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Y.J. Ji, X. Li*

Key Laboratory of Urban Underground Engineering of Ministry of Education, Beijing Jiaotong University, Beijing, China
Corresponding author: ceXuLi2012@163.com

The equilibrium time and deformation characteristic of sulfate saline soil in 1D saline expansion test

Abstract. The salt expansion disease is serious for the soil containing sodium sulfate in cold regions. This paper carried out one-dimensional swelling tests of saline soil, and numerical cooling tests of soil to explore the stability time of salt swelling deformation and determine the standard procedure of the salt swelling test method. The test results demonstrate that: (A) the temperature equilibrium and crystallization process are almost completed simultaneously in the one-dimensional (1D) salt expansion test; (B) Referring to the standard of consolidation test, a standard that the expansion rate is less than 0.02mm/h can be used in the salt expansion test; (C) The required time for temperature equilibrium of soil is quadratic to sample size and is much faster with liquid bath condition comparing to gas bath condition. Because the deformation and temperature are synchronized, the deformation stabilization time of different size samples in different cooling media is recommended.This can provide a reference for the deformation equilibrium time of the salt swelling test.
Keywords: Sulfate, Saline soil, Salt expansion, Cooling test, Stabilize time.

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Introduction

When the soil's soluble salt content is greater than or equal to 0.3%, and the sagged salt expansion, or corrosion occurs, the soil is referred toas saline soil [1]. Saline soil is widely distributed in Northwest China [2]. When the environmental temperature decreases, the salt crystallizes in sulfate saline soil and salt swelling happens.The salt will crystallize and dissolve driven by the temperature difference between day and night, and it is easy to cause engineering diseases in the continuous salt swelling-collapse process. To more clearly understand the effect of temperature on the salt expansion process, Wan et al. [3-6] conducted salt expansion experiments with different cooling rates. However, in a closed system, the salt expansion is driven by temperature, and how much crystallization is completed when the temperature is stable, and whether the salt expansion is synchronized with the soil temperature is unclear. Given the cooling conditions and sample size, what is the temperature stabilization time of the sample, the temperature stability of the sample, and the stability standard of deformation, there is no specific specification. The main purpose of this article is: (a) Determining whether the deformation stabilization time and the temperature stabilization time of saline soil are synchronized. (b) Determining the deformation stabilization time of the salt expansion test.

Methods

2.1 1D salt expansion test of big size samples

Test device andTest procedure:

The test equipment is the salt expansion test barrel, DT85, PT100 temperature sensor, and the digital dial indicator.

The soil sample is compacted in six layers, and two PT100 sensors are embedded in the center of the sample, and the temperature of the center point of the soil is collected every 1 minute through DT85. A digital dial indicator is installed on the top of the sample and set to collect data every 1 minute. The test box can realize the automatic constant temperature function. The test takes 25 ℃→12 ℃→8 ℃→

4℃ as the cooling gradient, the cooling rate of the incubator is 1 ℃/min, and the sample is cured at 25 ℃ for 12 h, and then cooled to 12 ℃, after the constant temperature for 24 h, decrease to the next level of temperature at the same cooling rate and so on.

2.2 1D salt expansion test of small size samples

Test device andTest procedure:

Test equipment is the cutting ring with a diameter of 6.18 cm and a height of 4cm, the Vernier caliper, and the C4-600 programmable thermostat.

The test chamber can automatically adjust thetemperature change according to the set cooling program. The test uses 25 ℃→12 ℃→8 ℃→4 ℃→1 ℃ as the cooling gradient, the cooling rate of the incubator cooling stage is set according to the test plan, the sample is cured at 25 ℃ for 24 h, and the temperature is reduced to 12 ℃ at the set cooling rate, after a constant temperature of 24 h, it will also drop to the next level of temperature at the set cooling rate and so on. At each level of constant temperature, it will be measured by Vernier calipers every certain time (usually 2-4 h).

2.3 Numerical simulation method

According to the soil type, dry density, and moisture content of the salt expansion test sample, refer to relevant literature[7], determine the parameters of the model, and determine the heat transfer coefficient based on the cooling method. The dry density is 1700 kg/m^3.The sample's moisture content is 15.50%.The thermal Conductivity and the Specific heat capacity are 0.8 W/(m·K) and 1600 J/(kg·K). In the air bath conditions, the Heat transfer coefficient is 5 W/cm^2·K. In the liquid bath conditions, the Heat transfer coefficient is 200 W/cm^2·K.The numerical simulation cooling process is consistent with the actual soil sample cooling process.

Results and Discussion

The test results of the 1D salt expansion test are shown in Figure 1 and Figure 2.

