Discussion on the Method of Intact Loess Humidification Considering Water Content Uniformity

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Abstract

Soil mass strength has a direct correlation with soil mass water content. The shearing test for soil under different water contents is the most important method of analyzing landslide (sliding belt) soil mass strength. According to the humidification requirements on the intact loess for indoor test, we should pay attention to the uniformity of humidification for the intact loess. Through comparative studies on three humidification methods, it is considered that when the same loess samples have reached the same preset humidity, the loess sample with the pre-wetting method for 24 h can reach the uniform water distribution; the loess sample using the burying method can reach to the uniform water distribution after 10 days and the loess sample using the steaming method can reach the uniform water distribution after 8 h. The burying method can get the large water content range for humidification and saturated loess samples can be obtained through humidification, whereas the saturated loess samples cannot be obtained through the pre-wetting and steaming method.

Keywords

Water content • Humidification method • Pre-wetting method • Burying method • Steaming method

Introduction

Loess landslide is one of the most common geo-hazards in the Northwest of China and the landslide disaster has become a major hazard for human settlements and urban construction. The triggers of loess landslide is the decrease in the strength of soil mass in the slope. The strength of the soil mass is closely related to its water content: when the water content in the slope reaches a certain value, the pore pressure in the loess is sharply increases and the shearing strength significantly decreases (Miao et al. 1999), thereby causing landslides.

The loess in China is mostly distributed in arid or semi-arid regions. In general, shallow layer loess is in the unsaturated state. The unsaturated loess has high strength and low compressibility when its water content is low, but its strength is greatly decreased and its compressibility is evidently increased when it has high water content. For loess slopes, precipitation, irrigation, temperature changes will cause changes in the water content of the unsaturated loess, which leads to changes in the strength of loess and thereby causing the landslide disasters (Chen 1997; Chen 1999; Chen et al. 2006; Li et al. 2012; Xiong and Hu 2007; Yin et al. 2004). Therefore, when analysing the stability of loess landslide, physical and mechanical parameters of intact loess at different water ratios should be obtained by tests (Li and Miao 2006; Xie 2001; Zhang and Li 2011). As controlled by sampling conditions or test requirements, humidification processing is often carried out for the intact loess samples

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Table 1 Pre-wetting method water content uniformity test

Initial dry density ($g \cdot cm^{-3}$)	Dry density after humidification ($g \cdot cm^{-3}$)	Average water content after humidification (%)	Water content (%)				Differential water content (%)
			Soil surface	In the soil	The lower part	The upper part	
1.28	1.28	21.2	21.4	20.6	21.3	21.6	1.0
1.27	1.27	21.3	21.4	20.9	21.4	21.7	0.8
1.29	1.29	21.3	21.5	20.8	21.4	21.7	0.9
1.28	1.28	21.6	21.8	21.2	21.8	21.7	0.6

Table 2 Burying method for water content uniformity test

Test sample	Water content (%)		Differential water content (%)
	Soil surface	In the soil	
Cutting ring test sample	17.1	16.1	1.0
	20.6	20.4	0.2
	31.1	30.3	0.8
	30.2	29.7	0.5
Triaxial test sample	17.3	16.8	0.5
	28.0	28.0	0.0
	29.8	29.5	0.3
	31.4	31.3	0.1

during testing in order to get loess samples with different water contents. For the special structure of the loess, how to change the water content in the intact loess samples uniformly without changing the structure of soil is the key to carry out pretreatment under the precondition. By introducing a contrastive analysis method on the prevailing humidification methods, it is hoped that it will be helpful for selecting the humidification method so that the physical and mechanical parameters of the intact soil mass can be better obtained during the follow-up tests.

Contrastive Study on Humidification Tests

Pre-wetting Method

The pre-wetting method is a widely used humidification method for testing. Firstly, we drip water on the surface of the loess samples directly, and then put the loess samples into the humidifier to stand still and let the water dropped on the surface of the soil layer penetrate into the soil mass to obtain an uniform water content.

Taking a triaxial shear test sample, as an example, the author used the pre-wetting method to carry out humidification for the intact loess samples. We dry the triaxial test samples, and drip water from upper and lower ends as well as sides using a dropper. After humidification, we let the samples stand still in the humidifier for 24 h to make the water distributed uniformly (Table 1). According to the soil test regulations (China Code for standard for soil test method 1999), this humidification method can meet the requirement of uniform water distribution in the test samples. However, as the triaxial test samples have large volumes, a large quantity of dripping water is needed. To prevent damaging the soil structure for excessive water, we select different positions for dripping and circulating for a certain time interval when dripping.

Burying Method

The burying method was rarely used in previous experimental studies. The specific approach is to bury the loess samples into the soil with basically the same target water content. Under the diffusion, it makes the loess samples reaching to the target water content. This is a humidification method under the natural conditions. This method realizes the humidification only through water migration using the humidification process under the natural state but without changing the structure of the loess samples during the humidification process.

