TECHNICAL NOTE

SOME DEFORMATION CHARACTERISTICS OF COLLAPSIBLE SOILS

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SYNOPSIS

This paper presents an experimental investigation for the deformation of collapsible soils which take place before and after they are inundated with water. The experimental program was designed so as to investigate the effect of some important factors such as the initial water content, dry density and pressure applied, on these deformations. Several groups of specimens were prepared at different initial water contents and different dry densities and were tested in the conventional oedometer under a wide range of pressures. The results obtained indicate that the initial water content, the dry density and the applied pressure have significant effect on deformation of collapsible soils. For soils with low water content, most of the deformation takes place after the soil has come into contact with water, while in case of soils of relatively high water content, most of the deformation takes place just after applying the pressure and before inundation.

INTRODUCTION

Problems associated with foundations on collapsible soile cause worlwide concern. The significant damage that results from the differential movement of collapsible soils when they are inundated with water are well recognized. These problems represent a challenge for the geotechnical engineer where good understanding of the behaviour of such soils is required for design.

Many research workers have investigated the different properties which characterize collapsible soils and the factors which govern their deformational behaviour (e.g. Dudley, 1970; Booth, 1975; Jennings & Knight, 1957 and 1975; Adikari et al, 1981; Milovic et al, 1981; Browzin, 1981; Austerlitz et al, 1983; Wiseman & Lavie, 1983 and El-Sohby & Rabbaa, 1984).

The work described herein presents an experimental investigation of the deformation of collapsible soils before and after inundation. The investigation

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is concerned with the effect of the change in the initial water content, the dry density and the pressure applied during the inundation, on these deformations.

TESTED MATERIAL AND TESTING TECHNIQUE

Three types of soils referred to as A, B and C were used in this work, Some index properties of these soils are given in Table 1.

Table 1 : Index Properties of Tested Material.

Soil Type.	Consistency limits		Grain Size Composition		
	LL%	PL%	Sand%	Silt%	Clay%
A	26	15	27	56	17
B	31	14	40	45	15
C	41	24	18	64	18

Samples were prepared by mixing a weighed quantity of the ground dry soil with a predetermined quantity of water. The mixed soil was sealed inside a plastic bag and left for 24 hours. Then, the prepared soil was poured into an oedometer ring and statically compacted to the required height which is calculated to produce the required unit weight.

Two series of tests were carried out in this work. The first series was performed to investigate the effect of the initial water content. The capacity of water absorption of an unsaturated soil is very relevant to its consistency limits. Therefore, the soil samples tested in this series of tests were chosen to have liquid and plastic limits representing, to some extent, the normal range that most collapsible soils have. This range is 10 to 25% for plastic limit and 25 to 50% for liquid limit. Samples of each soil; A, B and C were prepared at different initial water contents of 4, 8, 12, 16 and 20%. They had the same dry density of 14 kN/m^3 and were tested under the same pressure of 200 kN/m^2.

The second series of tests were carried out in order to investigate the effect of the initial dry density on deformation of collapsible soils under different pressures. Soil of type B was used in this series of tests. The dry densities used were 12, 13,

14, 15 16 and 17 kN/m^3. For each dry density, a group of specimens were tested under pressures which ranged from a low value close to 10 kN/m^2 up to a relatively high value of the order of 400 kN/m^2. The initial water content was kept constant (5%). Each specimen was initially loaded in the oedometer and its deformation was recorded, after equilibrium, it was then inundated with water and its collapse under the same applied load was also recorded.

DISCUSSION OF EXPERIMENTAL RESULTS

In this discussion, the following terms will be used to describe the deformation of collapsible soils before and after inundation with water:

Compression refers to deformation before inundation.
Collapse refers to deformation after inundation.
Total deformation refers to the sum of both compression and collapse.

In the following sections, the compression and collapse phenomena will be discussed separately.

COMPRESSION OF COLLAPSIBLE SOILS BEFORE INUNDATION

Considerable compression may take place for soils with a collapsible structure just after applying the loads and before the soil comes in contact with water. The magnitude of this compression depends on the initial water content of the soil, its dry density and the loads applied.

