

# The research of collapsibility test and FEA of collapse deformation in loess collapsible under overburden pressure

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**Abstract.** The collapsibility test in field may have huge error with computed results <sup>[1-4]</sup>. The writer gave a compare between single-line and double-line method and then compared with the field's result. The writer's purpose is to reduce the error of measured value to computed value and propose a way to decrease the error through consider the matric suction's influence to unsaturated soil in using finite element analysis, field test was completed to verify the reasonability of this method and get some regulate of development of collapse deformation and supply some calculation basis of engineering design and forecast in emergency situation.

## 1. Introduction

China had a criterion to describe the loess strength of collapsibility, coefficient of collapsibility. The loess can be divided into two different kinds of soil based on its coefficient of collapsibility. When it is smaller than 0.015, we called it loess non-collapsible under overburden pressure. Its weight cannot supply enough pressure that it will not cause a huge collapse when water appeared. But when the coefficient is larger than 0.015, it will bring a huge collapse deformation under the dual-impact of water and pressure, we called it loess collapsible under overburden pressure <sup>[5]</sup>.

The loess collapsible under overburden pressure is widely distributed in Qinghai province, China. It has typical large void ratio and water sensitivity, which make it very unstable. Its collapsibility may cause irregular settlement of foundation and lead to serious disaster <sup>[6-8]</sup>.

With the development of science in unsaturated soil, matric suction had been proved to have some effect to properties of soil include collapsibility <sup>[9-10]</sup>.

To decrease the error of measured results to computed results, the influence of matric suction must be considered, which has been proved to have a great influence on the properties of unsaturated soil. As the matric suction's measured will cost lots of resource, the author command to use numerical value simulation to simulate the matric suction change caused by seepage. In this experiment, we do a field test-water immersion test of foundation pit and a finite element analysis that consider the influence of seepage, which can change distribution of pore water pressure and lead to varies of matric suction.

## 2. Water Immersion test of loess pit

The water immersion test was launched in Xining and it adopt the levelling instrument in settlement measurement to obtain vertical settlement.



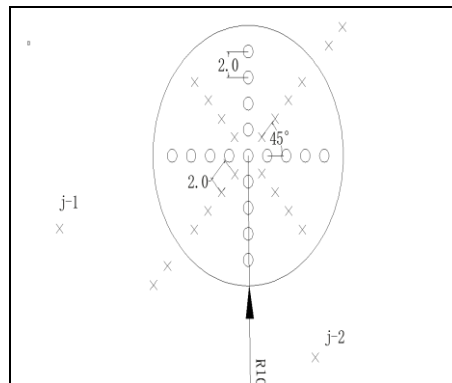


Figure1 the arrangement of marks. Include the shallow marks and deep marks. The shallow marks can reflect the surface deformation

Through the data get from the field test, the writer chose the deformation of central point to reflect the development of the collapse deformation.

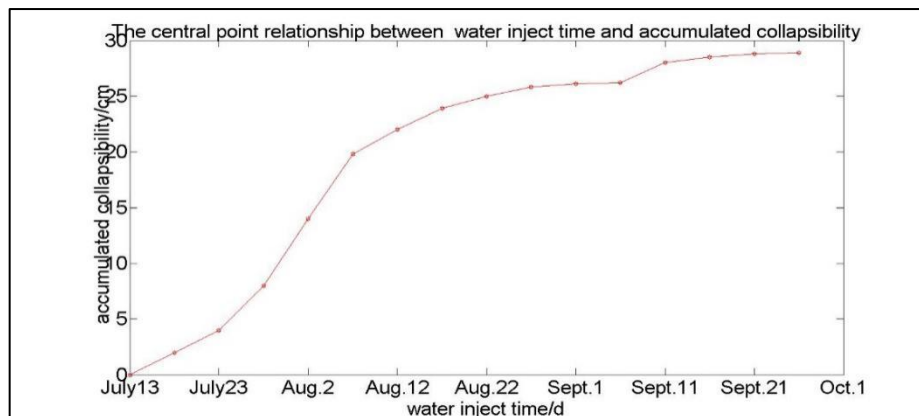


Figure2 relationship between inject time and collapse deformation.

