

Collapse Behaviour of a Calcareous Soil Using Oedometer Test

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ABSTRACT: Collapsible soils are the most widely distributed and costly of geologic hazards. These soils are subjected to change in volume and settlement in response to wetting and drying, often resulted in severe damage to structures. Collapsing soils are generally characterized by sudden and large volume decrease at constant stress when inundated with water. These are very sensitive to changes its porosity and water content. Suffusion i.e. grain movement in a ground layer from one horizon to another during wetting up is one of the main causes of collapse. Man- made fills, which were compacted at the optimum water content, may also develop a collapsible or metastable-structure at low density. A sound understanding of the mechanical behaviour of this type of material is thus required so that the engineer can devise safe and cost-effective solutions to these problems. A geotechnical engineer needs to be able to identify readily the soils that could collapse and to determine the amount of collapse that may occur. Most compacted soils have collapsible soil behaviours when, subjected to wetting or loading. Collapse potential increases with decrease in compaction water content, high void ratio and low dry density. The main theme of this study is to know the influence of variations in compaction dry density, initial water content, inundation stress, and void ratio on the collapse behaviour of the soil. Also, to determine the collapse behaviour of soils under wetting conditions by using oedometer test and control of collapse behaviour of soil.

KEYWORDS: Collapsible soils, Water content, dry density, Oedometer test, Metastable structure.

I. INTRODUCTION

In most countries of the world landfill is the primary method of solid waste disposal. Relevant legislation requires that waste disposal must be carried out providing containment systems to prevent or mitigate the threat to ground water and neighbouring environments. An important aspect of the operation of waste disposal facilities is the prediction of the effect of wetting on the subsequent performance of the compacted layer. In general wetting induces volume changes, and this leads to corresponding changes in strength and stiffness. The two induced volumetric change problems (i.e. collapse and swelling) that concern the operation of waste disposal facilities are both related to wetting processes. In the past much attention was not paid to collapse. Also erected structure tended to be inexpensive and of small size. Besides this, water consumption patterns were quite different from those of today. With rapid advancement of civilization and increasing use of water for irrigation, industrial and domestic purposes near the structure caused severe damage to a founded structure on collapsible soil. Also developments in all aspects of life have resulted in the construction of modern cities and large structures in areas of collapsible soil. This clearly establishes the need for an in depth study of the subject of subsidence is considerably important.

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COLLAPSE MECHANISM

The decrease in total volume of a soil resulting from wetting-induced breakdown of its structure at essentially unchanging total vertical stress is commonly referred to “collapse”. The main factors that contribute the collapse behaviour are

- An open, partially unstable and unsaturated soil.
- A high enough value of net total stress is applied to develop a metastable structure
- A high enough value of soil suction (or other bonding or cementing agent) to stabilize inter granular contacts, and whose reduction on wetting will lead to collapse.
- The addition of water to the soil, which causes the bonding or cementing agent to be reduced and the interaggregate contacts to fail in shear, resulting in a reduction in total volume of the soil mass.

Collapsible soils are generally associated with an open structure formed by fine grains, low initial density, low natural water content, low plasticity, relatively high stiffness and strength in the dry density. The larger pores are the ones that collapse at the low stress level and the smaller pores are the ones that collapse at the high stress level. The collapse problem was initially thought to be only with silt and sands of low dry density. However, it is now recognized that the phenomenon can occur with other soil materials ranging from gravel to fine clays under certain conditions of applied stress, density and degree of saturation. Generally collapsible soils are unsaturated conditions in the dry state, with negative pore water pressure resulting in high effective stresses and greater shear strength. Additionally, cementing agents such as CaCO_3 can also contribute to maintaining open ‘honey combed’ structure. Upon wetting, the pore pressure becomes less negative and the effective stresses are reduced causing a decrease in shear strength. Additionally, the water can dissolve or soften the bonds between the particles allowing them to take a denser packing. This mechanism, referred to as wetting induced collapse or hydro compression can take place with or without extra loading.

