Experiment Study on the Compression Resilience of Loess

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Abstract. Due to structure form of particles and the characteristics of loess, such as high strength and incomplete consolidation, in order to research the influence of structure on compression and resilience characteristics of loess, the compression resilience test for undisturbed soil and remoulded soil and compression resilience recompression test for undisturbed soil is carried out under five kinds of different water content. The results show that: the structure has great influence on the compression and resilience characteristics of loess, especially after or before the structure damage. And the structured yield stress is bigger, resilience characteristics is more and more strong. Moreover, when pre-consolidation pressure is ascertained, the structure must be considered. The research of compression and resilience characteristics of loess lays a foundation for proposing a new method of ascertaining pre-consolidation pressure.

1. Introduction

Broadly speaking, most of natural soil is structural soil. However, because of lack of considering for structure in early constitutive model, which established on the basis of research about remoulded soil and sand, so there is obvious defect in real application and problem that appeared obvious deviation in calculation precision.

Recently, research of structure has attracted wide attention and brings to the high attention, how to establish the constitutive model considering structure is an important hot issue that is discussed and concerned by many geotechnical workers. Research of structure had become a core problem in the 21 century [1], many scholars had carried out various forms research for structural soil based on the theory of microscopic morphology and solid mechanics and soil mechanics respectively, and a lot of research results had been obtained, such as Smith [2] had researched the yield characteristic of Bothkennar clay though triaxial compression test on different path. M.D.Liu and J.P.Carter (1999) [3] proposed the structural compression model according to compression test of soil. He put forward Sydney soil model subsequently based on critical state theory [4]. Shen zhujiang [5] proposed the complex model and the masonry model for structured clays. Liu enlong [6-7] had a lot of experimental study on mechanical properties of artificially structured soils, and then constructed the binary medium model. Xiao shufang [8] studied on the structural characteristics and elastic - plastic model of recent marine soft soil. Dorival M. Pedroso [9] considered the concept of reference curves for constitutive modelling in soil mechanics. Xie dingsyi and Qi jilin [10] put forward two new concepts that can reflect characteristics of arrangement and connection firstly, namely stabilizability and changeability, which can express characteristics of the strength and magnitude. It was first develop by Luo yasheng [11-12]
under complex conditions, and defined structured parameters based on considering strength. Chen Cunli [13-15] had studied on the relation of structure and deformation. Xu Yali [16-19] had studied the structure of loess soil and proposed a 1D compression model for loess based on disturbed state concept.

In this paper, in order to research the influence of structure on compression and resilience characteristics of loess, the compression resilience test for undisturbed soil and remoulded soil and compression resilience recompression test for undisturbed soil is carried out under five kinds of different water content, especially if change and different will occur after or before the structure damage. At the same time, the research of compression and resilience characteristics of loess lays a foundation for proposing a new method of ascertaining pre-consolidation pressure.

2. Soil sample and test design

2.1. Physical characteristics of the loess

When receiving the paper, we assume that the corresponding authors grant us the copyright to use the paper for the book or journal in question. Should authors use tables or figures from other publications, they must ask the corresponding publishers to grant them the right to publish this material in their paper. The samples of soil come from the different building sites in the north and south suburbs of Xi’an, the depth of borrow is about five meters. Soil samples show brownish yellow, samples are in plastic state, which are belong to classic Q3 loess. Physical and mechanical indexes of loess are shown in Table 1.

| Soil  | proportion | Moisture content w (%) | Natural density ρ (g/cm³) | Liquid limit wL (%) | Plastic limit wP (%) |
|-------|------------|------------------------|---------------------------|---------------------|----------------------|
| sample 1 | 2.71       | 22                     | 1.48                      | 34.3                | 18.9                 |
| sample 2 | 2.70       | 18                     | 1.35                      | 33.9                | 20.4                 |

Five different initial moisture content are designed according to need of test, its are 8% and 16% and 22% and 28% and saturation. Different initial moisture content of undisturbed soil is prepared respectively by using the air-drying method and dripping water method, and soil sample is put in the cylinder in order to keeping humidity. Its can be used after 24 hours, which can make water distributed uniformly in the soil sample. When remoulded soil sample is prepared, residual soil must be sieved from the sieve which pore size is 1mm. Under the condition of same dry density and moisture content with undisturbed soil, soil sample is done through layered pressing method. Saturated soil sample is done through pumping.