The initial collapse time is at the beginning of 4 days and that proceed lasted for 72 days. At the beginning time, the development of collapse is slowly because it need some time for water permeate the soil, as the time goes by, about 4-7days according to reference <sup>[11-12]</sup>, the water content is increase continuous and that caused the matric suction decrease and the loess' structure got damaged by the water and pressure's dual-functions, at this stage, collapse develop very quickly. In the third stage, most deformation has completed and it became more softly. The criterion of stop inject water is that the average of last 5 day's collapse deformation are less than 1mm/d. When stopped the inject, the collapse appears again, the loess got further damaged by the increase of the matric suction and it accounted almost 9.2 percent of general deformation. The central points of pit have the largest deformation, 0.283m. Overall, with the increase of time, the variation characters of the development of collapse deformation is slow-fast-slow.

### 3. Indoor test

As the field test cost a lot of resource of material and human, the indoor test was developed to forecast the field test result. The writer tested the coefficient of collapsibility, which can join the calculation of collapse deformation.

$\rho$	$\omega$	WL	C	$\phi$	$\mu$
1.56g/cm <sup>3</sup>	11.4%	10.4	25kpa	21°	0.3

In that test, the writer compared the double line method and single line method to get the coefficient of collapsibility.

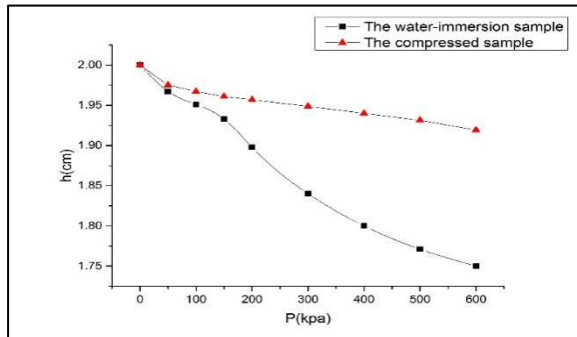


Figure3 the double line result

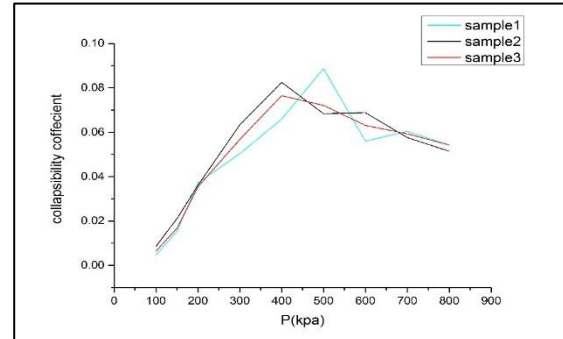


Figure4 the single line result

The coefficient of collapsibility measured by the single line method is closer to actual situation, because it added the water until the soil not emerge deformation under the maximum load, it simulated the real construction situation. The error of these two ways may be caused by the special structural property of Loess. The computed result is multiplied by the thickness of loess with coefficient of loess, we get more reasonable result through single line method, 0.301m. Difference between the outdoor test and computed result is because the indoor test can not consider the complex situation in field test.

#### 4. The FEA of collapse deformation

The author considers the influence of matrix suction through the finite element analysis.

GeoStudio is a professional, efficient and powerful calculate software, it has application in geological engineering and geological environment simulation. It is developed by rock and soil community famous professor Fredlund, it began to develop in 1970s, after 40 years of improvement, it has become a professional software for geotechnical engineering simulation. In this paper, the coupling SEEP/W module and SIGMA/W module are used to model and analysis the actual working conditions.

The SEEP/W module simulates the seepage after water immersion, which can obtain the distribution of pore water pressure and then influence the matrix suction, that change will alter loess' character. The SIGMA/W module will simulate the collapse deformation of loess after immersion, its water pressure and pore water pressure distribution will be obtained by coupling SEEP/W module.