II. LITERATURE REVIEW

Several researchers examined the role of soil structure in the collapse behaviour of compacted soils by varying the compacted dry density and clay content of the soil specimens. The amount of collapse is expected to increase with the increase in magnitude of the external stress (dry density and moisture being constant), at which the unsaturated specimen is wetted. Jennings and Knight [1] were the first propose a method to quantify the amount of collapse by means of oedometer test. One of the most common problems associated with unsaturated soils is that of collapse on wetting of materials with open fabrics such as loess and loosely compacted fills. These materials undergo significant settlements once wetted at relatively large over-burden pressures. They have shown that a single effective stress variable is not capable of completely describing partly saturated soil behaviour, especially the volumetric behaviour. As per Basma [2], 138 single-oedometer tests were conducted on eight different soils. The results indicate that well-graded soils tend to collapse more than poorly graded ones under same conditions. Jotisanakasa [3] introduced a methodology to investigate the collapse behaviour of unsaturated soils using suction-monitored oedometer tests. The proposed method has been used to investigate the collapse behaviour of compacted silty clay and to confirm the uniqueness of the loading-collapse surface as identified from loading and wetting paths. T.Ayadat and A.M. Hanna [4] had introduced the various methods of predicting collapse from simple and rapidly performed index have been suggested by several workers in the field. In his investigation, most of the well known collapses identifying criteria are reviewed and evaluated. D.G. Fredlund and J.K.M.Gan [5] studied the collapse behaviour of a compacted soil was studied in the laboratory using a modified conventional oedometer and a tensiometer for the measurement of matric suction. The results shown that collapse is a transient and continuous process.

III. MATERIAL AND METHODOLOGY

For this purpose, Calcareous soil has been collected from Gachibowli, Hyderabad. Calcareous soil is having high amount of cementing agent i.e. CaCO_3 , so during wetting cementing agent to be reduced and the intergranular contacts

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to fail in shear which leads to reduction in total volume of soil mass. Calcareous or lime-rich, may pose limitations not only to buildings and also to tree growth and their productivity because of physical and chemical properties. This soil is analysed for their properties and the relevant testing procedures have been included in the following.

The specific gravity test has been conducted as per the [7]. The sieve analysis and hydrometer tests are carried out to determine the particle size distribution of the soils according to [8] and classification [9]. The Liquid limit and plastic limit of the soil are determined according to the [10]. The standard proctor test was conducted to determine the OMC according to [11] and maximum dry density of the soil. The oedometer test [12] is used to determine the collapse behaviour of the soil and controlness of the soil by adding cement to the soil in proportions.

Oedometer test

A collapsible calcareous soil may withstand relatively large applied vertical stress with small settlement while at a low water content, but this soil will exhibit settlement (that could be large) after wetting with no additional increase in stress. Large applied vertical stress is not necessary for collapse. The oedometer test procedure is performed by taking the weight of soil is equal to the volume of cylindrical specimen ring. The oedometer specimen ring diameter 60mm and height 20mm. The specimen ring cleaned and weighed it empty. The soil is compacted in specimen ring to the required OMC and the flush off the sample smoothly with the top and the bottom of the ring. The specimen ring cleaned from outside and weighed with the specimen. The porous stones are saturated for 24 hours. The specimen is assembled as the porous stone are arranged at the top and bottom of the specimen providing filter papers in between. The pressure pad is placed centrally on the top porous stone. The assembly is placed in the loading frame and adjusted to centre such that the load is applied axially. The dial gauge is positioned to measure the vertical compression of the specimen. The first load of intensity 0.2 kg/cm^2 and the initial dial gauge reading is noted. The dial gauge reading is recorded at various time intervals. The test is repeated for successive load increments of 0.2, 0.8, 1.8, 3.0, 6.4 and 8 kg/cm^2 . The specimen is saturated at different loads for example: sample 1 should be saturated at 0.2 kg/cm^2 , sample 2 should be at 0.8 kg/cm^2 , sample 3 should be at 1.8 kg/cm^2 , sample 4 should be at 3.0 kg/cm^2 , sample 5 should be at 6.4 kg/cm^2 and sample 6 should be at 8 kg/cm^2 . The collapse point and the load of intensity of the sample noted. The sample is mixed with 1% of cement and the specimen is saturated at the point of load intensity collapsed. Thus the cement admixture controls the collapse of the soil specimen.

It has been found that the inundation stress of 6.4 kg/cm^2 is found to be critical for the calcareous soil. Hence, cement in various proportions, viz., 1%, 2%, 4% and 6% has been added by weight and the collapse studies have been performed on the cement mixed soil.

The vertical stress at which a compacted specimen is inundated is termed as the flooding pressure then swell/collapse potential was calculated from the equation

$$\text{Swell/collapse potential} = \pm \Delta h/H * 100\%$$

Where

Δh = Increase (swell) or decrease (collapse) in height of the compacted specimen on wetting under the applied stress.

