Influence of Stress and Soaking History on Double Consolidation Test

Unsaturated Soil, Collapsible Soil,
Double Consolidation Test, and Collapsible Potential

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1 INTRODUCTION

Collapsible soils are a common geotechnical concern in arid regions. These relatively high void-ratio soils exhibit significant strength and low compressibility at their natural, in-situ water content, collapse significantly upon wetting under load. The decrease in soil suction and weakening of bonds associated with accidental or intentional wetting triggers the collapse. Thus, engineering problems with collapsible soils are almost always associated with changes in the groundwater or surface water regime. Geomorphological setting is often indicative of soils which may possess collapse potential, with loessial, debris flow, and alluvial and colluvial deposits frequently exhibiting these characteristics. However, compacted soils, particularly those compacted dry of the optimum water content, have been shown to exhibit significant collapse strain upon wetting in numerical cases.

In many parts of the world, collapsible soils are notorious of damage to buildings or other constructions. Most often, the damage results from differential settlements or deformations which had not been anticipated at the design and construction stages. Also in Thailand, almost soils in Northeast Thailand, especially loess, pose problems to the engineering works on or with these soils because they are easily erodible, collapsible and dispersive. To deal with proving such those problems in Thailand, a study of the collapsibility of soil is necessary for material selection. This research deals only with the uncemented, dry collapsible soils. As shown in Figure 1, the “Shirasu”, volcanic sandy soil was remolded by static compacted method. Due to the fact that the Khon Kaen soil is also sediment by wind, the “Shirasu” soil can be used to study the mechanism of collapsible soil and to improve collapsible potential of the Khon Kaen loess.

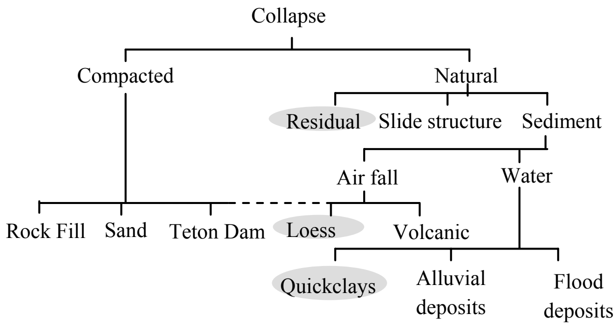

Fig. 1. A classification of collapsible soil, Rogers (1993)

2 COLLAPSIBLE INDEX

The single and double consolidation tests have been performed to investigate collapse potential of compacted soil in term of collapse index (I_C) by ASTM D 5333-92. It can be calculated by the following equation:

$$I_C = \frac{100\Delta e}{1+e_0} = \frac{100\Delta H}{H_0}$$

where Δe and Δh are the changing of void ratio and sample height due to inundation at the same applied pressure; e_0 and h_0 are initial void ratio and initial sample height.

3 EXPERIMENTAL PROGRAM

A laboratory test program was conducted to study the collapse of a statically compression of volcanic sandy soil, Shirasu soil. The index properties of Shirasu soil are shown in Table 1. The tests were conducted to verify the effort of collapse and to study the effects of initial dry density, initial water content, vertical stress for soaking and soaking pressure on collapsibility.

Table 1 Index properties for Shirasu soil

Property	Shirasu
Specific gravity	2.54
Grain size distribution	
Sand : Silt : Clay	85%:13%:2%
Water content	0.6%-1.3%
Optimum moisture content (OMC)	8.1%
Maximum dry density	1.44 g/cm^3
γ_{dmin}	0.95 g/ cm^3
γ_{dmax}	1.30 g/ cm^3

3.1 Test program

Test series were conducted on specimens which were each compacted to achieve the initial relative density of 20%, 65% and 90%, respectively, with the optimum moisture content, OMC, approximately 8 % water content, as shown in Table 2. Two specimens of each conditions, one with OMC and another one with saturated condition, were conducted by the single consolidation test. The remaining specimens with OMC were subjected to inundation at different vertical stress corresponding to the designed pressure.

Table 2 Initial condition of specimens

Dr	e	γ_d (g/ cm^3)
20%	1.52	1.01
65%	1.20	1.15
90%	1.03	1.25

3.2 Test procedures

The collapse tests were conducted in a conventional oedometer. In each test, the specimen was placed between two air dry porous stones in the oedometer ring. The preparation of the specimens depends on the design initial water content and degree of relative density. The oedometer rings are 60 mm in inner diameter and 20 mm high.

To reconstitute, it was statically compacted to the design condition before doing consolidation test. The height of the specimens after compaction will be the full height of the rings. The maximum stress history can be found from the relationship between void ratio and vertical stress applied as the preloading pressure.

Experimental Investigation of Collapsible Sandy Soils on Double Consolidation Test
D. Hormdee, H. Ochiai and N. Yasufuku (Kyushu University)

In the consolidation process, the specimen was loaded every two hours by doubling the previous load. When settlement under the desired load completed, the specimen was inundated with distilled water. Subsequent to saturation of the specimen for 24 hours, further loads were again applied to the specimen under saturated conditions.