2.2. Test design

In order to research the influence of the structure on the characteristics of compression and compression-resilience and compression-resilience-recompression, a lot of confined compression tests and unconfined compression tests for undisturbed soil and remoulded soil are designed under five moisture content, such as: 1) the compression test for undisturbed soil and remoulded soil; 2) unconfined compression test for undisturbed soil and remoulded soil; 3) the compression-resilience tests for undisturbed soil and remoulded soil; 4) the compression-resilience-recompression tests for undisturbed soil and remoulded soil, load of 400kPa and 800kPa is used as the unloading point.

3. Test results and analysis

(1) The compression curves of undisturbed soil and remoulded soil at different moisture content
Figure 1. The compression curves of undisturbed soil at different water moisture.

Seen from Fig.1, there is obvious different compression characteristic for undisturbed soil and remoulded soil at the same moisture content. Influence of moisture content on compression curves of undisturbed soil is extremely significant, especially for two stages of the development of compression curves. When the moisture content is low, compression curves change greatly before and after the structured yield stress, especially compression curves is very steep when load is more than the structured yield stress, and inflection point of curve is more obvious, namely dividing point in compression curves is obvious for the gentle segment and plunged segment. The more is the moisture content low, and the more structural performance of the loess obvious is, which influence on the compression performance is the more notable. When water moisture is high, compression curves on the whole is relatively gentle, gentle segment and plunged segment of the boundary is also more and more is not obvious. This feature also explains that water is the main factors weaken connection strength in particles, the increase of the moisture content already damaged structure in undisturbed soil. At the same time, along with the increase of the water moisture, compression curves in the later is more gentler. Especially water moisture is high and pressure is great, it appears a kind of phenomenon that the segment in the end of compress curve occurs upwarping. And, with the increase of the moisture content, pressure value corresponding to the starting point of the curve occurred upwarping also have decreasing trend.

Figure 2. The compression curves of remoulded soil at different water moisture.

Shown as in Fig.2, the moisture content also has effect on compression curves of remoulded soil, but the impact is small, except at relatively low moisture content (w=8% and w=16%), the weak secondary structure makes compressed curve occur obvious inflection point, curves at the other water content show linear distribution basically, its have no inflection point.

For compression curves of undisturbed soil and remoulded soil at the same water content, as the same loads, because of cementing material between the original soil particles, there will produce the reinforcement. So when the load is applied, cementing material of soil particles at contact point began
to play a role. When the load is to a certain extent, the structure destroys gradually, soil particles produced the slip between each other and rearrange, until it reaches the structure stable state under this load. So at the same moisture content and pressure, compression deformation of undisturbed soil is smaller than remolded soil. However when the soil structure is completely destroy, mechanics properties of soil will no longer be affected by structure. And the compression curve of undisturbed soil is near to compression curve of remolded soil gradually, and also pattern of compression curve is similar. So when the moisture content is higher, compression curve of undisturbed soil is more close to remoulded soil, especially at saturated moisture content, both the performance of curve is the linear distribution.

(2) The unconfined compression curves of undisturbed soil and remoulded soil at different moisture content

![Figure 3](image1.png)

**Figure 3.** The unconfined compression curves of undisturbed soil and remoulded soil at different water content.

Shown as in Fig.3, in the undisturbed soil experiment, there is an obvious softening and curve changes as the change of moisture content of the peak strength is larger in the low water content. With the increasing of water content, its peak intensity is relatively close, and weak type curve also by softening to soften to the ideal elastic-plastic model and sclerosis type change. This is due to the effect of water changed soil structural. In the remolded soil samples, the shear strength is obviously less than that of the undisturbed soil under the same water content, and it also has the softening property at a lower water content.

(3) The compression-resilience curves of undisturbed soil and remoulded soil

![Figure 4](image2.png)

**Figure 4.** The compression-resilience curves of undisturbed soil and remoulded soil.
Shown as in Fig.4, for undisturbed soil and remoulded soil at the same water content, when pressure is small, two curves compression deformation is basic quite. Along with the increase of the pressure, structure of undisturbed soil come into play gradually, changes in two curves occur the obvious difference. When pressure had not reached the structured yield stress, deformation of undisturbed soil is relatively small, because of the existence of the structure strength. So compression curve of undisturbed soil is more gently than remoulded soil obviously. However, when the pressure is more than structured yield stress, structure of undisturbed soil damage. Because of the special structure form of the loess particles, at the same time, with the aggregate is crushed and internal uniformity of pore, which lead to compression deformation increased rapidly, but also it is more obvious than remoulded soil. Therefore when pressure is over structured yield stress, the compression curve of undisturbed soil is steep more than remoulded soil, namely the compression index of undisturbed soil is bigger than remoulded soil. With the load increasing, structure of undisturbed soil is destroyed gradually, and until completely lost at last, so compression curve of undisturbed soil also is gradually near to remoulded soil. When they reach a certain pressure, two curves intersect at some point. Since then, because the remoulded soil sample is done by sieving, so particles is uniform, so the restructuring of the particles and line up with the load increasing make structure more closely, ability to resist the compressing has slightly fortified trends at this moment, the compression deformation is very limited, so compression curve of undisturbed soil is located under remolded soil. In addition, seen from both the resilience curve, when the load is applied to the last level, both of resilience ability is basic quite, namely the expansion index is same. Because as load increases, structure of undisturbed soil has been destroyed, structure has not affected resilience.