H = Height of the compacted specimen before water was added at the particular stress.

A positive sign was assigned to the swell potential to denote increase in specimen thickness from swelling. A negative sign was assigned to the collapse potential to denoted reduction in specimen thickness from collapse. Void ratio of the soil can be calculated from the following equation

$$\gamma_b = G \gamma_w / 1 + e$$

Where

γ_b = Bulk density

G = Specific gravity

γ_w = Unit weight of water

e = void ratio

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Change in void ratio can be defined by

$$\Delta h/h = \Delta e/1+e$$

$$\Delta e = \Delta h (1+e)/h$$

Where

Δe = Change in void ratio

Δh = Decrease (collapse) in height of the compacted specimen on wetting under the applied stress.

h = Height of the specimen



Fig.1. Oedometer test

IV. RESULTS AND DISCUSSIONS

Extensive laboratory investigations are conducted to evaluate the index and engineering properties of the calcareous soil. The results obtained from the tests are presented in the Table 1. It can be observed that the selected soil have good variance in the properties and also their characteristics, which give good selection criteria for the study. Also, it can be noticed that the calcareous soil considered fir the study consists of the fine-grained soil. The details of the results are discussed below.

Table -1: Index properties

PROPERTIES	CALCAREOUS SOIL
Specific gravity	2.42
Gravel %	0
Sand %	37
Silt %	44
Clay %	19
Liquid limit %	33
Plastic limit %	21
Plasticity index %	12
Optimum moisture content (OMC) %	13.13
Maximum dry density (MDD) gr/cc	1.898

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Oedometer test has been performed for the calcareous soil and inundation was done at normal stress of 0.2 kg/cm^2 , the results obtained from the test are plotted in Fig. 2 (a) from the figure, it can be observed that no collapse has been found. Hence, it can be concluded that the calcareous soil is stable at a given pressure of 0.2 kg/cm^2 under inundation condition. Oedometer test has been performed for the calcareous soil and inundation was done at normal stress of 0.8 kg/cm^2 , the results obtained from the test are plotted in Fig. 2 (b) from the figure, it can be observed that 1.35% collapse has been found. Hence, it can be concluded that the calcareous soil is susceptible to collapse at a pressure of 0.8 kg/cm^2 under inundation condition.

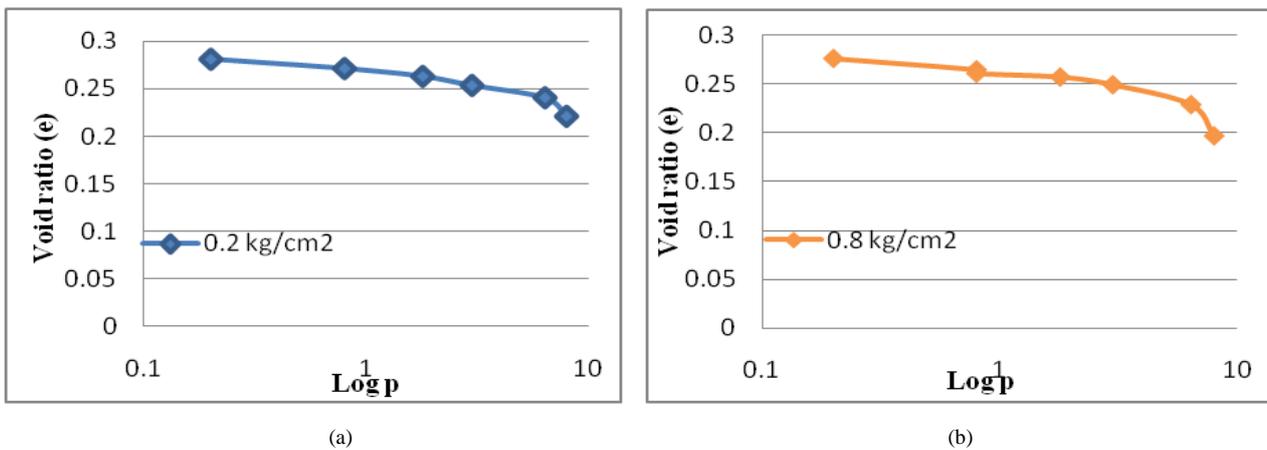


Fig.2 (a) Collapse condition for inundation stress of 0.2 kg/cm^2 (b) Collapse condition for inundation stress of 0.8 kg/cm^2

Oedometer test has been performed for the calcareous soil and inundation was done at normal stress of 1.8 kg/cm^2 , the results obtained from the test are plotted in Fig.3 (a) from the figure, it can be observed that 2.10% collapse has been found. Hence, it can be concluded that the calcareous soil is susceptible to collapse at a pressure of 1.8 kg/cm^2 under inundation condition. Oedometer test has been performed for the calcareous soil and inundation was done at normal stress of 3.0 kg/cm^2 , the results obtained from the test are plotted in Fig. 3 (b) from the figure, it can be observed that 3.19% collapse has been found. Hence, it can be concluded that the calcareous soil is susceptible to collapse at a pressure of 3.0 kg/cm^2 under inundation condition.