Effect of Initial Water Content

Fig. 1 shows the compression of soils A, B and C which had taken place before they were inundated with water. It can be noted that this compression increases as the initial water content increases for the three soils tested. This could be attributed to the water acting as a lubricant facilitating the sliding of soil particles each against the other and resulting in higher compression. It can also be noted that the rate of increase in the compression occurring before inundation depends on the consistency limits of the soil. In general, this rate lessens as these limits become higher.

The ratio of the compression taking place before inundation to the total deformation against the water content is shown in Fig. 2. It can be noted that this ratio increases as the water content increases. For example, while the

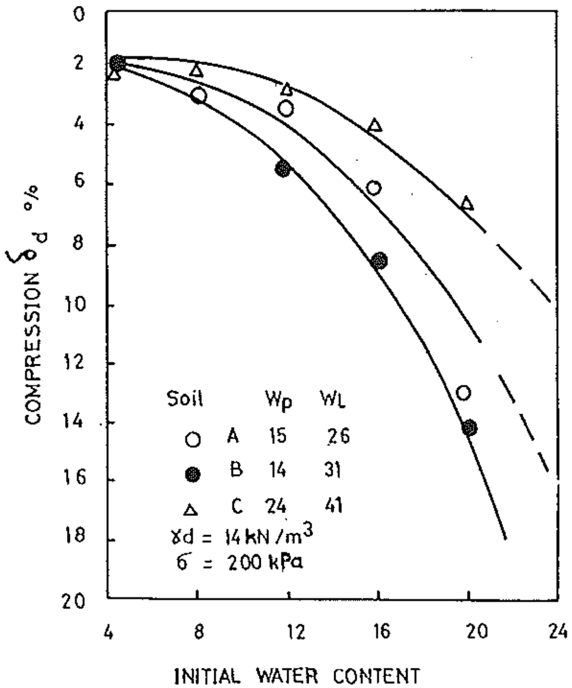

Fig. 1 Relationship between Initial Water Content and Compression of Collapsible Soils before Inundation.

compression that occurred before inundation represented only 10 to 30% of the total deformation when the water content was about 4%, it reached 80 to 90% when the water content became about 20%. As has already been explained, this is thought to be due to the lubrication effect of water which enables the soil particles to have a denser structure prior to complete inundation.

Effect of Dry Density

Since the dry density can be considered the best representative factor for describing the state of the soil structure; dense or open, it is expected to play a very important role in determination of the deformation behaviour of soils. As can be seen in Fig. 3, that under the same applied pressure, the compression of

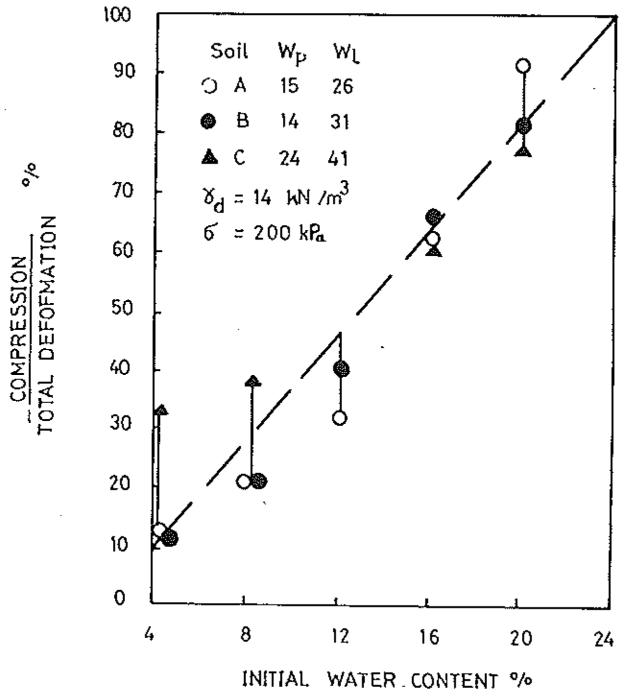

Fig. 2 Ratio of Compression of Collapsible Soils Occurring before Inundation to the Total Deformation against the Initial Water Content.

the tested soil increased by several times when the dry density decreased from 15 kN/m^3 to 12 kN/m^3. For example, under a pressure of 200 kN/m^2 the soil experienced compression less than 2% when its dry density was 15 kN/m^3, but its compression reached more than 9% when its dry density decreased to 12 kN/m^3.

