A Development of Instrument for Measuring Soil and Rock 's Expansion Force

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Abstract

In order to accurately measure the three dimensional swelling stress of the bentonite's sample and the expanded rock's sample, to discuss and analyse the effects of temperature, strain and initial pressure on the bentonite's sample and the expanded rock's sample, we developed this kind of instrument. The instrument is mainly composed of a primary frame, three sets of counter force frame "up and down ", "left and right "as well as"front and back",temperature control component, test-measurement component "load sensor" and "a dial indicator", osmosis system, reading device, etc. The instrument can accurately measure the mechanical parameters of the sample, such as the axial expansion force and the radial expansion force, meanwhile, the instrument can ensure high testing accuracy and unfailing measurement result, which can provide a scientific and reasonable reference for scientific research and engineering application.

Keywords

Bentonite; Expanded rock; Three dimensional swelling stress.

1. Introduction

Expansive soil and expansive rocks are a very special research field in modern engineering geology and research of soil mechanics research. Expansive soil is a special kind of unsaturated soil, which has characteristics of swelling and softening after absorbing water, shrinking and cracking as well as deforming repeatedly after losting water .At the same time, it also has the characteristics of super consolidation and multiple fracture[1].At present, the domestic and foreign scholars had done a lot of researches on swelling capacity of expansive soil and have achieved a great number of useful research results[2-10].But the research results about the relationship between the expansion force and the deformation of expansive soil are few.

Existing research shows that the main indicators of expansive soil swelling are the initial water content and dry density. Among them Luorong Tan and Lingwei Kong studied on compacted expansive soil samples of Jingmen [11] ,they summarized that the effects of dry density, saturation and water content to swelling power. Xianmin Li and his colleagues have investigated that the engineering deformation characteristics of compacted expansive soil in Shaoyang, Hunan [12] ,They fited that the curve of expansion force and the changeable regulars of the expansion volume were all exponential. Xie Yun , as well as colleagues, had done an three direction expansion force test with the Nanyang expansive soil in the Middle Route Project Of The South To North Water Transfer Project by using their three direction expansion[2] .They obtained the formula of the expansion force to control the deformation.

The expansive soil is different from the expansive soil and soft rock. Not only it has the characteristics of water swelling, softening, shrinkage of water loss, but also has the characteristics of disintegration and cracking [13].The issue of expansive rock is one of the most complex global

research topics in the field of engineering geology and rock mechanics [14].In engineering practice, the problem about how to effectively deal with the kind of rock has been plagued by engineers. It is often called "geotechnical engineering's Cancer" by enginees [15].At present, our country is concerned about the evaluation method and the standard of expansive rock, there is still no national industry standard form. At the same time, the research on the expansive deformation constitutive relation of expansive rock has yet to be further strengthened [16].

China is one of the most extensive areas country of expansive soil and expansive rock in the world[17] .There is a large number of constructions suffered the expansive soil's and expansive rock's expansibility that caused huge damage, such as retaining wall, pile foundation, underground pipe, culver etc, in every year, which has caused great economic losses[18].Therefore, it is of great practical significance to study the expansion properties of the expansive soil and the expansive rock to the exploration, design and construction of the project.

At present, there is a test device for measuring the expansion stress of expansive soil in the three direction. But there are many defects in the existing measuring instruments, such as the three direction expansion and contraction instrument developed by the Northwest Research Institute of the Ministry of Railways. The expansion stress and deformation of X, Y and Z directions can be measured by the instrument. Although The Logistics Engineering Institute of the instrument has been improved, but there are still many problems such as a poor contact between the adjusting screw and the piston pressure, water leakage, poor contact, measurement results error, slow heating, pressure piston stuck etc. Then Hua Zhang, Shanxiong Chen, Wenlong Hu[19] , China Three Gorges University, made a further improvement. However, the improved instrument has no heating function, it can not achieve the drying shrinkage of the sample as well as measuring of the expansion stress of the specimen at a certain temperature, also there is no drainage function as well as it has a long time by water infiltration. For the expansive rock experiment, our country does not have the special test equipment, we often use the consolidation apparatus of geotechnical test apparatus to do the test - the measurement of inflation index. In view of so many deficiencies in the device to test the expansive soil ,and there is no special instrument to test the expansion performance of the expansive rock, so the new type of rock and soil expansion stress measuring instrument were developed.

2. The composition of the instrument and the principle of the experiment

The instrument is mainly composed of a sample box, an expansion stress, a strain measurement system, a temperature control system, a seepage system and so on. Fig. 1 Schematic diagram of the instrument structure. Fig. 2 The top view figure of the instrument.