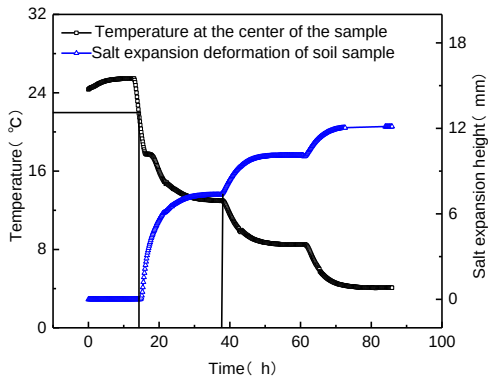

Figure 1. Variation of temperature at sample time center and sample height (big size sample)

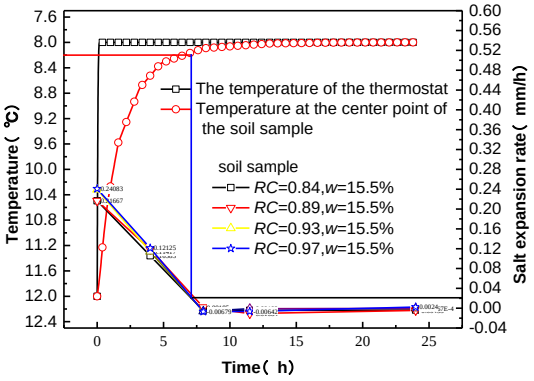

Figure 2. Curve of soil sample swelling rate versus at 8℃ (small size sample)

The test results in Figure 1 demonstrate that the salt expansion and temperature equilibrium are occurring co-transcriptionally.

Because the salt swell test is similar to the consolidation test, the deformation stability standard of the salt swell test can be formulated by analogy with the consolidation test. Therefore, the stability standard of the salt expansion test is: the deformation per hour at each temperature is not more than 0.02 mm or the temperature is stable for 24 hours. Figures 2 shows that the soil sample is deformed and stabilized at 12 °C and then cooled to 8 °C. Taking the temperature completion rate of 95% (ie 8.2 °C) as the temperature stability standard, and taking the salt expansion rate less than 0.02 (mm/h) as the deformation stability standard, the temperature curve, and the salt expansion rate curve under this stable standard can be obtained. At one point, this time point is the salt swelling and deformation

stability time. The time when the temperature completion rate reaches 95% is the same as the deformation stability standard.

When the cooling conditions are the same and the sample size is different, the temperature gradient inside the sample is different, and the temperature equilibrium time is also different. The effective radius r_s characterize different sizes, and its expression is:

$$r_s = 3V / S \quad (1)$$

where V is the sample volume; S is the sample surface area.

The temperature completion rate of 95% is taken as the sample temperature's stability standard comprehensively considering the test efficiency and the test accuracy. As the temperature stabilization time is minimal when the temperature difference differs, the average value of the temperature stabilization time at all levels is taken as the temperature stabilization time of the sample. The relationship between the sample's temperature stabilization time and the effective radius is shown in Figure 3.

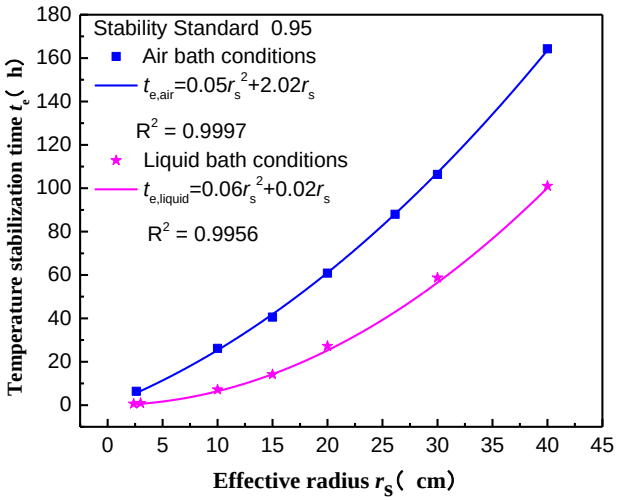

Figure 3. The relationship between the temperature stabilization time of the sample and the effective radius of the sample

The list of deformation stability time of samples under different sizes and different cooling methods are shown in Table 1.

Table 1

List of deformation stability Time

Experiment type	Sample size(D,H)	Equivalent radius (cm)	Cooling method	Balance time (h)
Confined 1D salt expansion test	6.18 cm, 4 cm	2.61	Gas bath	7
	17.9 cm,11.59 cm	7.59		20
	61.8 cm, 40 cm	26.1		88
3D salt expansion test	3.91 cm, 8 cm	2.37	Liquid bath	0.5
	5 cm, 10 cm	3		0.7
	50 cm, 80 cm	28.56		46

Conclusion

Through the laboratory and numerical tests, the following conclusions are obtained:

1. In the sulfate saline soil, the salt crystallization, salt expansion, and temperature equilibrium are occurring co-transcriptionally.