##### 4.1. Simulate the seepage consider the influence of matrix suction

The soil water characteristic curve is based on the data point measured by test and the permeability coefficient is predicted by the soil water characteristic curve based on VG model.

$$k_w = k_s \frac{[1 - a\psi^{n-1}(1 + (a\psi^n)^{-m})]^2}{(1 + a\psi^n)^{m/2}}$$

$$a = \frac{1}{\psi} (2^{\frac{1}{m}} - 1)^{1-m}, \quad n = \frac{1}{1-m}$$

In that formula,

$k_w$  refers to unsaturated permeability coefficient,

$k_s$  refers to saturated permeability coefficient,

$a$ 、 $m$ 、 $n$  are parameters, among them,  $m$  is related to the slope of SWCC

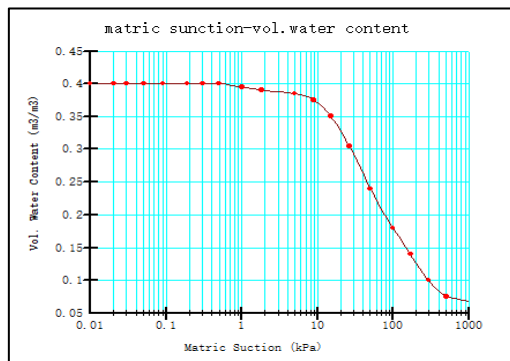


Figure5 SWCC

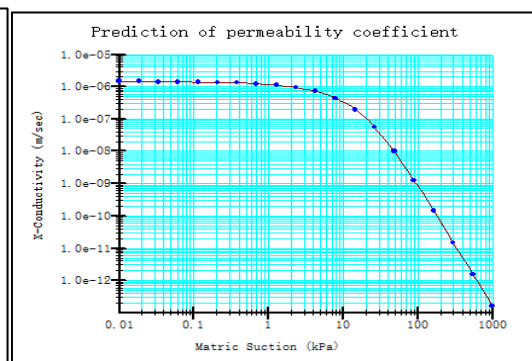


Figure6 prediction of permeability coefficient

Then get the seepage and distribution of pore water pressure:

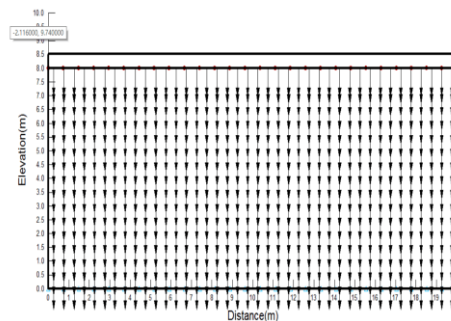


Figure7 Final seepage condition

#### 4.2. Simulate the final collapse deformation

Select Deformation as analytical type, initial pore pressure conditions are obtained from SEEP/W analysis results. On this basis, with the SEEP/W boundary condition unchanged, the displacement of X and Y is 0 at the bottom of soil, and the left and right boundaries' X displacement is 0.

And then calculate collapse deformation in SIGMA/W, the results are as follow:

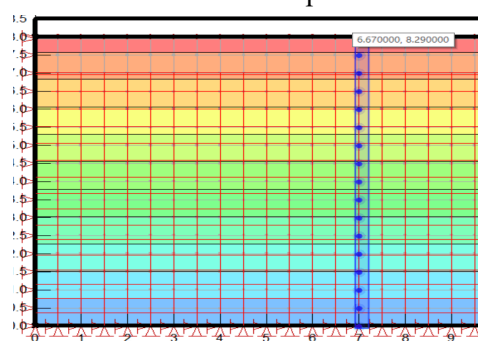


Figure8 Choose the central point

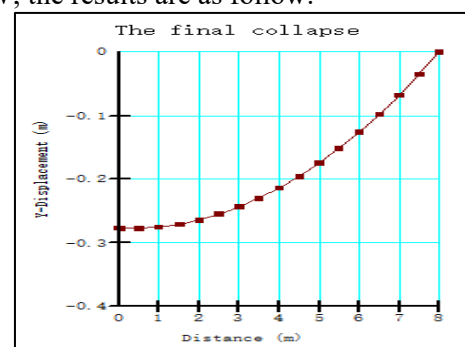


Figure9 Final collapse deformation

The reason to choose the central point of pit to see the collapse deformation is because the central point has the largest collapse deformation in field test according to references <sup>[13-15]</sup>, the simulate collapse deformation is 0.277m.

## 5. Conclusions

(1) The water immersion test shows that the loess collapse deformation has the character of slow-fast-slow, which have some function in forecast loess' collapsibility.

(2) Difference between the outdoor test and computed result is may cause by complex situation in field test, which not consider in computed results.

(3) The simulated collapse deformation is 0.277m, which is smaller than the measured value of 0.283m. Considering the influence of matric suction on unsaturated loess, the result is very close to the field test and it have more basis and more accurate than the computed ways.

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