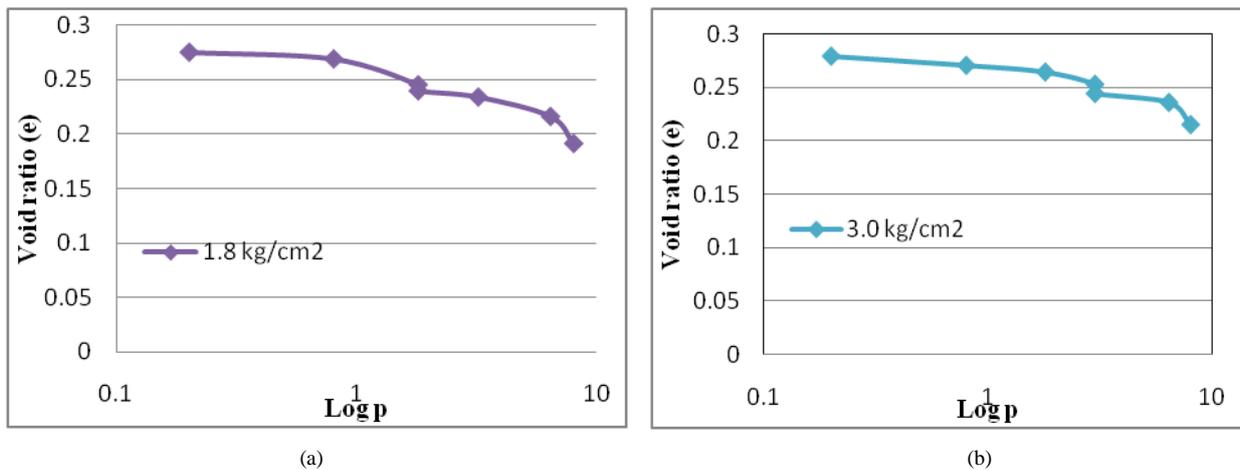


Fig.3. (a) Collapse condition for inundation stress of 1.8 kg/cm^2 (b) Collapse condition for inundation stress of 3.0 kg/cm^2

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Oedometer test has been performed for the calcareous soil and inundation was done at normal stress of 6.4 kg/cm^2 , the results obtained from the test are plotted in Fig. 4 (a) from the figure, it can be observed that 4.9% collapse of the sample has been found. Hence, it can be concluded that the calcareous soil is susceptible to collapse at a pressure of 6.4 kg/cm^2 under inundation condition. Oedometer test has been performed for the calcareous soil and inundation was done at normal stress of 8.0 kg/cm^2 , the results obtained from the test are plotted in Fig. 4 (b) from the figure, it can be observed that no collapse of the sample has been found. Hence, it can be concluded that the calcareous soil is stable at a given pressure of 8.0 kg/cm^2 under inundation condition.