(4) The compression curve and compression-resilience curve of undisturbed soil

![Compression curve and compression-resilience curve of undisturbed soil](image)

**Figure 5.** The compression curve and compression-resilience curve of undisturbed soil.

Shown as in Fig.5, when water content is same for undisturbed soil and remoulded soil, compression-resilience curve and compression-resilience-recompression curve rebound to compress curve is quite before the rebound points, two curves compression deformation basic quite. After compressing and rebounding and recompressing, rebound deformation of resilience-recompression curve is much smaller than compression curve apparently. Since then resilience-recompression curve become gently, so the slope of resilience-recompression curve is smaller than compression curve, namely compression index is small. In addition, the slope of resilience curve in the last level load is same basically, namely the expansion index is same. But after rebounding, the eventual porosity ratio has a little of difference. The initial and final pore porosity ratio of resilience-recompression curve is bigger than compression-resilience curve, namely final compression deformation is small. Obviously, it is just explained it has certain structure in undisturbed soil, and structure is the result of joint action characteristics and coupling characteristics. In the compression process, the part of the structure is damaged, which make particle generation and arrangement and close to the stability. The adjustments that make it in later compression performance play a positive role. Another part of structure is
recovered after rebounding, the comprehensive results of two kinds of action result in that compression deformation of resilience-recompression curve is less than compression curve. However, this part that is recovered has be destroyed gradually with the load increasing, and until structure is all destroyed, so the expansion index of both of curve is same basically.

(5) The compression-resilience curve and compression-resilience-recompression curve of remoulded soil

![Figure 6](image)

Figure 6. The compression-resilience curve and compression-resilience-recompression curve of remoulded soil.

Shown as in Fig.6, at the same water content, compression-resilience curve and compression-resilience-recompression curve of remoulded soil is anastomosing, also the slope of curve is in accord with. For remoulded soil, even if resilience and recompression can’t change ability of resistance pressure. So it proves that there is no structure in remoulded soil. However, after rebounding, amount of compression in resilience-recompression curve is less than compression-resilience curve, which explain in the resilient process, because of the secondary structure of sample preparation caused the compressive performance has also improved, but the extent of the increase is very limited.

(6) The compression-resilience-recompression curve of undisturbed soil and remoulded soil

![Figure 7](image)

Figure 7. The compression-resilience-recompression curve of undisturbed soil and remoulded soil.

Shown as in Figure 7, whether the resilience curve for last load level or any load, resilience ability is basic equal after exceeding structure yield pressure. The slope of resilience curve for undisturbed soil is in accord with remoulded soil, namely the expansion index is equivalent. But the curve of the resilience-recompression change slightly, the resilience-recompression curve of undisturbed soil is gently, because structure of undisturbed soil lost a little after compressing, but it is not all. So even if it is rebounded, structure is helpful to compressive pressure.
4. Conclusion
Based on the compression resilience test for undisturbed soil and remoulded soil, the influence of structure on compression and resilience characteristics of loess is analyzed, especially change of mechanical after or before the structure damage for undisturbed soil, after study above, the conclusions follow as:

(1) Due to the influence of structure, the compression performance of the undisturbed soil is significantly different from the remoulded soil, which is manifested in the obvious inflection point of the compression curve of undisturbed soil, and the inflection point positions of different soil samples under different confining pressures are different, indicating that the structural strength of undisturbed soil has a great influence on its compressibility.

(2) The influence of structure on compression and resilience characteristics of loess is very significant, especially before and after the structural yield stress, resilience ability changes greatly.

(3) Through the research of characteristics of compression and resilience and recompression for loess, the traditional method of ascertaining pre-consolidation pressure is no longer applied, and it need to seek a new method of pre-consolidation pressure accurately. At the same time, when the pre-consolidation pressure of undisturbed loess is ascertained, it must be considered the influence of the structure. This research lays the foundation for proposing a method of calculating the pre-consolidation pressure of structural loess.

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