Iranian Journal of Engineering Geology
Summer 2018, Vol.11, No.2

Investigation of tensile strength and deformation characteristics of Varamin collapsible soils at undisturbed, reconstituted and treated states

M. Hashemi*[1], H. Mahmoudian[2], R. Ajalloeian[3]

Abstract

Tensile failures including tensile cracks on the upper part of unstable slopes, earth fissures, tensile cracks in earth dams, and any kind of tensile failures resulted from tensile stresses within soil body are considered as important engineering geological features. Studying tensile strength and deformation characteristics of soils can have a great role in the prevention of adverse phenomena resulted from tensile failures in soils. The Varamin collapsible soils are subjected to tensile fractures and earth fissuring because of the tensile stresses raised from the land subsidence of the Varamin plain. Therefore, in this study, the tensile strength and deformation characteristics of these soils were investigated at undisturbed, reconstituted and treated states. Results indicate that, when undisturbed collapsible soils are subjected to tensile stresses, they show a low tensile strength and behave brittle in tension. Reconstituted soils have a lower tensile strength in comparison with undisturbed soils and behave very soft and fail easily in tension. Treated soils have a higher tensile strength in comparison with undisturbed soils and behave more ductile in tension and tolerate more deformation before tensile failure. Results indicate that the treatment of the collapsible soils with stabilizer materials together with compaction is an efficient method for strengthening these soils against tensile stresses and for improving their performance in tension.

Keywords: *Collapsible soil, tensile strength, tensile failure strain, brittleness, ductility*

[1] Assistant Professor, Department of Geology, University of Isfahan, m-hashemi@sci.ui.ac.ir
[2] MSc student, Department of Geology, University of Isfahan
[3] Professor, Department of Geology, University of Isfahan
* **Corresponding Author**

Extended Abstract:

1. Introduction

The tensile strength of a soil is important when it is subjected to tensile failures such as tensile cracks on the upper surface of soil slopes, tensile cracks behind retaining walls, tensile cracks in earth dams, earth fissuring, etc. (Kim et al. 2012, He et al. 2018). Sun et al. (2009) showed that the weak tensile strength, the loose structure, and the collapsibility are the important contributing factors to the development of ground fissures in China's loess areas.
Sun et al. (2016) studied the mechanical characteristics of fractured loess in western China. They showed that the tensile strength and deformation of fractured loess soils depend on the inclination of their fracture surfaces. The characteristics of the fractures have an important role in the occurrence of geohazards in the loess regions of western China including ground fissures, ground subsidence, landslides, collapses, and soil and water losses.
Li (2018) reviewed the shear and tensile strengths of the Malan Loess in China. He showed that Both tensile and shear strengths of the Malan loess decrease with water content and increase with dry density. Review results indicate that the undisturbed samples of Malan Loess have tensile strength almost 50% greater than the disturbed ones that indicate the significance of its structure in creating its tensile strength. the increasing of water content results in eliminating the soil structure and consequently the decrease of the soil tensile strength. Therefore, the dramatic increase of water content because of rainfall in summer month triggers numerous failures in Malan Loess (Li, 2018).
The Varamin collapsible soils are subjected to tensile fractures and earth fissuring because of the tensile stresses raised from the land subsidence of the Varamin plain. Therefore, in this study, the tensile strength and deformation characteristics of these soils were investigated at undisturbed, reconstituted and treated states.

2. Materials and methods

Collapsible soils used in this study were collected from the peripheral area of the Varamin plain (Fig. 1), which is subjected to earth fissuring. This area consists of collapsible soils and is under tensile stresses caused by land subsidence of the Varamin plain. Three collapsible soils (i.e., Soil1, Soil2, and Soil3) were selected under both undisturbed and disturbed conditions.
The tensile strength and deformation of soils were investigated in three conditions include undisturbed, reconstituted and treated states. Cylindrical undisturbed specimens with a length to diameter ratio of about 2.5 were trimmed manually from undisturbed soil samples according to the procedure proposed by Avsar et al. (2015). For the preparation of the reconstituted specimens, soil samples were compacted in a cylindrical split-mold under static load. This type of specimens was prepared in two compaction degree of 95% and 100% of the maximum density. In order to obtain treated specimens, additives of silica and alumina powders were added to the soil samples and uniform mixtures containing 0.5%, 1%, and 1.5% additives referred to dry weight were prepared. The mixtures were then compacted in cylindrical split-mold under static load at optimum moisture content.
Finally, a tensile load was applied on the specimens at a rate of 0.24 mm/min and at the same time, the values of deformation, load, and time were recorded. By calculating the tensile stress and deformation, tensile stress-strain curves were obtained for each test.