2. The salt expansion and deformation stability standard can be used as that the expansion rate is less than 0.02 mm/h, and the temperature stability standard can be used as that the temperature completion rate reaches 95%.

3. The temperature stabilization time of the sample has a parabolic relationship with the effective radius of the sample.

4. Comparing to an air bath, the liquid bath can greatly reduce the equilibrium time.

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Y.J. Ji, X. Li

Білім министрлігінің қалалық жерасты инженериясының негізгі зертханасы, Бейжің Цзяотун университеті, Пекин, Қытай

1D тұздан ісіну сынағындағы сульфатты-тұзды топырақтың тепе-теңдік уақыты мен деформациясы

Аңдатпа.Тұздан ісіну мәселесі натрий сульфаты бар топырақ үшін салқын аймақтарда ауыр болып келеді. Бұл жұмыста тұзды топырақтың бір өлшемді ісінуі, қаныққан натрий сульфаты ерітіндісінің кристалдану сынағы және топырақтың сандық салқындату сынақтары жүргізіліп, тұздан ісіну деформациясының тұрақтылық уақытын зерттеп, тұздан ісінуді сынау әдісінің стандартты тәртібі анықталды. Өткізген сынақ нәтижелері: (A) температураның тепе-теңдігі және кристалдану процесі бір бағыттағы тұздан ісіну сынағында бір мезгілде аяқталады; (B) консолидация сынағының стандартына сілтеме жасай отырып, ісіну жылдамдығы 0,02мм/сағ-тан аз болатын тұздан ісіну стандартты сынағында қолдануға болады; (C) топырақтың

температуралық тепе-теңдігінің талап етілетін уақыты квадраттық өлшемге сәйкес келеді және сұйық орта жағдайымен газ ортасының күйімен салыстырғанда әлдеқайда жылдам болады. Деформация мен температура синхрондалғандықтан, әр түрлі салқындатқыш ортадағы әр түрлі өлшемді үлгілердің деформацияны тұрақтандыру уақыты ұсынылады. Осы тұжырымдардың негізінде бір өлшемді тұздан ісіну сынау әдісінің стандартты процедурасы ұсынылады, онда сынақ жабдықтары, сынақ процесі, тұздан ісінудің деформациясын тұрақтандыру уақыты және мәліметтерді өңдеу әдісі келтірілген.

Түйін сөздер: сульфат, тұзды топырақ, тұзды ісіну, уақытты тұрақтандыру, тәжірибе әдісі.

Яньцзе Цзи, Ксу Ли

Ключевая лаборатория городского подземного строительства Министерства образования, Пекинский университет Цзяотун, Пекин, Китай

Продолжительность равновесия и деформационные характеристики сульфатно-засоленного грунта: набухание при одномерном испытании

Аннотация. Проблема солевой экспансии является очень серьезной для грунтов, содержащих сульфат натрия в холодных регионах. В статье представлены результаты, связанные с испытаниями на одномерное набухание засоленной почвы, испытанием на кристаллизацию насыщенного раствора сульфата натрия и численными испытаниями на охлаждение почвы для изучения времени стабильности деформации набухания солевых грунтов и определения стандартной процедуры метода испытания на набухание солевых грунтов. Результаты испытаний показали: (A) процесс температурного равновесия и кристаллизации почти завершаются одновременно при одномерном испытании на солевое расширение; (B) стандарт испытания на уплотнение, согласно которому скорость расширения составляет менее 0,02 мм/ч, может использоваться при испытании на солевое расширение; (C) требуемое время для температурного равновесия почвы квадратично по отношению к размеру образца и намного быстрее в условиях жидкой среды по сравнению с условиями в газовой среде. Поскольку деформация и температура синхронизированы, рекомендуется время стабилизации деформации образцов разного размера в разных охлаждающих средах. На основе этих результатов предлагается стандартная процедура метода одномерного испытания на солевое расширение, в котором приводятся испытательное оборудование, процесс испытания, время стабилизации, деформации солевого расширения и метод обработки данных.

Ключевые слова: сульфат, засоленный грунт, солевое расширение, время стабилизации, экспериментальный метод.

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Information about authors:

Яньцзе Цзи, - Бейжің Цзяотун университетінің құрылыс бөлімі, Пекин, Қытай.
Ксу Ли - Бейжің Цзяотун университетінің құрылыс бөлімі, Бейжің, Қытай.
Yanjie Ji - Department of Civil Engineering, Beijing Jiaotong University, Beijing, China.
Xu Li - Department of Civil Engineering, Beijing Jiaotong University, Beijing, China.