4 RESULTS AND DISCUSSIONS

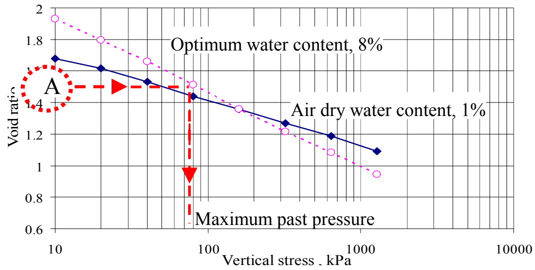

Fig. 2. Relationship between e and vertical stress

A summary of the results of tests is presented in Figures 2 to 5. The results of void ratio changes with vertical load in Figure 3, for specimens inundated at

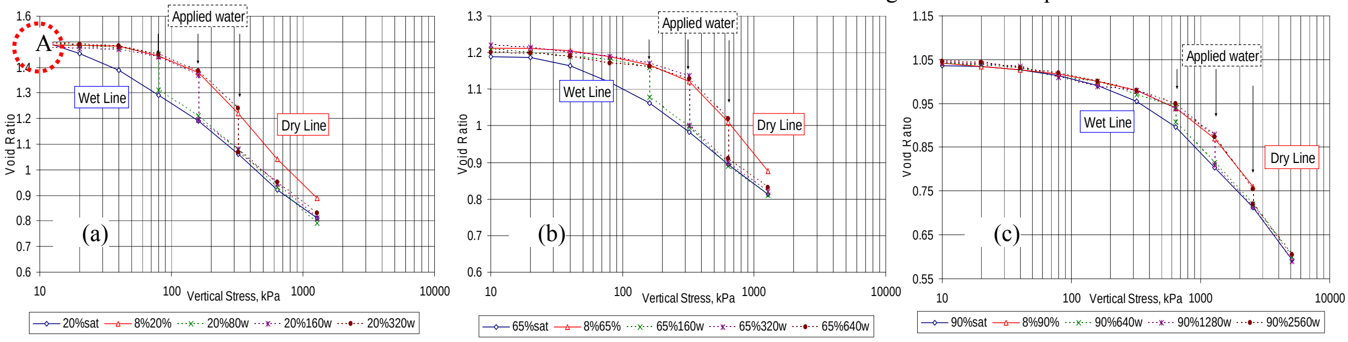

Fig. 3. Effect of vertical stress on collapsibility (a) at Dr = 20% (b) at Dr = 65% (c) at Dr = 90%

various vertical load referring to the maximum stress history, as shown in Figure 2, with initial relative density of 20%, 65% and 90%, respectively. For the dry line or unsaturated condition line, and the wet line or saturated condition line, they can be presented as the guideline for the remaining result of the double consolidation test. The results show that the void ratios of the initially unsaturated specimens approach the consolidation line of the saturated specimen after being subjected to inundation. The experimental results clearly indicate that the total volume of the specimen started to decrease as the changing the status from unsaturated to saturated condition. The volume of specimen continues to decrease until the saturated condition approach.

Figure 4 shows the relationship between collapsibility coefficient and loading pressure of soaking. In term of the effect of initial water content on maximum collapsible potential in various initial densities shows in Figures 5. In order to determine the variation of collapsibility with increase in the applied vertical pressure, samples were compacted to various initial relative densities with initial air dry water content and with optimum moisture content. With increase of the applied loading pressure, collapse potential increases in step-wise fashion up to a point at which the value of collapse index shows a slight decline or even approximates a constant value. Two sharp inflexions can be seen more obviously in the higher value of initial relative density of the samples and those agree quite well in both initial water contents. The first (P) can be considered as a critical pressure threshold: before point P, the value of collapse index rises gently with almost no collapse, probably representing compression deformation. After point P, values rise sharply, indicating collapse. The value of collapse index reaches its maximum at point Q, above which shows no further rise with increasing loading pressure. This indicates that the soil has reached its highest compression due to inundation. Repeatedly, those have shown that the loading pressure at which I_c reaches its maximum value is around the value of preloading pressure or the maximum stress history. Theoretically, the loading pressure at point P can be termed the initial pressure. If the I_c is treated as an indicator of collapse intensity, the initiating pressure can be considered as a measure of sensitivity of collapsible soil as points P and R of different initial relative densities line.

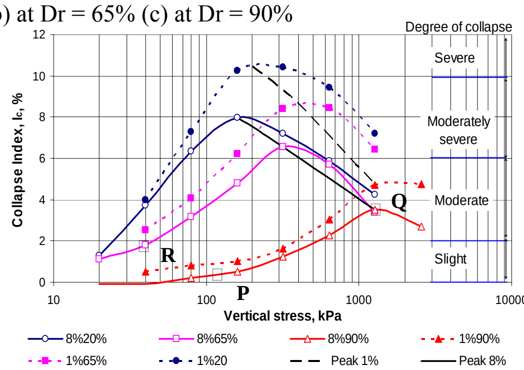

Fig. 4. Relationship between I_c and loading pressure

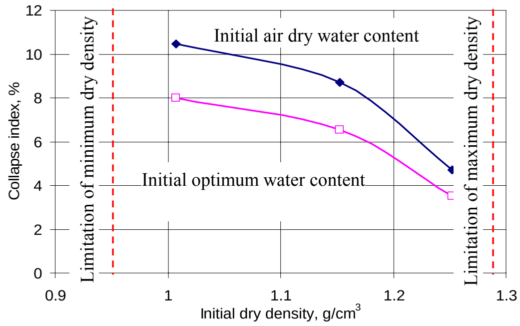

Fig. 5. Relationship between I_c and soil density

5 CONCLUSIONS

According to collapsible soils are notorious of damage to building or other construction that collapsible soils arise when the existence and extent of collapse potential are not recognized prior to construction. Therefore a laboratory or field test is commonly used for identification of collapsible soils, and for obtaining a quantitative estimate of collapse potential for use in estimating potential settlements of a structure. These experiment tests mainly concern with the potential of collapsibility on the effects of stress history, in term of preloading pressure, and the soaking history, as well as the initial water content. The volume of specimen continues to decrease until it reaches the saturated condition. It shows that increasing in initial water content decrease the collapsible potential being one reason to confirm that the collapsibility will be finished when the water added until reaching the saturated condition. The maximum potential of collapsible usually occurs nearly the point where maximum stress history occurred at the point of preloading in this case.