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COMPRESSIBILITY AND COLLAPSE POTENTIAL UPON WETTING OF CEMENTED LOOSE SANDS

Anuchit Uchaipichat[1] and Cheevin Limsiri[2]
[1]Department of Civil Engineering, Vongchavalitkul University, Nakhon Ratchasima, Thailand
[2]Department of Engineering Management, Vongchavalitkul University, Nakhon Ratchasima, Thailand
E-Mail: anuchitu@yahoo.com

ABSTRACT

This paper presents an experimental investigation on compressibility due to loading and a collapse potential upon wetting of cemented loose sands, which is proposed to be used as a material for construction of artificial aquifer. The experiments were performed on the cemented loose sand samples with various cement contents and periods of curing time. The results show a decrease in compressibility due to loading and collapse potential upon wetting of cemented loose sand with increasing period of curing time. Moreover, it was found that, with increasing applied stress, the compressibility due to loading increased while the collapse potential upon wetting decreased. The total compression due to both loading and wetting increased with increasing applied stress.

Keywords: cemented sand, compressibility, collapse potential, wetting process, aquifer.

INTRODUCTION

In Thailand, a large area of land is used for agriculture. The irrigation systems have been set up to support the agricultural activities in the country. However, in the arid and semi-arid areas such as the northeastern region of Thailand, water resources need to be managed effectively for all activities, including agricultural ones. For the area outside the irrigation zone, the water ponds have typically been used to keep water for utilization. The major problem for pond water is that the pond cannot hold the water all year round, particularly in arid area with underlain sandy soils. This problem can be solved by improving the pond lining.

However, a massive loss of water due to evaporation is very difficult to prevent since Thailand is located in the tropical zone. The evaporation rate can be as high as 2, 200 millimeter per year in some areas. Thus, underground water storage is one of possible techniques to overcome the evaporation problem.

To overcome the evaporation problem, the water pond can be replaced with artificial aquifer. The area above the aquifer can be used for other activities. To be capable of storing large amount of water, the artificial aquifer must be made of materials with high porosity and permeability. Sand is a good choice for this purpose. However, several investigators (Jenning and Knight, 1975; Phien-wej *et al*., 1992; Houston *et al*., 2002) found that loose soil is high compressible and susceptible to collapse upon wetting. Kohgo *et al*. (1993) and Loret and Khalili (2000) indicated that the collapse upon wetting is a plastic deformation involving the variation of yield surface with suction in soil. Thus, the loose sand layer, which is used as artificial aquifer, need to be stabilized.

It has been known for several decades that adding agents improves properties of soils (Clough *et al*., 1981; Balasubramaniam and Buensuceso, 1989; Kasama *et al*., 2000; Miura *et al*., 2001; Horpibulsuk *et al*., 2003; Kalantari and Huat, 2008). The examples of adding agents are lime, cement and lime-fly ash. However, work on effects of adding agents on loose sand has been limited.

Thus, the main propose of this research is to investigate the compressibility and collapse upon wetting of cemented sands with high porosity through results from a comprehensive program of laboratory testing in a conventional oedometer. The test data are carefully presented and discussed.

EXPERIMENTAL PREPARATION AND TEST MATERIAL

The tests were performed on a laboratory-compacted-sand with various cement content in a conventional oedometer as shown in Figure-1. The grain size distribution of the sample is shown in Figure-2. The cement admixed sand samples were statically compacted in the sample ring to the dry unit weight of approximately 12.27 kN/m^3 with the water to cement ratio of 0.8. The porosity of compacted sand sample at this condition, defined as void volume over total volume, is as high as 0.54. The compacted samples were then cured in the sealed plastic bags for testing at the curing time periods of 1, 7, 14 and 28 days.

TESTING PROGRAM AND PROCEDURE

A total of 78 tests were performed using the conventional oedometer as shown in Figure-1 to investigate the compressibility and collapse potential upon wetting of cemented loose sands with cement contents of 0, 2, 4 and 6 percent. The tests were performed on the compacted samples with the curing time periods of 1, 7, 14 and 28 days.

Prior to each test, the ring containing the cured sample was removed from the sealed plastic bag and placed in the testing container with the porous disks on the top and the bottom of the sample as shown in Figure-1. The loading cap was placed on the top to uniformly distribute load on the sample. The dial gauge was set-up to monitor the compression of the sample.