The ratio of compression to the total deformation for different dry densities is shown in Fig. 4. It can be seen that this ratio is almost constant and equal to about 20% for a wide range of dry densities (between 12 kN/m^3 and 15 kN/m^3). For soils of dry densities greater than 15 kN/m^3, this ratio increases. This could be explained by considering that the deformation of soils of dry

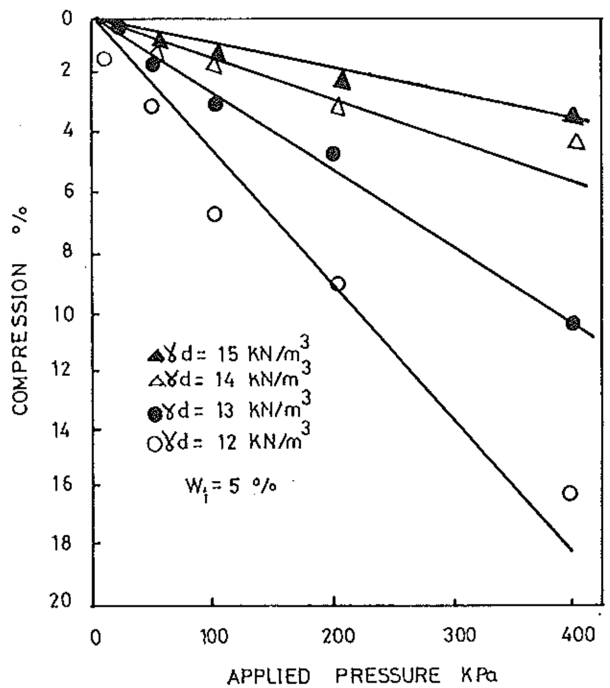

Fig. 3 Effect of Dry Density and the Applied Pressure on the Compression of the Collapsible soils.

densities between 15 and 17 kN/m^3 is mostly due to the compression since collapse occurring after inundation is much less. For soils of higher dry density, the deformation before inundation represents a very minor portion and the total deformation is mainly due to the swelling occurring after inundation.

Effect of Applied Pressure

The pressure applied to a collapsible soil plays an important role in determining the magnitude of its deformation both before and after inundation. As shown in Fig. 3, the compression of the tested soils greatly increases as the applied pressure increases. The effect of the applied pressure on the

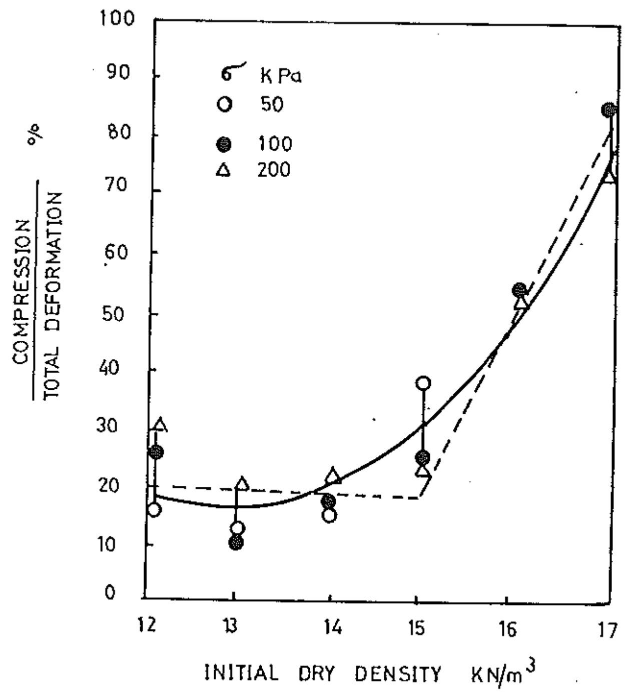

Fig. 4 The Relationship between the Dry Density and the Ratio of Compression to the Total Deformation.

compression of collapsible soils before inundation is more pronounced in the case of low dry densities. For example, a soil of dry density equal to 12 kN/m^3 experienced compression less than 3% under 50 kN/m^2 of pressure while it experienced more than 16% when the applied pressure increased to 400 kN/m^2. Collapsible soils of low dry densities under relatively high pressures behave in a similar way to loose sands i.e. most of their deformation takes places during the loading before any inundation occurs. However, the effect of the applied pressure on the compression of collapsible soils is closely related to dry densities. The ratio of compression to the total deformation seems to be independent of the pressure applied (see Fig. 4).

