Collapse Potential and Permeability of Undisturbed and Remolded Loessial Soil Samples

S. Mohsen Haeri, Atefeh Zamani, and A. Akbari Garakani

Abstract. Loessial collapsible soils are in the group of problematic soils and have been encountered in many parts of the world such as some regions in Iran. In these soils, sudden and large volume changes occur while the water content, overburden stress or both are passed a threshold limit. In this paper the collapse potential of a loessial soil taken from Gorgan; a city in Golestan province in North of Iran; has been investigated on both undisturbed and remolded specimens by using oedometer tests. For both types of samples, the effect of initial moisture content and also inundation stress have been investigated on the collapse potential and permeability behavior of the aforementioned soil. The results show that the type of specimen, initial water content, initial dry density and inundation stress have strong affect on collapse potential and permeability coefficient of the studied loess.

Keywords: collapse potential, loess, permeability, oedometer test, undisturbed samples, remolded samples.

1 Introduction

Loess is one of the major problematic soils in the world. There are similar features that are typical to most of collapsible soils. These features are: open structure,

S. Mohsen Haeri
Sharif University of Technology, Iran, Tehran
e-mail: smhaeri@sharif.edu

Atefeh Zamani
Civil Eng. Dept, Sharif University of Technology, Tehran
e-mail:zamani_atefeh@yahoo.com

A. Akbari Garakani
Sharif University of Technology, Iran, Tehran
e-mail: Akbari_amir@civil.sharif.edu

high void ratio, low dry density and geologically young or recently altered deposits. The behaviour of collapsible soils is highly affected by the change of water content and effective stresses (Rogers 1995).

Several researchers studied the effect of initial water content, dry density and overburden pressure on the magnitude of collapse such as Alawaji (2001), Fredlund (1996), Phien-wej et al. (1995) and Lawton et al. (1992). To summarize the major results of these studies, the following general conclusions can be reached:

1. For a given set of conditions, the amount of collapse decreases with increase in initial moisture content and increase in dry density.
2. For a given set of initial conditions, there is a critical pressure at which the amount of collapse is the greatest.
3. For any soil, there are specific combinations of initial water content, initial dry density and overburden pressure at which no volume change will occur when the soil is inundated.

In this study, the effects of initial moisture content and inundation stress on collapse potential are investigated. In addition, the permeability of Gorgan loess soil is studied. Tests have been conducted on specimens with different initial moisture contents and inundation stresses.

2 Test Program

In this study, a number of collapse potential tests were performed on remolded and undisturbed loess samples. Undisturbed samples of the soil for tests were taken from Gorgan, a city in Iran, by means of block sampling. The samples were carefully trimmed and waxed. When sampling the soil, its natural water content was about 3%. Undisturbed specimens were directly taken from mentioned boxes. After determining the water content of each specimen, sufficient water was gradually introduced to the specimen through spraying and waiting to get to the target water content of the test program.

In order to prepare remolded samples, loess soil was passed through a No. 100 sieve and oven dried. Having the volume of the ring, initial dry density and initial water content, the required volume of water and dry soil needed for making the remolded specimen could be calculated. The water was added to dry soil and thoroughly blended and the wet soil was compacted in odeometer rings to get to the preplanned density.

Undisturbed samples were prepared and tested in three groups of initial water content: 3-4% (natural water content), 8-9% and 13-15%. Remolded samples were prepared at four initial moisture contents: 3, 7, 11 and 15% with an initial dry density of 1.6 kg/cm^3.

3 Physical Characteristics

Index properties of the loess soil are summarized in Table 1 and Fig. 1, representing the particle size distribution of the soil.

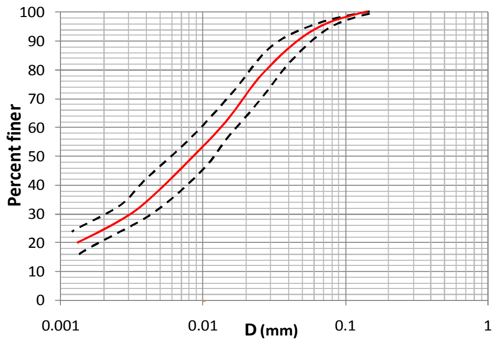

Fig. 1. Soil particle size distribution.