The vertical test load was then applied on the loading cap and the compression was recorded when the dial gauge reading was constant. The strain at this stage is called "compressive strain due to loading". Finally, the water was filled in the container to the level above the sample under constant applied load to monitor the compression of the sample. The percentage of compression in this stage is called "collapse potential upon wetting".

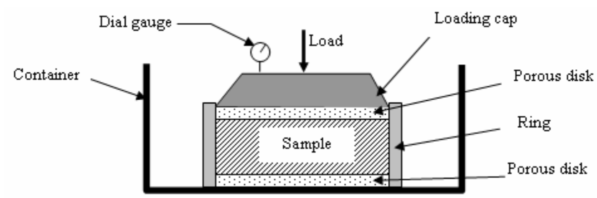

Figure-1. A conventional oedometer.

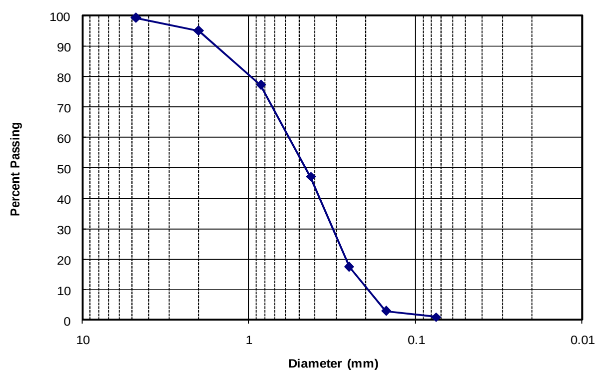

Figure-2. Grain size distribution of sample.

TEST RESULTS

Influence of curing time on compressibility and collapse potential

In this research, the tests were performed on cemented loose sand samples with various cement contents at different curing times ranging from 1 to 28 days. Figures 3 to 5 show the influence of curing time on compressive strain due to loading. It can be seen that the compressibility decreases with increasing curing time for all testing loads and cement contents. The effect of curing time on compressibility of cemented loose sand samples is obvious at the range of small period of curing time but is insignificant for the curing time greater than 14 days. These Figures also show that the compressibility increases with increasing applied load for all period of curing time. The similar trends can be observed for the relationship between collapse potential upon wetting and curing time as shown in Figures 6 to 8. However, the collapse potential decreases with increasing applied load.

Effect of cement content on compressibility and collapse potential

Typically, the stress, strain and strength of cement admixed soils with the curing time period of 28 days are considered as reference values since most of cementation bond is developed during this period of curing time (Horpibulsuk *et al*., 2003). Figure-9 shows the effect of compressive strain due to loading for the curing time of 28 days. It is obvious that compressibility increases with applied stress for all values of cement content. However, it decreases with increasing cement content for all values of applied load. It can also be seen that increasing small amount of cement content such as 2 percent can much improve compressibility of loose sand samples.

The relationship between collapse potential upon wetting and applied stress for the samples with various cement content is presented in Figure-10. It can be seen that the collapse potential upon wetting decreases with increasing applied stress and cement content. It is obvious that adding cement into loose sand can decrease the collapse potential. For cemented sand samples, the effect of cement content on collapse potential can be noticed at stress level less than 100 kPa and becomes insignificant at stress level greater than this value.

Total compression at various applied stresses

The relationship between total compression, including compression due to loading and collapse upon wetting, and applied stress for curing time period of 28 days is presented in Figure-11. It is obvious that the total compressive strain increases with increasing applied stress. It can also be found that the total compressive strain of loose sand samples decreases dramatically with adding cement. It can be noticed that increasing cement content causes a decrease in total compressive strain for all levels of stress.

DISCUSSIONS

The test results show a decrease in compressibility due to loading and collapse potential upon wetting of cemented loose sand with increasing period of curing time. This is because the strength of cementation bond developed during curing process and increased dramatically at the initial range of curing time period. Thus, the resistant force against the movement between the soil particles increased with increasing curing time period.

The results also show that, with increasing applied stress, the compressibility due to loading increases while the collapse potential upon wetting decreased. It should be noted that a large amount of compression occurred at high stress level. Thus, the volume of voids between soil grains was small and the collapse of soil structure upon wetting was consequently minimal at high stress level. As a result, the cementation bond also became insignificant in collapse upon wetting of cemented sand at high stress level.

Since the amount of compression due to loading is much greater than the amount of collapse up on wetting, the trend of relationship between total compression due to loading and wetting and applied stress is similar to that between compressive strain due to loading and applied stress.