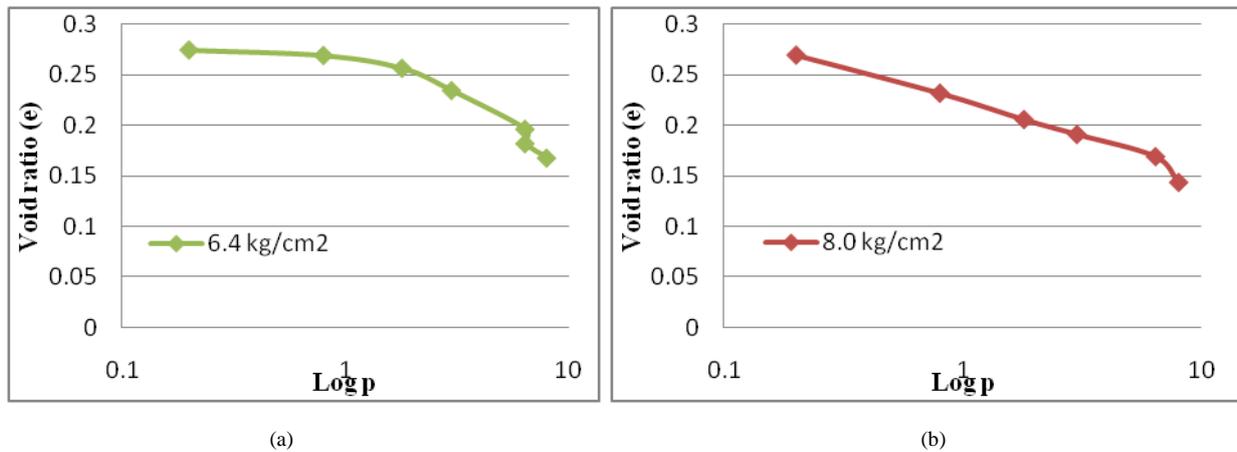


Fig. 4 (a) Collapse condition for inundation stress of 6.4 kg/cm^2 (b) Collapse condition for inundation stress of 8.0 kg/cm^2

Fig.5(a) shows that collapse condition at different inundation stress and from fig.5(b), it can be observed that collapse percentage increased with the increase of inundation stress and the soil did not show any collapse at higher inundation stress of 8 kg/cm^2 . The maximum collapse for calcareous soil is observed at 8 kg/cm^2 .

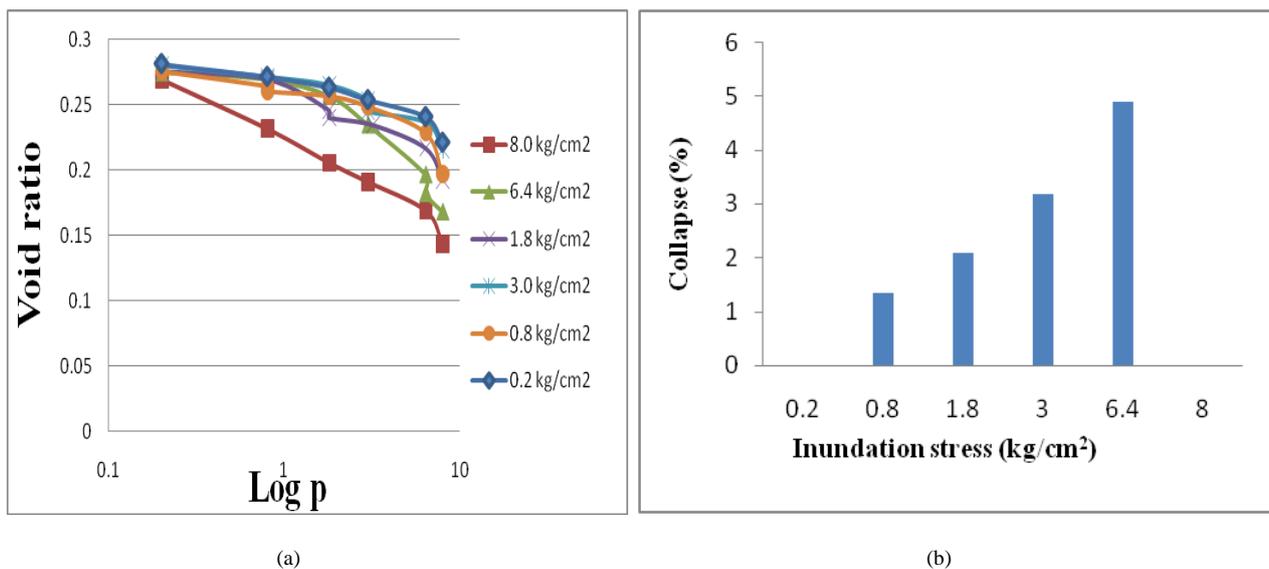


Fig. 5 (a) Collapse condition at different inundation stress (b) Comparison of collapse at different inundation stress

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EFFECT OF ADDITION OF CEMENT

From the above tests, it has been found that the inundation stress of 6.4kg/cm^2 is found to be critical for the calcareous soil. Hence, cement in various proportions, viz., 1%, 2%, 3% and 6% has been added by weight and the collapse studies have been performed on the cement mixed soil. The results obtained are discussed in the following.