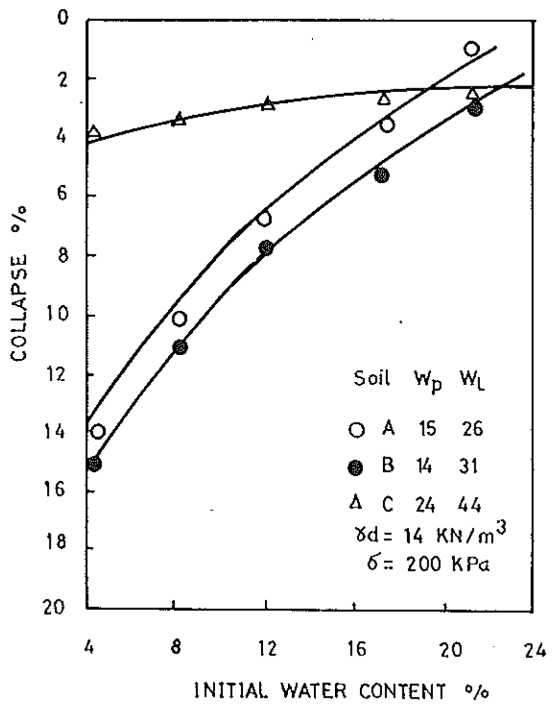

Fig. 5 Effect of Initial Water Content on Soil Collapse after inundation.

COLLAPSE OF SOILS TAKING PLACE AFTER INUNDATION

The collapse which takes place when an unsaturated soil under pressure comes in contact with water is considered to be the main cause for the troubles experienced with collapsible soils. The reason is that such soils can often bear relatively large loads in the dry state without experiencing considerable deformation. However when they become saturated, they collapse. Also, the collapse occurs suddenly just after water reaches the soil. In the following section, the effect of initial water content, dry unit weight and the pressure applied, is discussed in relation to soil collapse.

Effect of Initial Water Content

The collapse which occurred for soils A, B and C after inundation is

shown in Fig. 5. As can be seen, the magnitude of collapse decreases as the initial water content increases. This is attributed to the concept that the higher the water content the easier is the sliding of the soil grains and consequently the greater is the compression. This means that at high water contents, most of the soil deformation will take place, before any complete submersion occurs and vice versa. Fig. 6 demonstrated this result. As shown, the ratio of collapse to the total deformation was between 70 to 90% when the water content was about 4%, while it reached only 10 to 30% when the water content increased to 20%.

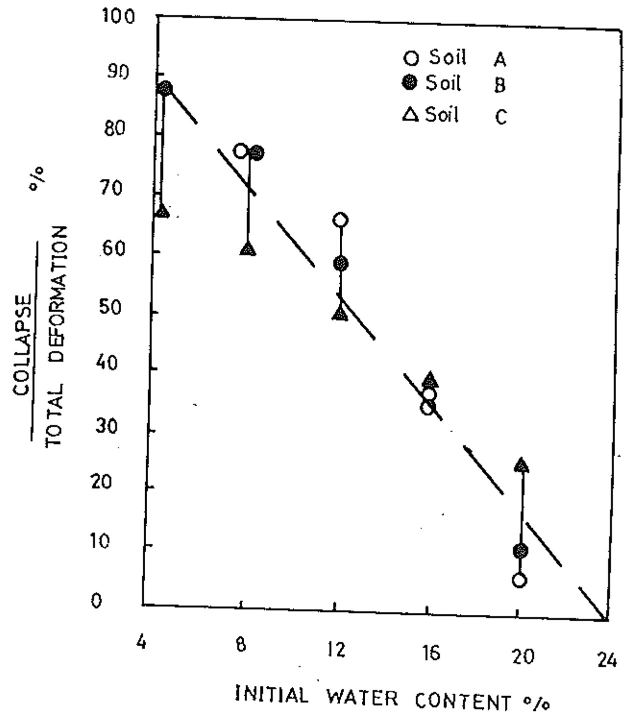

Fig. 6 Relationship between Initial Water Content and Ratio of Collapse to the Total Deformation.