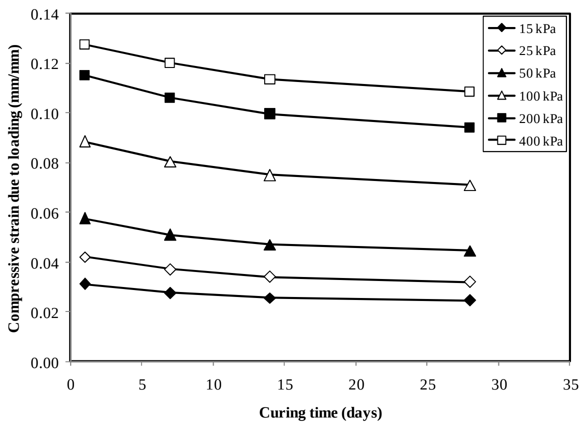

Figure-3. Compression due to loading for samples with cement content of 2%.

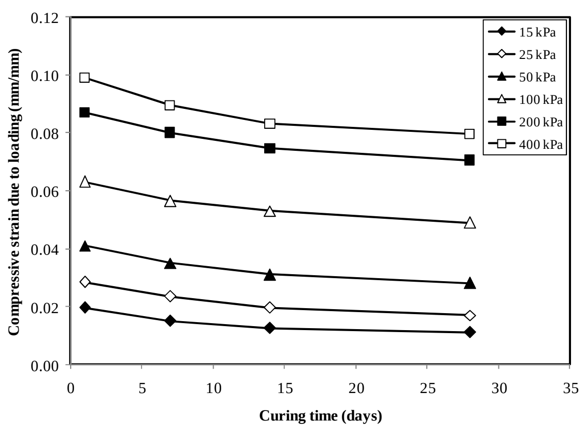

Figure-4. Compression due to loading for samples with cement content of 4%.

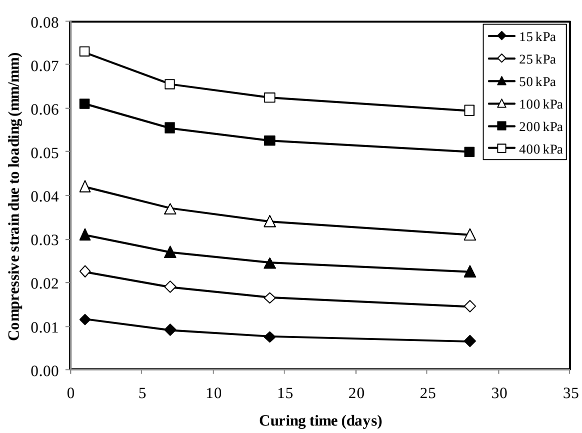

Figure-5. Compression due to loading for samples with cement content of 6%.

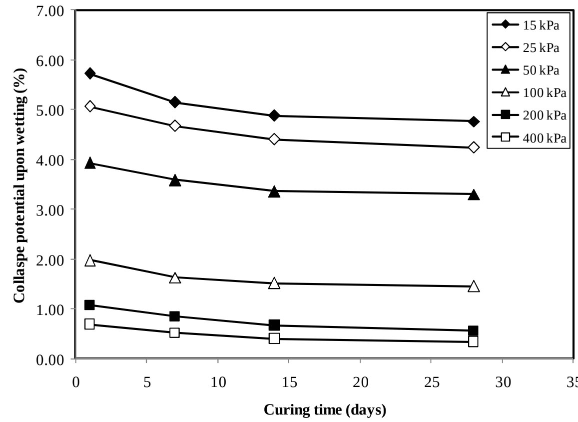

Figure-6. Collapse potential upon wetting for samples with cement content of 2%.

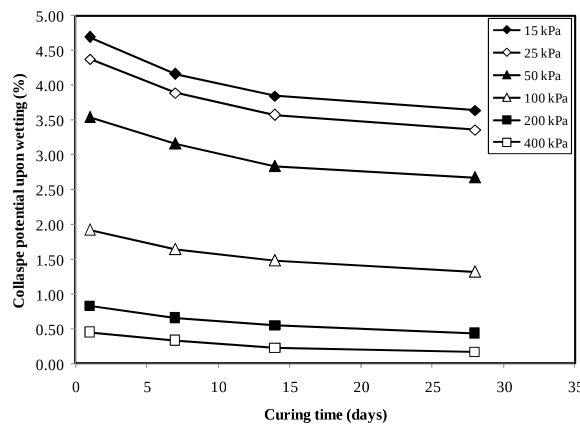

Figure-7. Collapse potential upon wetting for samples with cement content of 4%.