Oedometer test has been performed for the soil mixed with 1% of cement by weight and inundation was done at 6.4 kg/cm^2 , the results obtained from the test are plotted in Fig.6 (a) from the figure, it can be observed that 3.13% collapse of the sample has been found. Hence, it can be concluded that the percentage collapse of soil mixed with 1% cement is comparatively less than that of only soil at the pressure of 6.4 kg/cm^2 under inundation condition. Similarly, soil is mixed with 2%, 4% and 6% of cement by weight and inundation was done at 6.4kg/cm^2 . The results obtained 1.18%, 0.45% of collapse at 2% and 4% cement. And no collapse of the sample has been found at 6% cement. Hence, it can be concluded that the soil does not collapse at the inundation stress of 6.4 kg/cm^2 with the addition of 6% cement. The same effect has been observed with the increase of addition of cement. Therefore, it can be concluded that 6% of the cement can be mixed with soil to control the collapsibility of the soil at any inundation stress.

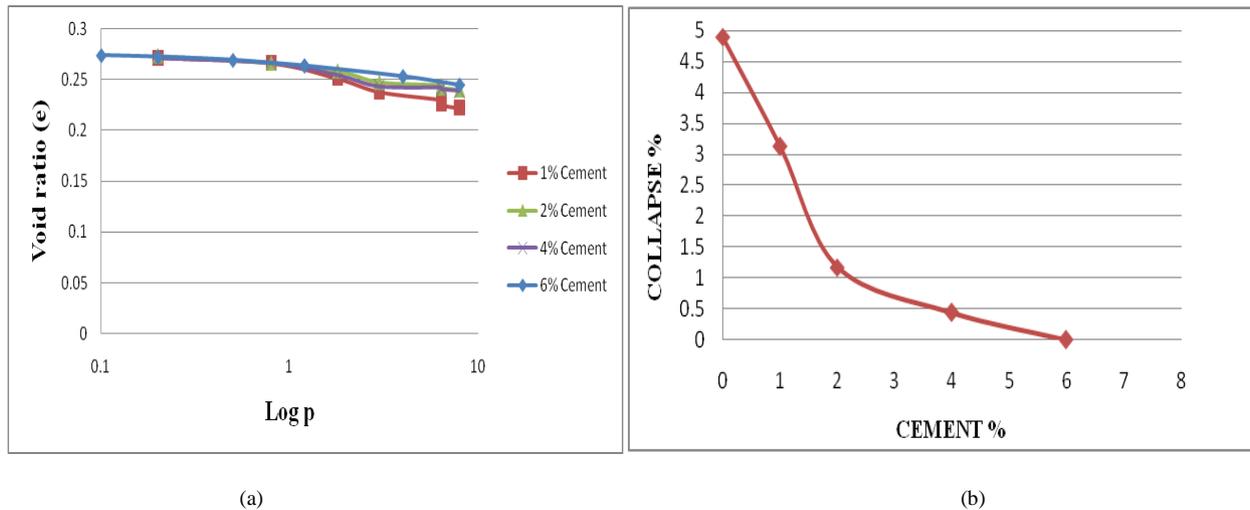


Fig. 6 (a) Collapse condition at different cement percentages (b) Comparison of collapse at different cement percentages

A comparison of the collapse values obtained from the various tests has been plotted in Fig. 6 (b) from the figure, it can be observed that the collapse percentage decreased with the increase of cement and the soil did not show any collapse at an optimum cement content of 6%. Since the maximum collapse for the soil is observed at an inundation stress of 6.4 kg/cm^2 , it is understood that with the addition of 6% cement to soil, the collapse can be controlled.

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V. CONCLUSION

From the oedometer test performed for the calcareous soil it can be observed that maximum collapse of the sample has been found to be 4.9% at inundation stress of 6.4 kg/cm^2 and no collapse have been observed for stress more than that. Hence, it can be concluded that the soil is collapsible at a given pressure of 6.4 kg/cm^2 under inundation condition. It has been observed that the collapse increases with the increase in the inundation stress and the values tend to zero above 6.4 kg/cm^2 . From the above tests; it has been found that the inundation stress of 6.4 kg/cm^2 is found to be critical for the soil. Hence, cement in various proportions, viz., 1%, 2%, 4% and 6% has been added by weight and the collapse studies have been performed on the cement mixed soil. The collapse of the soil can be controlled by addition of even 1% of cement and percentage collapse is found to reduce with the increase in cement content. However, no collapse has been observed for more than 6% addition of cement, hence, in order to control the collapse, an optimum amount of 6% of cement should be added to the soil.

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BIOGRAPHY



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