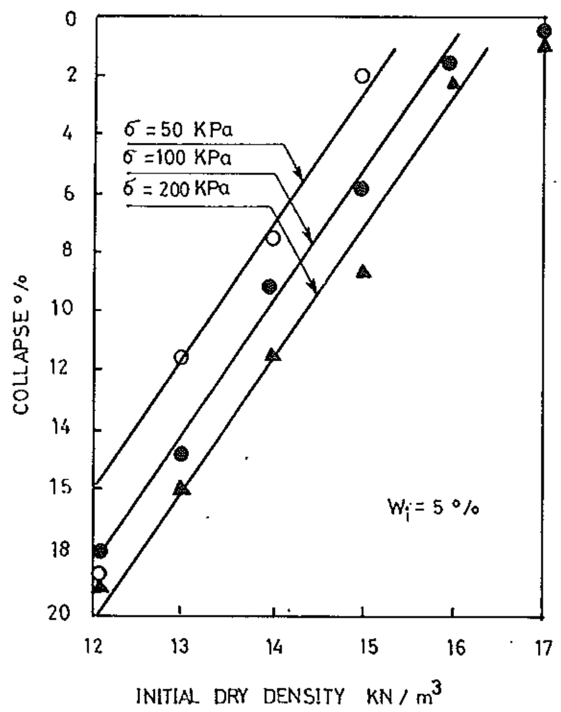

Fig. 7 Effect of Dry Density on Soil Collapse under Different Pressures.

Effect of Dry Density

Fig. 7. shows the relationship between the soil collapse and the dry density under different applied pressures. The dry density has a great effect on the magnitude of collapse which a soil may suffer. For example, the soil of dry density equal to 16 kN/m^3 experienced almost less than 2% collapse under a pressure of 100 kPa while the soil of dry density equal to 12 kN/m^3 suffered more than 18% collapse under the same pressure.

The ratio of collapse to the total deformation versus the dry density and for different applied pressures is shown in Fig. 8. This figure indicates that this ratio is almost constant and equal to about 80% for a wide range of dry densities (12 to 15 kN/m^3) which most collapsible soils have. For soils of dry densities higher than 15 kN/m^3, this ratio decreases as the dry density increases and is due to the fact that such soils of relatively high dry density are not prone to collapse.

Effect of Applied Pressure

The applied pressure has the same effect on the collapse taking place after inundation as that on the compression before inundation. As shown in Fig. 7, the applied pressure increases as the collapse increases. The effect of applied pressure is closely related to the dry density. For example, while an increase of pressure from 50 kPa to 200 kPa caused an increase of collapse from 2 to about 10% when the dry density was 15 kN/m^3, it caused an increase of the collapse from 18 to only 19% when the dry density was 12 kN/m^3.

