Analysis of compressibility of red clay considering structural strength

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Extended Abstract:

Introduction:

In southwest China, there has been an increasing interest in the properties of red clay. Buildings are usually designed and constructed without the concern of its special properties which is high water content, high liquid limit, high plastic limit and high void ratio of the intact soil. The compression behavior of red clay has increasingly been studied in the last decades. Most studies have focused on the structural strength intact specimens. As a result of special pedogenesis, structural strength varies with the depth and usually is depicted by comparison intact specimens and remoulded specimens. In order to fully understand the influence of the soil structure, the compression of intact red clay should be studied, compared with the data of experimental of remoulded specimens.

Virgin soils exhibit some form of ‘structure’. It is usually acknowledged that the structure is formed during their depositional history (Mitchell, 1986; Leroueil & Vaughan, 1990). The term ‘soil structure’ is to mean the arrangement and bonding of the soil constituents, and for simplicity it encompasses all characteristics of a soil that are different from the corresponding remoulded soil. There is large experimental data to suggest that soil structure, as well as stress history, are influences of first importance on the mechanical behavior of natural soil (e.g. Rowe, 1972; Skempton, 1985; Burland, 1990; Shen, 1998). It is also well recognized that weathering or sampling or loading; modify the original structure of soil. Xiao et al. (2005) studied the mechanical properties of the residual laterite and revealed the failure forms of the intact and reconstructed soil under different confining pressure. The variability of mechanical properties of red clay under the action modes of water content change, dry and wet alternation, hydrochemical action and so on is presented by Wang et al. (2007).

The engineering physical and mechanical properties of red clay are analyzed, and the microscopic “aggregate” structure model is put forward by Zhou et al. (2012). The effects of water sensitivity, compactness and cementation of red clay on the shear strength of soil were obtained by analyzed the test of data (Fu et al. 2014). The compression and shear characteristics of structural soil and remodeling soil were loaded using a displacement-controlled method at different rates from the research of Chen et al. (2004). Scanning electron microscopy and mercury injection test were carried out by Zhang et al. (2012), the microscopic pore changes of structural clay during
compression were studied that the evolution of microstructure morphology during compression could be divided into 3 stages of structural fine-tuning, structural breakage and structural curing. However, the analysis of structure strength associated with depth is less. The relationship between structure and depth would be very useful in geotechnical practice.

In this paper, intact compression behavior of structured red clay is examined. A basic compression regulation is suggested. A new compression pattern to describe soil structure is introduced, together with the concept of ICL associated with soil structure. Important features of the compression behavior of structured red clay are discussed and the influences of depth and other factors on destructuring are briefly investigated.

**Methods:**

The soil of specimens was sampled from Liuzhou (LZ) and Laibin (LB), two cities in Guangxi. They were well ground and sieved through 0.075 mm sieve. The detectable oxides compositions of red clay were determined using the atomic absorption spectrometer. The result from the preliminary tests was shown in Table 1. The intact specimens are treated with a thin-walled soil sampler in the drilling. The soil specimens below 2m were selected for experimental use, for excluding the effect of human activities and plant. The reconstructed specimens are carried out the same pore ratio as the same water content as the intact specimens. Then, According to Borland’s (1990) method of making slurry specimens, taking water content as 1~ 1.5 times liquid limit, however, stirring fully, and putting into the sample barrel (diameter 9.2cm, high 15cm), applying 20kPa vertical pressure. The effects of soil structure on the compression behavior, such as the mineral composition, void ratio, and initial relative density are discussed by the One-dimensional compression test on intact specimens (IS), remoulded specimens (RS) and slurry specimens, respectively.

**Results:**

The result from Fig.1 shows that the RS curve tends to be in the ICL line, and eventually shows a tendency to coincide. The ICL line is obtained by normalized the slurry specimen, which shows the inherent properties of the soil. The RS compression normalization curve shows the overall downward translation due to residual structural, the bond and the arrangement of particle. The deeper IS specimen of compression curve is located in the shallower specimen, that is, the mechanical strength of the shallower soil is greater than that of the deep soil.