Table 1. Physical properties of soil tested in this study.

Property	
Specific gravity	2.72
Natural void ratio	0.67-0.77
Natural dry density (gr/cm3)	1.57-1.64
Natural water content (%)	2.9-3.6
Liquid limit (%)	33
Plastic limit (%)	24
Plasticity index (%)	9
Soil classification (USCS)	ML

4 Collapse Potential

The results of the tests conducted on undisturbed and remolded specimens with water contents of about 3-4% and 3%, respectively, and subjected to wetting at different levels of inundation stresses are presented in Figs. 2 and 3. The results indicate that the higher the inundation stresses the higher amount of collapse at that stress. However, if after inundation the loading continues, to say 16 kg/cm^2, the final volume change increases with decrease in inundation stress. This is clearly shown in Figs. 2 and 3 even during unloading.

Fig. 4 and Fig. 5 represent the best fits for both pre-wetted and wetted states of undisturbed and remolded samples. Test results showed that initial water content has a considerable effect on the final void ratio of specimen during collapse phenomenon due to wetting. The final void ratio of specimens with higher initial water content was higher in comparison with specimens with lower initial water content meaning that the amount of collapse increases as the initial water content decreases.

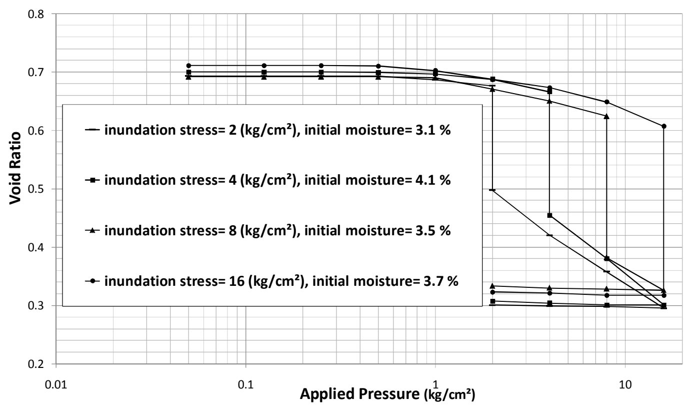

Fig. 2. Single oedometer collapse test for undisturbed loess specimens.

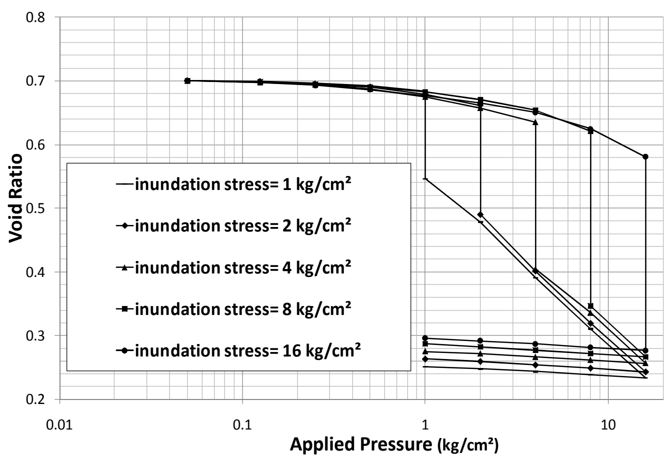

Fig. 3. Single oedometer collapse test for remolded loess samples.

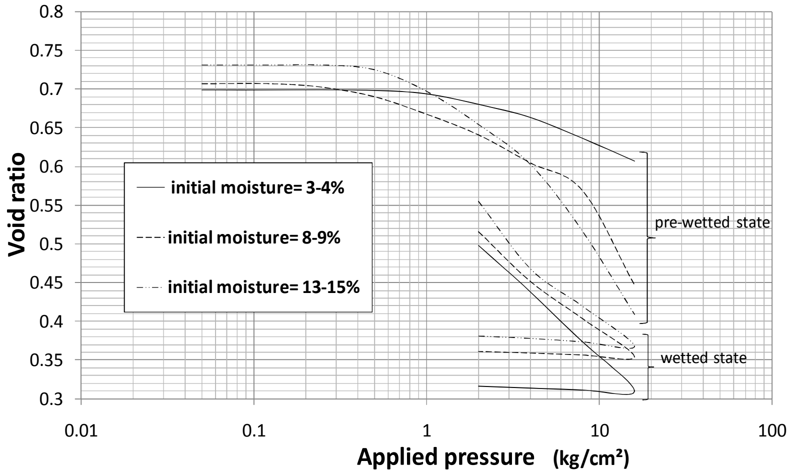

Fig. 4. Changes of the void ratio of undisturbed samples in pre-wetted and wetted state.

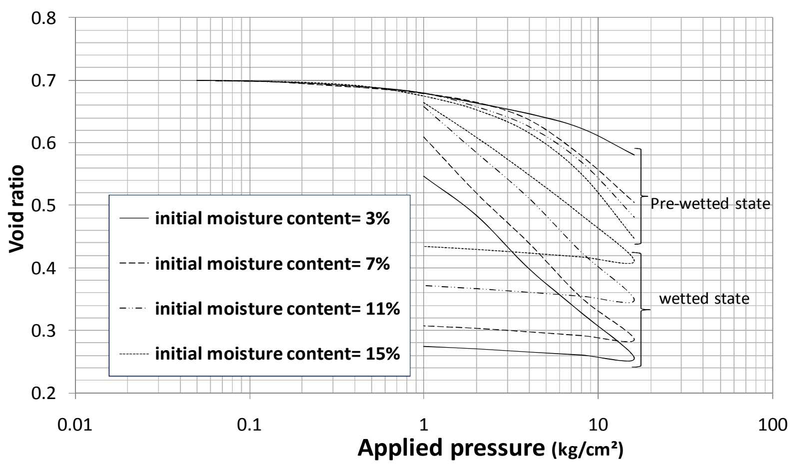

Fig. 5. Changes of void ratio of remolded samples in pre-wetted and wetted states.

Fig. 6 represents the variations of collapse potential (I_c), and applied pressure for undisturbed and remolded samples. I_c could be defined as expressed by Equation 1. In which ΔH and H_0 stand for the variation of the sample height due to inundation and the sample height just before inundation, respectively. For both types of specimens, at the same inundation stress, collapse potential increased with a decrease in initial water content. For the same initial water content, an increase in stress below critical pressure led to a greater collapse potential. However beyond the critical pressure at which the effect of stress alone caused significant soil collapses, the collapse potential decreased with a further increase in stress.

$$I_c = \frac{\Delta H}{H_0} \quad (1)$$

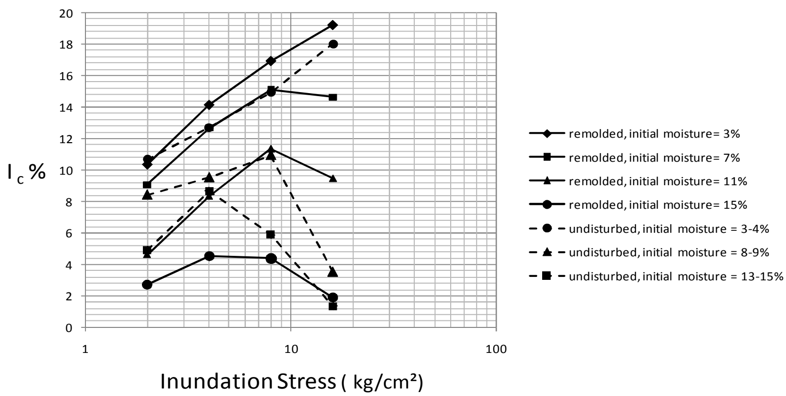

Fig. 6. Relationship between collapse potential and inundation stress of loess.

Critical pressure is the pressure at which the dry loess changes from a low compressibility response to a high compressibility response. The critical pressure is strongly influenced by initial water content. Increase in initial water content reduces the strength of the bond between loess particles and finally decreases the critical pressure. Table 2 represents the critical pressure of remolded and undisturbed samples with different initial water content.

Table 2. Critical pressure of undisturbed and remolded samples.

Initial moisture of undisturbed loess	Initial moisture of remolded loess	Critical Pressure (kg/cm^2)
3-4%	3%	>16
8-9%	7%	8
N.A	11%	4
13-15%	15%	4

5 Permeability

After inundating and collapse of the specimen and increase in stress level, the permeability coefficients of the collapsed specimens are measured in every stage of increasing stress and the result are illustrated in Fig.7. As it is presented in Fig.7, permeability of the collapsed loess increases with increase in initial water content of the specimen. As it is illustrated in Fig. 4, the specimens with higher initial moisture content end in a higher void ratio after collapse. Void ratio is a factor that influences the permeability of soil and increase of void ratio results in an increase in permeability of the soil.

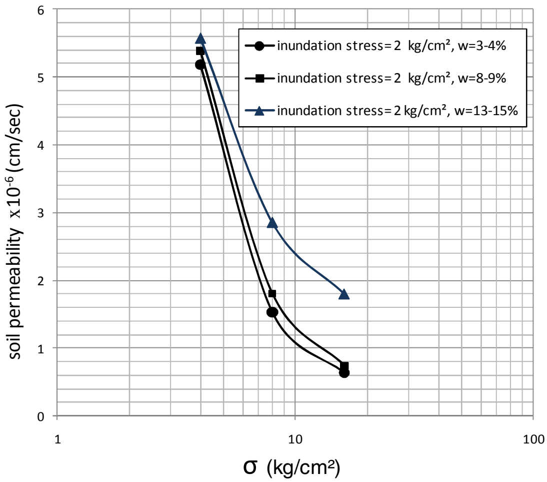

Fig. 7. The influence of initial moisture content and stress level after inundation on the soil permeability of collapsed soil (Undisturbed specimens).

6 Conclusions

1. The results indicate that the higher the inundation stresses the higher amount of collapse at that stress. However, if after inundation the loading continues, the final volume change increases with decrease in inundation stress.
2. In both remolded and undisturbed specimens, initial water content influences the amount of collapse potential. Collapse potential increases as initial water content decreases.
3. In both remolded and undisturbed specimens, critical pressure increases as the initial water content decreases.
4. Specimens with higher initial water content, in contrast with the specimens with lower initial moisture content, have a higher void ratio after collapse.
5. As the initial moisture content of the soil before collapse increases, the permeability of the soil after collapse increases.

References

Alawaji, H.A.: Settlement and bearing capacity of geogrid-reinforced sand over collapsible soils. Geotextiles and Geomembranes 19, 75–88 (2001)

Fredlund, D.G.: The emergence of unsaturated soil mechanics. In: The 4th Spencer J. Buchanan Lecture, College Station, Texas, 39 p. A&M University Press (1996)

Lawton, E.C., Fragazy, R., Hetherington, M.D.: Review of wetting-induced collapse in compacted soil. Journal of Geotechnical Engineering, ASCE 118, 1377–1394 (1992)

Phien-wej, N., Pientong, T., Balasubramaniam, A.S.: Collapse and strength characteristics of loess in Thailand. Engineering Geology 32, 59–72 (1992)

Rogers, C.D.F.: Types and distribution of collapsible soils. In: Derbyshire, E., et al. (eds.) Genesis and Properties of Collapsible Soils, pp. 1–17. Kluwer Academic Publishers (1995)