3. Results

Undisturbed specimens of Soil1, Soil2, and Soil3 have a tensile strength of 38, 26, and 36 kPa and a tensile failure strain of 0.18, 0.24, and 0.33%, respectively. When the tensile load is applied, specimens resist against deformation until the appearance of tensile fractures on the specimen surface. These fractures propagate and change to a single failure plain with an inclination degree of between 30 to 60̊. The failure of the undisturbed specimens occurs without necking.

The tensile strength and deformation characteristics of reconstituted specimens also were investigated. Results indicate that the tensile strength of reconstituted specimens of Soil1, Soil2, and Soil3 compacted to 95% of the maximum density is 15, 16, and 18 kPa whereas the strength of these specimens compacted to 100% of the maximum density is 18, 22, and 19 kPa, respectively. The failure strain of f reconstituted specimens of Soil1, Soil2, and Soil3 compacted to 95% of the maximum density is 0.55, 0.66, and 40% and of specimens compacted to 100% of the maximum density is 0.45, 67, and 45%, respectively.

Results indicate that treatment of specimens with the addition of 1% of both additives of silica and alumina results in the highest strength and ductility. The tensile strength of Soil1, Soil2, and Soil3 treated with 1% silica is 50, 33, and 28 kPa and the strength of these soils treated with 1% alumina is 43, 34, and 36 kPa, respectively. The tensile failure strain of Soil1, Soil2, and Soil3 treated with 1% silica is 0.73, 0.45, and 0.32% and the failure strain of these specimens treated with 1% alumina is 0.93, 0.82, and 0.52, respectively.

Investigation of the relationship between tensile and compressive strength of reconstituted and treated specimens indicates that there is a linear relationship between these two types of strength of specimens in which the tensile strength is about 5 to 10 percent of their compressive strength ($q_t = 0.05q_u \sim 0.1q_u$).

4. Discussion

Results indicate that undisturbed specimens of Varamin collapsible soils have a higher tensile strength in comparison with reconstituted specimens. This observation is because of the natural structure of the soil in its undisturbed state. In undisturbed specimens, a cement bonds soil particles and results the higher tensile strength of the soil. When undisturbed soils are subjected to tensile stresses, the cemented structure of the soil resists against tensile deformation until the tensile stress reaches the tensile strength and causes the failure of soil. Therefore, undisturbed specimens have higher tensile strength and lower tensile failure strain in comparison with reconstituted specimens. Undisturbed collapsible soils of Varamin plain behave brittle in tension and shows a very small tensile deformation before failure and fail without necking.

Comparison of tensile strength and deformation of treated soils with those of undisturbed reconstituted soils indicate that treated soils have a higher strength and behave more ductile before failure. In comparison with undisturbed specimens, treated specimens have a more compacted structure in addition to a cemented structure. On the other hand, in comparison with reconstituted specimens, treated specimens have a cemented structure in addition to a compacted structure. Therefore, treated soils perform better in tension in comparison with undisturbed and reconstituted soils.

5. Conclusion

Varamin collapsible soils have a low tensile strength and a low tensile failure strain in its natural and undisturbed condition. When this soil is reconstituted with compaction, its tensile strength reduces because of losing its cemented structure. On the other hand, when Varamin collapsible soil is treated with additive materials, its tensile strength and tensile failure strain increase and soil behaves more ductile and resists more tensile stress before failure. Therefore, it can be concluded that treatment of collapsible soils with the addition of stabilizer materials is an effective method for strengthening these soils against tensile stress and deformation.

References

Avsar, E., Ulusay, R., Aydan, O., Mutluturk, M., 2016. On the difficulties of geotechnical sampling and practical estimates of the strength of a weakly bonded volcanic soil, Bulletin of Engineering Geology and the Environment, 74: 1375-1394.

He, S., Bai, H., Xu, Z., 2018. Evaluation on Tensile Behavior Characteristics of Undisturbed Loess, Energies, 11: 1974.

Kim, T., Kim, T., Kang, C., Ge, L., 2012. Factors influencing crack-induced tensile strength of compacted soil, Journal of Materials in Civil Engineering (ASCE), 24(3): 315-320.

Li, Y., 2018. A review of shear and tensile strengths of the Malan Loess in China, Engineering Geology, 236: 4-10.

Sun, P., Peng, J., Chen, L., Yin, Y., Wu, S., 2009. Weak tensile characteristics of loess in China — An important reason for ground fissures, Engineering Geology, 108: 153-159.

Sun, P., Peng, J., Chen, L., Lu, Q., Igwe, O., 2016. An experimental study of the mechanical characteristics of fractured loess in western China, Bulletin of Engineering Geology and the Environment, 75(4): 1639-1647.