In the $I_p$-$\log \sigma$ coordinate, the normalized compression curve of IS panned down with the increase of depth. The IS normalized curve before the yield point is more flat, earlier than RS’s through the ICL line. The normalized curve of RS has a steeper slope. And $\Delta I_p$ is the performance of the structure of intact soil on the compression curve.

The normalized curve of IS precedes the normalized curve of RS, and then intersects with the ICL line. The reason is that IS has strong structure, and pore ratio of the original specimen decreases less when under the same vertical stress.

The first stage of the formation of red clay is chemical weathering; soluble components are taken away by rain, refractory oxide in the shallow accumulation, particularly Fe$_2$O$_3$ oxide, so that the soil has a certain structural strength (Fig.2). The structural strength of soil depends on the degree of chemical weathering. As the depth increases, the pore ratio increases and the soil is looser from Fig.5. The soils closer to the surface suffer intenser chemical weathering. The dry density
decreases with depth, which indicates that the shallow soil has a large structural strength (Fig.3). The Fig.4 shows that the regulation of plastic index with depth is similar to dry density, and then is basically unchanged, which is due to the effect of clay on the aging of clay minerals, causing the loss of plasticity.

The structure of red clay makes it different from the compression curves of general clay, and GASPARRE et al. (2007) research shows that the structure of clay in London decreases with the depth (Fig.6). Red clay, on the other, behaves in the opposite regularity. The result from Fig.7 shows a regularity of the normalized curve which is the normalized curve moves along the longitudinal axis with the deepening of the depth, such as the Z1 curve panning down to the Z2 position. The yield point is always at the upper end of the ICL line. When the stress exceeds the yield point, the soil structure is destroyed, the curve will be parallel to the ICL line, and the greater the structural strength, the farther away from the ICL line. The normalized curve translation direction is perpendicular to the ICL line, the greater the structural strength, the greater the translation distance.

Conclusions:

From the results of the normalization of the compression curve of intact specimens, it is concluded that the structure makes the one-dimensional compression behavior different from other clays. Compared with the experiment result of remoulded specimens and slurry specimens, found that the normalized curve shows the translational characteristics with depth or structural strength caused by the physical and chemical weathering, which is that the insoluble substances produced in cycle of dissolve-organize-gelatinous-age. Finally, it emerged a soil with a certain structural. But, its structural strength depends on the intensity of the cycles, that is, the depth of the distance from the surface. The plastic index increased with depth, and then remains basically unchanged at certain deep. The dry density increased with depth and the reducing of refractory oxides. The deeper structural strength of the deposited clay is bigger than the shallow, while the red clay not. Meanwhile, the yield points of intact specimens are located above the ICL line. According to the compression characteristics of red clay, it is found that the laterite effect was influenced by the depth. From the experiment result; the normalization regularity of compression curve of red clay has been summarized.

Reference

200.

Figure captions

Fig.1 Normalization of compression curve of intact specimen and remolded specimen
Fig.2 Fe elements with depth distribution
Fig. 3 Change of dry density with depth
Fig. 4 Variation of liquid plastic limit with depth
Fig. 5 Variation of void ratio with depth
Fig.6 Normalized depth curves of London clay (GASPARRE et al. 2007)
Fig.7 one-dimensional compression behavior of red clay
(b)

Fig. 1 Normalization of compression curve of intact specimen and remoulded specimen

Fig. 2 Fe elements with depth distribution

Fig. 3 Change of dry density with depth
Fig. 4 Variation of liquid plastic limit with depth

Fig. 5 Variation of void ratio with depth

Fig. 6 Normalized depth curves of London clay (GASPARRE et al. 2007)
Fig. 7 one-dimensional compression behavior of red clay

<table>
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<th>Number</th>
<th>deep/m</th>
<th>w₀/%</th>
<th>Gₛ</th>
<th>c₀</th>
<th>Iₚ</th>
<th>W₁</th>
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