soils using various additives such as lime, cement, fly ash, industrial waste products, potassium nitrate, calcium chloride and phosphoric acid [14,2,4,8,10,12]. Mat et al. [15] considered the potential of gypsum, organic polymers, organic matter waste materials, and fly ash, as soil stabilizers. Addition of gypsum to soil can limit clay swelling and dispersion, and improve soil structural stability. Synthetic organic polymer addition to soil surface aggregates leads to their stabilization, improves bonding between adjacent aggregates, and clay flocculation. Fly ash additives can improve soil physical characteristics such as texture, structure, water holding capacity, hydraulic properties, and aeration [11]. In Al-Khod (northern Oman), a swelling clayey soil was treated with cement by-pass dust (CBPD), the formation of aggregations as a result of the clay cement interaction had reduce the clay potential of swelling [13]. Lime is widely used in civil engineering applications such as road construction, embankments, foundation slabs and piles. Generally the amount of lime needed to modify a clay soil varies from 1% to 3%, whilst that required for cementation varies from 2% to 8% [6,7]. Cement stabilization is similar to that of lime and produces similar results [14,5].

Synthetic fibers such as cellophane, steel or glass wool have found very limited application in the soil stabilizing process. Vegetable oils and fats, tannins, arabic gum, are used as soil stabilization but they have very slow and limited applications [12]. Fibers are widely used when building with earth. Generally, fibers can be most easily mixed in with the soil if it is in a plastic or liquid state. The synthetic fibers serve to increase the tensile strength, reduce density, accelerate drying and reduce cracking by dispersing stresses. Fibers vary in shape, size, strength, elasticity and their bond strength with earth, so possible improvements with different types of fiber will vary, as will the amount of a particular fiber required.

2. Plan of study

2.1. Materials

The soil studied is a silty clayey soil. The soil is gray to black color and is quite expansive. The soil is obtained through pit excavated till 2.5 m depth below the ground surface. A free swell test as described in IS:2720-(PART-XL), was carried out and gave a reading of 120%. Therefore, the soil is considered quite expansive [3]. The grains of hay take a longitudinal shape of about 15–25 mm and an approximate thickness of 0.5 mm as shown in photo (Fig. 1).

Fig. 1. Photo of used hay.

2.2. Performed tests

2.2.1. Index tests

The determination of materials finer than No. 200 (75-μm) is carried out as described in ASTM D1140-00R06. Liquid Limit, Plastic Limit, and Plasticity Index are carried out as described in ASTM D4318-10. The shrinkage limit is carried out as described in per IS:10077. Standard compaction test is also carried out as described in ASTM D0698-07E01. The free swelling readings are obtained from the application of their standard tests per IS:2727-1977. The results are shown in Table 1.

2.2.2. Strength tests

To investigate strength properties of the clayey soils, three tests were applied.

(i) The unconfined compression test, as described in ASTM D2166-06.
(ii) The direct shear test, as described in ASTM D3080-04.
(iii) The indirect tension test on dry samples, as described in ASTM D3967-08.

In each test the soil is compacted in the normal test mold. The samples are prepared at the maximum dry density and optimum water content.

Standard unconfined compression test as described in ASTM D3080-04 was carried out. The test samples are prepared according to ASTM standard specifications. The sample dimensions are 2.54 cm in diameter and 6.35 cm in length, having its maximum dry density with the optimum water content. More than three tests are carried out and the average is obtained. The relation stress–strain is plotted.

The direct shear test is carried out as described in ASTM standard procedures. Samples are prepared with the maximum dry density and optimum water content. A series of tests are carried out on the clayey samples under normal vertical applied load of 0.5, 1.0 and 1.5 kg/cm^2.

For the determination of materials strength, their tensile strength is of major importance. The direct testing of brittle materials however is very complex. An alternative to this is the indirect testing or so called Brazilian disk test. This test is used for concrete testing since long time [1]. The Brazilian test set is shown in Fig. 2. A cylindrical specimen is broken in tension perpendicular to one diameter, by applying compressive force (F) in a direction perpendicular to this diameter (D). The diameter of specimen is one half its length (L). The load increased slowly until specimen breaks. The test is a good one for brittle materials that have shear strength greater than their tensile strength [1].

For samples with length $L = 2D$, the tensile stress can be determined as in following equation: