THE COLLAPSE POTENTIAL IN COLLAPSIBLE SOIL

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ABSTRACT

The paper presents the influence of moisture content and void ratio on the compressibility of laboratory compacted collapsible soil. The samples were recovered from different sites at the Western Egyptian desert and prepared in laboratory at a specified moisture content to achieve a desired density and then subjected to one dimensional consolidation tests using oedometer. The results showed that the collapse potential of these soils is critically affected by the initial void ratio, moisture content and applied stress level.

INTRODUCTION

Water deterioration characteristics of some soils are important, to soil engineer, for many practical applications. Collapsible soils undergo large decrease in volume upon increase in moisture content even without increase in external loads. These soils cause lots of troubles to foundation engineer, and need special precautions.

The collapse phenomenon was studied by many investigators, for instance [1,5]. Jennings and Knight [1] reported that the phenomenon of collapse settlement occurs when the degree of saturation of the soil is below a critical value, this critical value depends upon the type of soil.

Houston, Houston and Spadola [2] attributed the occurrance of the collapse potential of the collapsible soil to the softening of the binder between the soil particles. Abdrabbo and Mahmoud [3] reported that, the shear strength ratio (τ/σ_0') of compacted loess soil, decreases linearly as the moulded water content increases. Evert et al [6] carried out oedometer tests on compacted fill and reported that collapse and swelling could be eliminated by compacting the soil to a degree of saturation greater than or equal to the degree of saturation, corresponding to the line of optimums for impact compaction and at a given dry density. Also, the overburden stress level at which the maximum amount of collapse took place varied inversely with the compaction water content.

This work is devoted for studying the effect of both initial void ratio and water content on the behaviour of collapsible soil in one dimensional consolidation test.

THE SITE

The Western desert of Egypt, especially the northern side, contains a top layer of wind-deposit of low plasticity silty clay, extending to 20 m depth. The formation of this layer is very dense, SPT values in the range of 250/300 blows were recorded during sampling. Only disturbed soil samples were obtained from the following sites at the desert: Sidi-Baranee, which is 60 km to the east of international Western Egyptian border and 30 km south of the mediterranean sea shore. El-Ameria, which is 60 km south-west of Alexandria city. The third site, called El-Boustan, is a new cultivated land project at 120 km south-west of Alexandria city. The Fourth site is located at 160 km south-west of Alexandria city, where a new village is under construction.

The soil samples extracted from these four sites are almost similar in characteristics, and may be classified as clay of low to medium plasticity according to the unified classification system with liquid and plastic limits of 30% and 20% respectively. The ground water table in these sites is located below a 40 m depth from ground surface.

EXPERIMENTAL PROCEDURE

After drying the soil samples in an oven at 110 °C for 24 hours, the soil passing from 150 μm B.S. sieve were placed dry in an oedometer ring at a predetrmined unit weight. The soil in the ring was tamped by steel rod of 13 mm diameter to reach the desired density. The initial unit weight of the tested samples was controlled by weighing soil to an accuracy of 0.01 gm. The top porous plate was placed to be flush with the oedometer ring, and the specimen was loaded incrementally. Each increment was mentained constant, and the vertical displacement of the sample was measured using a dial gauge of 0.001 inch accuracy, up to the deformation of the sample was ceased. After the final deformation of the soil sample, at applied stress of 100 kN/m^2, had been attained the specimen was allowed to access through the top and bottom porous stones with enough water to become fully saturated. The resulting collapse strain is monitored for 24 hours. The inundated sample was further loaded incrementally up to a vertical stress of 400 kN/m^2. Some tests were carried out also with inundation at different stress levels. In the second series of tests, oedometer tests were carried out on two identical samples, that is to say with the same initial void ratio, one sample was dry but the other was mixed thoroughly with a predetermined amount of water. In the third series of tests, double oedometer tests were carried as in the second series, but on samples having different amount of fine sand (effective diameter = 0.15 mm and uniformity coefficient = 1.33).

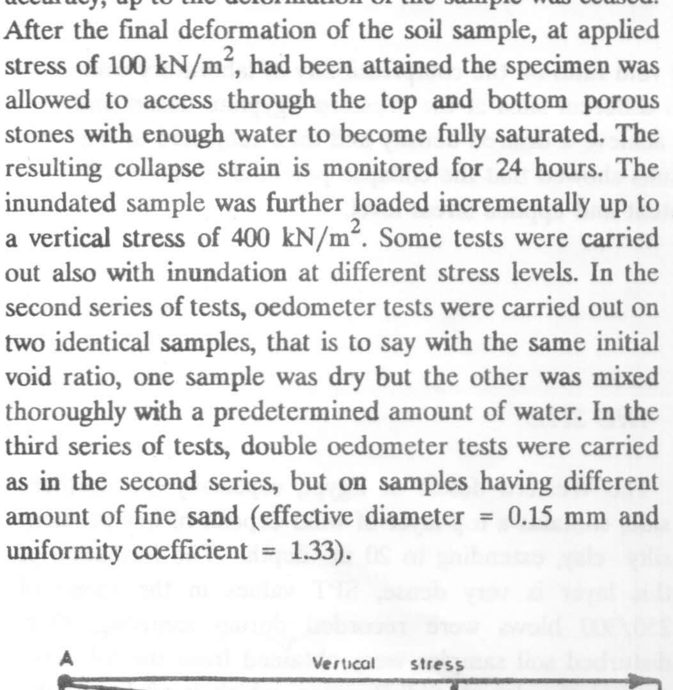

Figure 1. Typical test results on collapsible soil.

ANALYSIS OF EXPERIMENTAL RESULTS

Figure (1) illustrates a typical oedometer test results on dry collapsable soil, inundated at a certain stage of loading. Such relationship shown in Figure (1) is characterized by: the initial curved part AB of the stress-compression relationship of dry sample followed by the collapse strain BC and the curved part CD of the stress-strain behaviour of inundated sample.

The curved part AB was approximated as straight line and the average coefficient of compressibilities $\Delta e/\Delta p$ of soil before inundation was calculated and plotted against the initial void ratio of the soil, Figure (2). Figure (2) shows that the coefficient of compressibility is effected critically with the change of initial void ratio of dry soil. Figure (2) indicates that values of $(\Delta e/\Delta p)$ decreases as the initial value of e_o decreases and a practical value of 0.0001 m^2/kN at void ratio of 0.85 can be obtained from the figure.

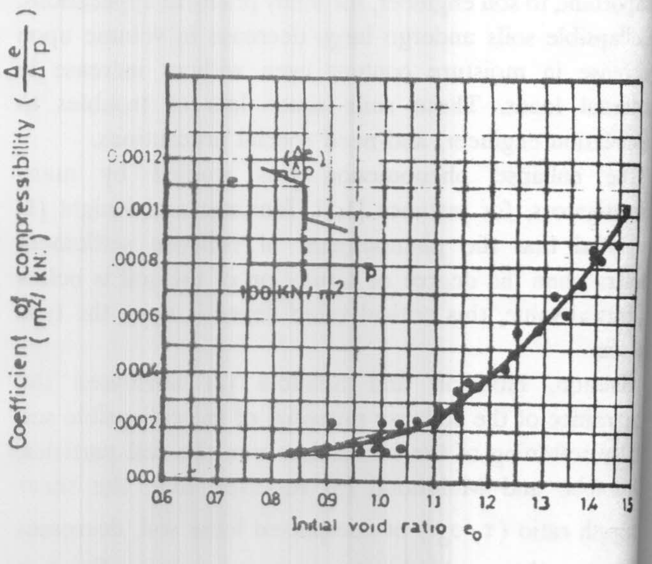

Figure 2. variation of the average coefficient of compressibility of dry sample with initial void ratio.

The collapse Potential $\Delta e_c/1+e_o$ of soil samples was calculated and its variation against the initial void ratio was drawn as shown in Figure (3). The variation of $\Delta e_c/1+e_o$ against e_o may be placed as follows with correlation factor equal to 0.71:

$$\frac{\Delta e_c}{1+e_o} = -0.066 + 0.17\, e_o \qquad 0.45<e_o<1 \qquad (1)$$

and,

$$\frac{\Delta e_c}{1+e_o} = -0.287 + 0.39\, e_o \qquad e_o>1 \qquad (2)$$

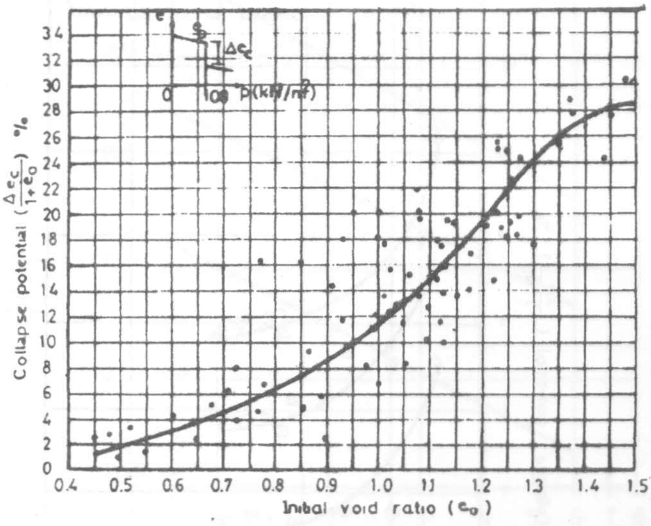

Figure 3. Collapse potential vs initial void ratio.

Also, the figure indicates that the dense sample, the better particles orientation and the less collapse strain $\Delta e_c/1+e_o$ due to inundation. It is interesting to note that a collapse potential, of about 30%, occurred when the samples were prepared at void ratio of 1.5. These results indicate how dangerous the effect of increasing water content on the behaviour of a loaded soil. The authors suggest for constructing on such soil, either to excavate the soil up to the foundation significat depth and then backfill by another stable soil, or to compact the existing soil to attain a void ratio less than 0.5 by means of some form of vibratory displacement procedure of compaction.

To investigate the effect of stress level on the collapse strain of the soil, Figure (4) illustrates the results of oedometer tests on four identical samples. Each sample was loaded dry incrementally up to a predetermined vertical stress, then the sample was inundated and the collapse strain was recorded, after which the sample was further loaded up to a vertical stress of 400 kN/m^2. The four samples were tested by the same procedure but the inundation took place at different stress levels.

In Figure (4) a_1 b_1 c_1 d_1 represents the stress- strain relationship of a sample inundated at a vertical stress of 50 kN/m^2, and the vertical line b_1 c_1 represents the collapse strain at a stress level of 50 kN/m^2. b_2 c_2, b_3 c_3 and b_4 d_4 represent the collapse strains of the soil at stress levels of 100, 200, and 400 KN/m^2 respectively. Figure (4) also suggusted that oedometer tests, one on dry sample and the other on inundated sample, can be used for determination of the collapse strain at any stress level.

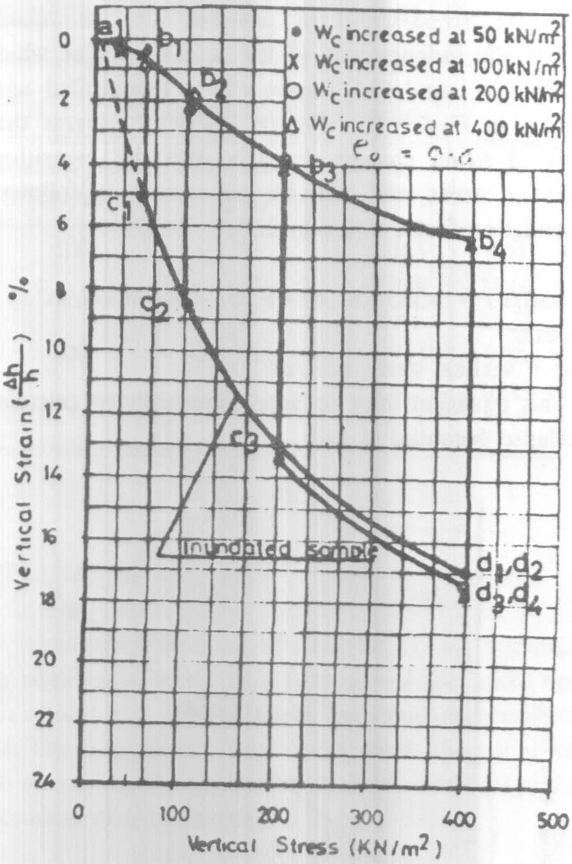

Figure 4. Oedometer test results.

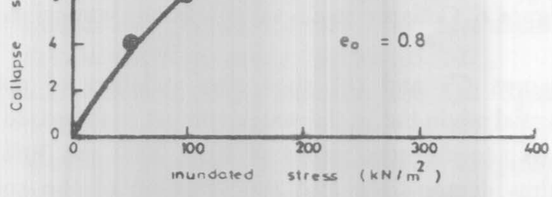

Figure 5. Collape strain vs vertical stress.

Figure (5), produced from Figure (4), indicates that as the stress level increases the collapse strain of the soil increases, but with a decreasing rate up to stress level equal 400 kN/m^2. The figure indicates that beyond a specified stress level, the collapse strain is found to be independent of the applied stress. Figure (4) also indicates that the stress-strain of samples after inundation is practically independent of the stress level at which the sample is inundated. Figure (5) is recompiled again as shown in Figure (6). Figure (6) demonstrates that the vertical strain changes linearly with the logarithmic of vertical stress and can be expressed as follows with correlation factor equal to 0.95.

$$(\Delta h/h) = 3.383 \text{ Ln } (\sigma) - 9.26 \quad \sigma < 400 \text{ kN/m}^2 \qquad (3)$$

where:

σ = vertical stress (kN/m^2)

This equation may be used practically to calculate the collapse potential of soil.

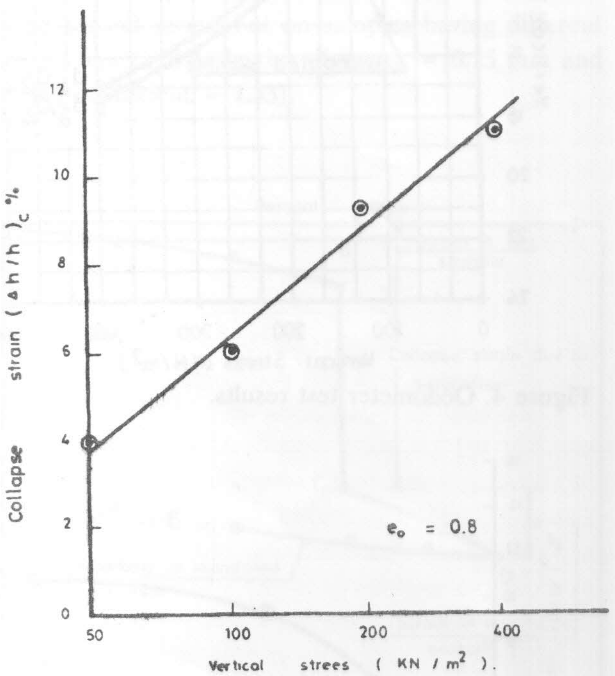

Figure 6. Collapse strain vs logarithmic vertical stress.

Figures (7) and (8) show the variation of collapse potential when the initial water content is increased from zero up to different values of 10%, 20% and 30%. The Figures demonstrate also the variation of the collapse potential with the variation of percentage of fine sand. Figure (7) and (8) are recompiled again and reploted on a semi logarithmic scale as shown in Figures (9) and (10).

The relation between the increase in collapse potential (c_p) with the water content and percentage of sand (S) may be expressed as:

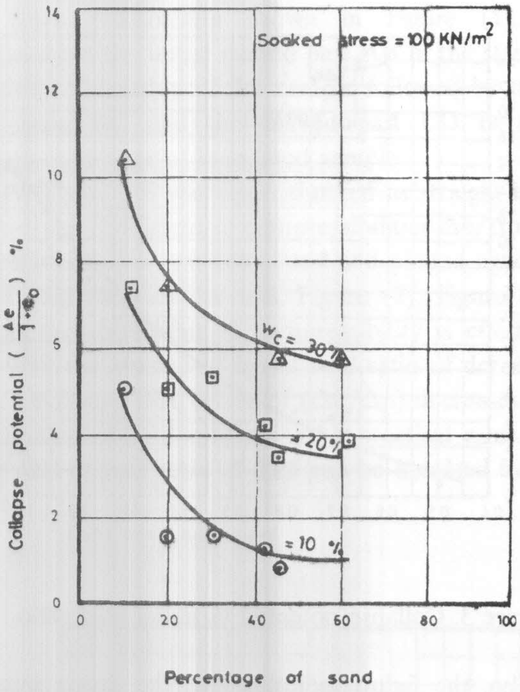

Figure 7. Collaps potential vs. percentage of sand in soil sample.

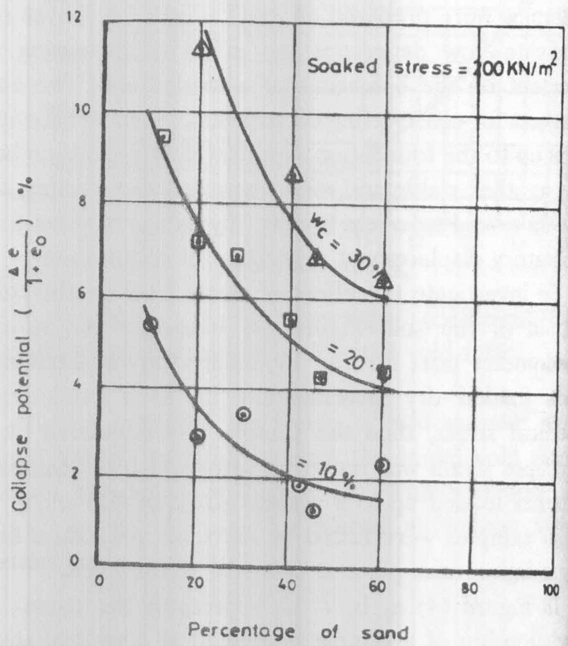

Figure 8. Collapse potential vs percentage of sand in soil sample.

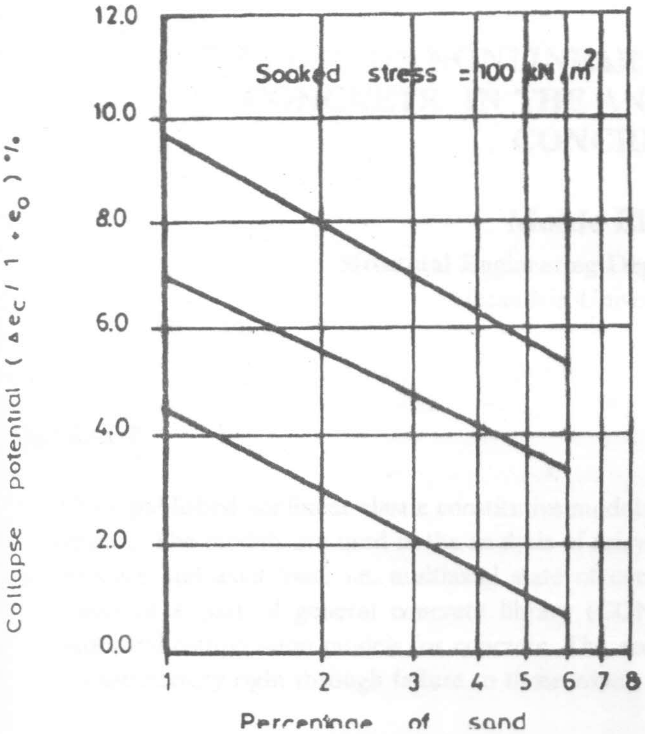

Figure 9. Collapse potential vs. logarithmic percentage of sand.

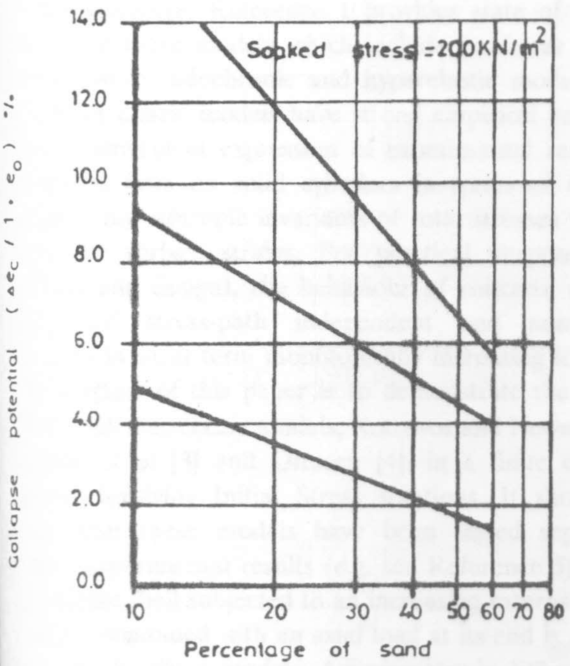

Figure 10. Collapse potential vs logarithmic percentage of sand.

$$c_p = c + m \text{ lin } (s) \qquad (4)$$

where:

s = percentage of sand

The values of m and c are tabulated as follows:

Table (1). Constant values.

soaked press. (KN/m^2)	water contant (%)	m	c
100	10	-2.165	9.51
	20	-2.036	11.69
	30	-2.44	15.33
200	10	-1.933	9.35
	20	-2.95	16.13
	30	-5.615	28.72

CONCLUSIONS

The Collapse Potential of soil $\Delta e_c/1+e_o$, associated with soaking in water is a function of the initial void ratio of soil, the applied stress level and percentage of sand. The collapse potential decreases as the initial void ratio decreases, the applied stress level decreases and as percentage of sand increases.

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