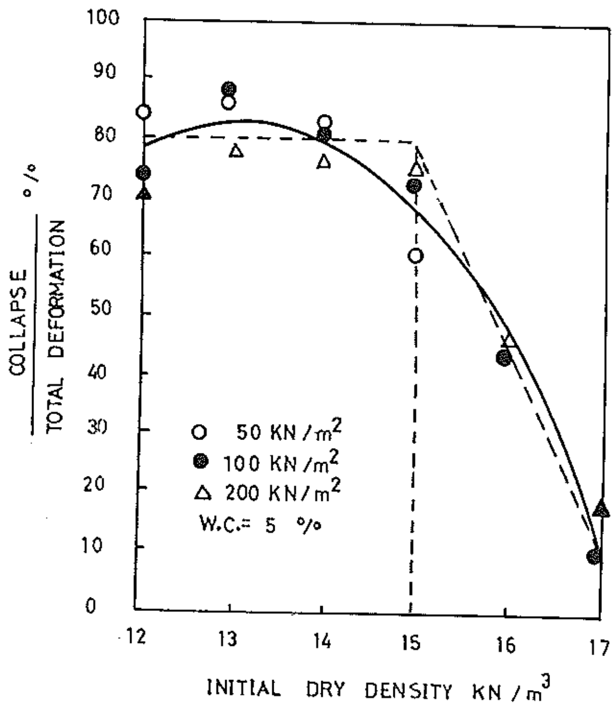

Fig. 8 Relationship between Dry Density and Ratio of Collapse to the Total Deformation.

The same effect was observed in the case of compression, it seems that the applied pressure has relatively little effect on the ratio of collapse to the total deformation (see Fig. 8).

Finally, Fig. 9 shows the combined effect of dry density and the applied pressure on the total deformation of collapsible soils. It can be deduced from this figure that a soil under relatively high pressure may experience collapse but while under low pressure may swell.

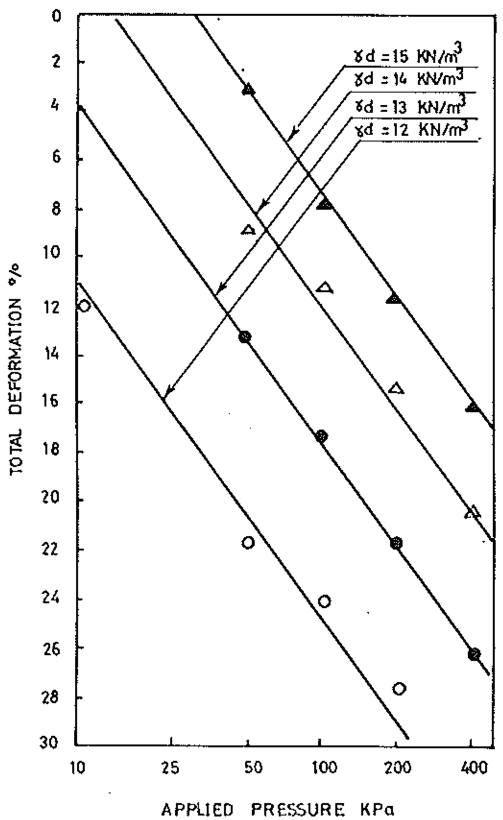

Fig. 9 Effect of Dry Density and Applied Pressure on the Total Deformation of Collapsible Soils.

CONCLUSIONS

From this work, the following conclusions could be drawn :

- Much of the total deformation which collapsible soils experience can be attributed to the compression which takes place before inundation. For soils of low initial water content (less than 10%) the ratio of this compression to the total deformation is about 20% for a wide range of dry densities (from 12 to 15 kN/m^3).
- The magnitude of this compression increases as the initial water content increases since the water acts as lubricant facilitating the sliding of the soil grains.
- The value of this compression depends also on the dry density and the applied pressure. Soils of relatively low dry densities experience considerable amounts of compression before inundation especially under relatively high pressures. In these circumstances such soils behave like loose sands.
- The collapse which takes place after inundation represents the major part of the total deformation of collapsible soils especially those of relatively low initial water content. The collapse, in this case, contributes about 80% of the total deformation. This result is for soils of dry densities less than 15 kN/m^3. Most collapsible soils have dry densities below this level.
- The magnitude of collapse decreases as the initial water content increases. This is because most of the deformation of the soil at higher water contents occurs before inundation. For the tested soil, the ratio of collapse to the total deformation decreases from an average value of about 80% to only about 20% when the water content increased from 5 to 20%.
- The magnitude of collapse depends on the dry denstiy and the pressure applied. It increases as the applied pressure increases and decreases as the dry density increases.
- The experimental results of this work have confirmed that reported by previous research workers, namely there is a common area of dry density at which soil may collapse under a certain pressure and swell under another.
- Finally from the above conclusions it can be said that in case of collapsible soils of relatively low initial water content, it may be advisable to submerge the site before the construction to saturate the soil and allow the major part of the total deformation to occur simultaneously with applying the loads during the construction.

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