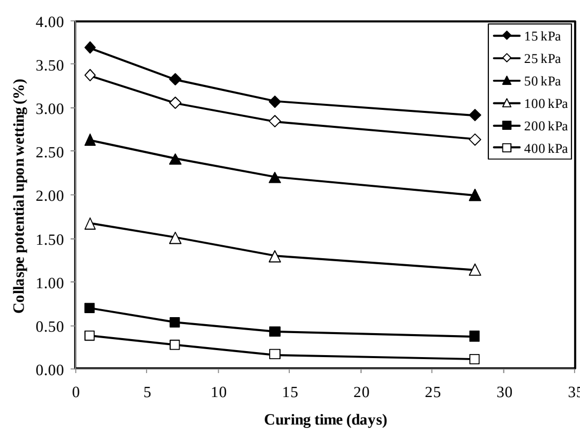

Figure-8. Collapse potential upon wetting for samples with cement content of 6%.

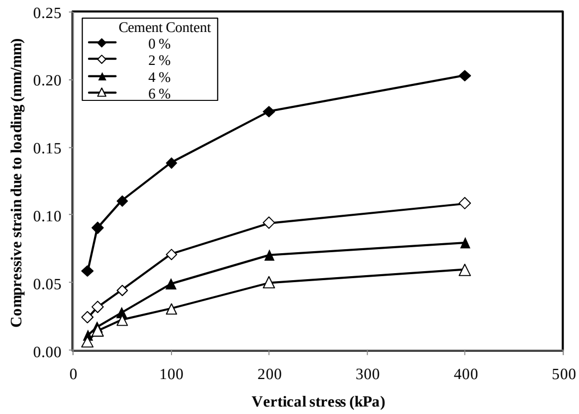

Figure-9. Relationship between compressive strain due to loading and vertical stress for samples with curing time period for 28 days.

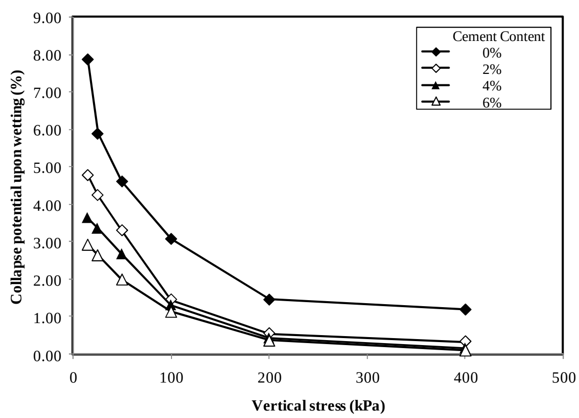

Figure-10. Relationship between collapse potential upon wetting and vertical stress for samples with curing time period for 28 days.

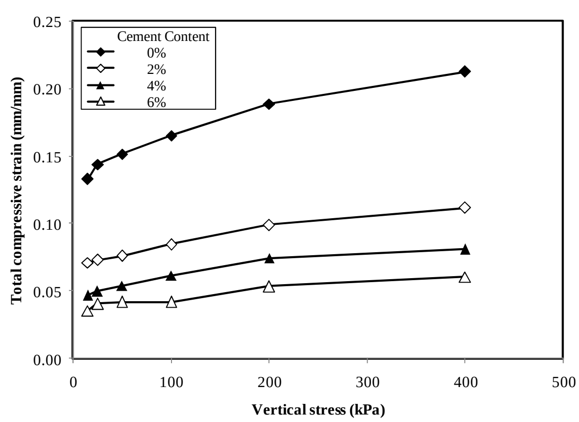

Figure-11. Relationship between total compressive strain and vertical stress for samples with curing time period for 28 days.

CONCLUSIONS

The compressibility due to loading and collapse upon wetting of cemented loose sands were investigated through results from a comprehensive program of laboratory testing in a conventional oedometer. The laboratory tests were performed on the cemented loose sand samples with various cement contents and periods of curing time. The test results show a decrease in compressibility due to loading and collapse potential upon wetting of cemented loose sand with increasing period of curing time. The results also show that, with increasing applied stress, the compressibility due to loading increases while the collapse potential upon wetting decreased. Furthermore, the total compression due to loading and wetting increased with increasing applied stress.

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