To simplify the test operation, the authors attempted to make the following improvement: wrap the loess samples with filter paper and bury them into the sawdust with proper water content for humidification. We buried the intact loess samples with initial water content of 13.9 %, in-situ void

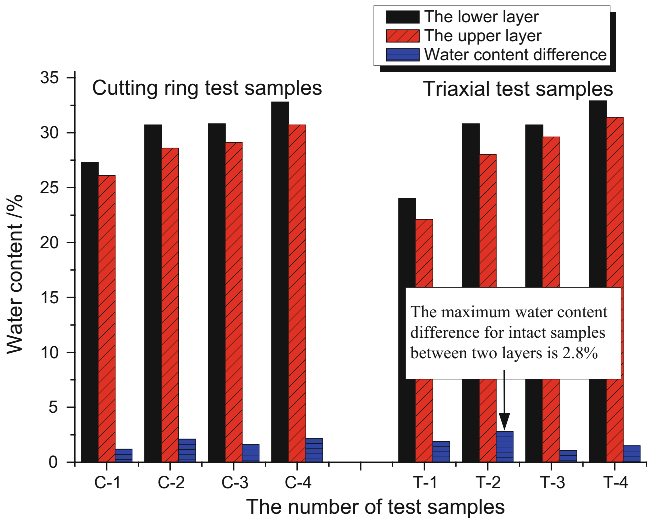

Fig. 1 Water content difference between samples in upper and lower layer

ratio of 0.895, specific gravity of soil particles of 2.69 into two layers of sawdust with the same water contents with a vertical elevation difference of 15 cm between the upper layer and the low layer. We measured water contents from the surface of the test samples and the soil core respectively after the samples are buried and carried out water content comparison for the upper layer and the lower layer soil samples (Table 2). The results indicate that the uniformity of water contents in the two layers of loess samples meet the requirement, however, because the samples are buried for a long period, under the gravity, water is transferred, resulting in dry sawdust in the upper layer and humid sawdust in the lower layer in the humidifier. The water content of the loess samples buried in the upper layer is less than that in the lower layer. The maximum water content difference for samples in two layers is 2.8 % (Fig. 1), which is beyond the regulation requirement (China Code for standard for soil test method 1999). As a result, two layers of loess samples cannot be used for carrying out experiment as the test samples with the same water content. Therefore, it is required that the loess samples should be buried in the same level height for the burying humidification method to ensure that each loess sample have the same water content. During the burying method tests, the maximum water content of the triaxial test samples is 32.9 % and the saturation is 96.5 %. Therefore, the burying method can humidify the intact loess samples into the saturated state.

Steaming Method

The steam humidification method is a new method that was suggested in recent years but it is rarely used at present. The basic idea of the steam humidification method is to carry out even pre-wetting through the uniformity of the steam. We cut the loess samples first, carry out steam humidification, and then use preservative film to wrap the loess samples after humidification and put them into the humidifier to stand still until the water content inside the loess samples is uniformly distributed.

In case there is no special equipment such as the steam tank, the steam can also be provided by a pressure cooker. When testing, we put the loess samples into a pressure cooker and open the pressure valve of the pressure cooker to make the vapour in a non-pressure state (with respect to atmosphere). The length of time for providing the steam has no major impact on the effect of humidification, as it generally takes 10 min. After humidification the samples are set on standing for 8 h to ensure that the water ratio is evenly distributed in the loess samples (Wang et al. 2010).

Taking the 10 min non-pressure humidification as an example (Table 3), the test results indicate that when carrying out humidification for the unsaturated loess using the non-pressure steam the humidification rate is about 20 % of the initial water content and there is almost no change in dry density before and after loess sample humidification (Wang et al. 2010), therefore the non-pressure state humidification does not have impact on the soil structure.

Table 3 Steam humidification method effect test (according to Wang et al. 2010)

Initial water content (%)	Initial dry density ($g \cdot cm^{-3}$)	Dry density after humidification ($g \cdot cm^{-3}$)	Water content (%)		Differential water content (%)	Average water content after humidification (%)	Increased water content (%)
			Soil surface	In the soil			
14.5	1.25	1.25	17.3	17.1	0.2	17.2	2.7
15.0	1.25	1.25	17.7	17.5	0.2	17.6	2.6
21.4	1.35	1.34	25.6	25.2	0.3	25.4	4.0
21.6	1.34	1.34	25.7	25.2	0.5	25.5	3.9
25.9	1.28	1.28	31.9	31.4	0.5	31.7	5.8
25.8	1.28	1.29	31.6	31.2	0.4	31.4	5.6

Conclusions

1. For using the same test samples to achieve the same pre-set humidity, setting the loess samples on standing for 24 h for the pre-wetting method can make the water distributed uniformly in the samples, while setting the loess samples on standing for 10 days in the burying method can make water distributed uniformly. Likewise, setting the loess samples on standing for 8 h using the steaming method can make water distributed uniformly in the samples.
2. The idea of the pre-wetting method is simple, but it requires repeated dripping for humidification, and a frequent manual operation.
3. The burying method can carry out humidification for a large range of water contents. The saturated soil samples can be obtained by humidification but not using the pre-wetting method and the steaming method. However burying method requires longer time for water to be distributed uniformly and in-situ humidification. It also requires that the loess samples with the same water content be buried in the same level/height.
4. The operation of the steam humidification method is the most simple and convenient, it requires the shortest time for humidification but the volume of loess samples for humidification is limited. It is fitting for cutting ring test samples but not for loess samples with large volume. When the target water content is large, steam should be used repeatedly for humidification.

When carrying out the tests, we select an appropriate humidification method according to the type of test samples, requirements on the humidification speed as well as the specific test conditions.

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