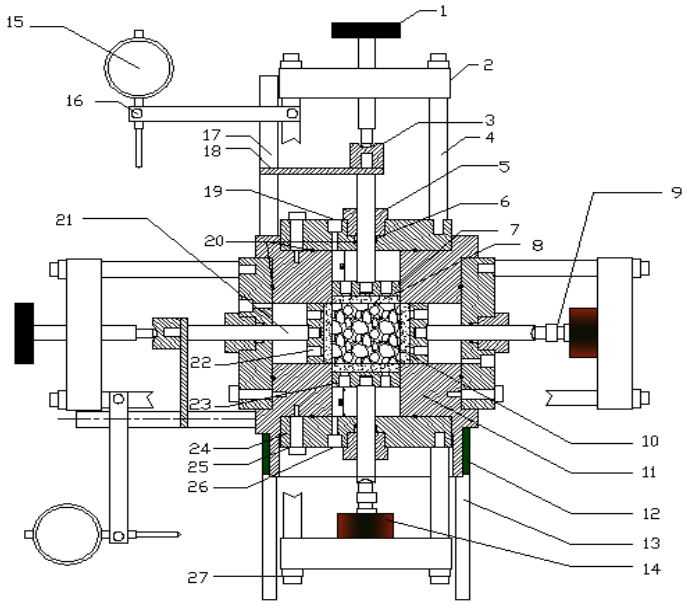

Fig. 1 Schematic diagram of the instrument structure.

(1) Adjusting bolt (2) Crossbeam (3) Positioning cap (4) Pull rod (5) Seal nut (6) Pressure ring (7) Compression piston (8) Permeable plate (9) Ddowel head (10) Again sample box (11) The body frame (12) Heater ring (13) Support rods (14) The load cells (15)Displacement gauge (16)The clamp of displacement gauge(17)The support of displacement gauge (18) Contact plate of the displacement gauge (19) Inlet hole (20) Sealing ring (21) Piston rod (22) Piston plate inlet apertures (23)Bearing a piston (24) Sealing cover (25) Fastening bolt (26) Drain hole (27) The exclusion cap

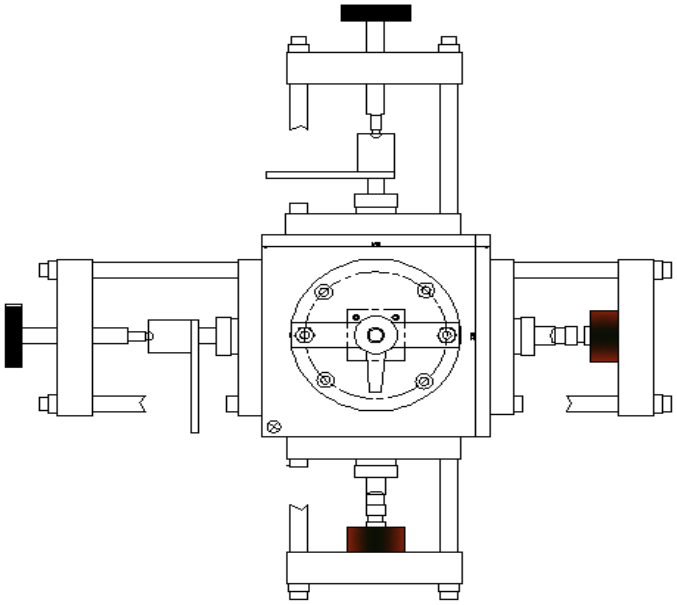

Fig. 2 The top view figure of the instrument.

2.1 Expansion stress and strain measurement system.

The main measurement device of the expansion stress is mainly made up of three reaction force structures. Three sets of reaction frame are respectively provided with a sealing cover, sealing ring, a piston rod, a compression piston or a pressure piston , sealing cap, permeable plate, a positioning cap, displacement micrometer touch panel, double rods, beams, adjusting bolts, load sensor, power head, a fastening bolt etc. The sealing cover is used to fix rod, double rod, displacement gauge support, beam, adjusting bolt and nut sealing etc. Mobilize the adjusting bolt can make closer contact between the permeable plate, compression piston or piston pressure and sample .Three load sensors are respectively installed in the three direction of the anti force frame beam, through the load sensor can measure the expansion stress of the specimen can be measured .

Strain measuring device is mainly composed of displacement gauges, fixture structures of the displacement gauges, support structures of displacement gauges, contact plate structures of the displacement gauges and so on. The displacement gauge are fixed by itselves' fixture structures and support structures. The position of compression piston can be changed by regulating adjusting bolt, measuring displacement by the amount of contact plate with displacement gauge as well as measuring the expansion stress which corresponds to the sample deformation by load sensor, the purpose is to make sure the relationship between the stress and the strain.

2.2 Infiltration system

Infiltration system mainly consists of two parts: water injection system and water storage system.

Water injection system

The water injection system is mainly composed of permeable pipe, osmotic pressure gauge, osmotic pressure valve, water inlet valve of seepage pipe, water inlet valve of water discharge pipe ,tempera -ture display instrument and so on. See Fig. 3

Water storage system

The water storage system mainly consists of storage space , permeable stone, permeable plate, water inlet , water outlet and so on. The water storage space is composed of a compression piston or a pressure piston, a sealing cover and a main body frame, and the height is 2.5cm, which can be used for storing water when water is injected. Permeable stone and permeable rock plate dimensions are 40mm × 40mm, and covered with 1mm on permeable microporous pad for drainage when water samples and expansion of steel and alloy materials sealing cover plate disposed inlet holes water hole, and the "O" ring seal. The materials of production of it is stainless steel materials, the system will not rust for a long time underwater. Physical diagram see figure 4.

2.3 Temperature control system

Temperature control system consists of heating the ring and reading instrument components. Heating ring piston is stalled on bottom of the panel, it is showed and controlled by temperature secondary instrument.

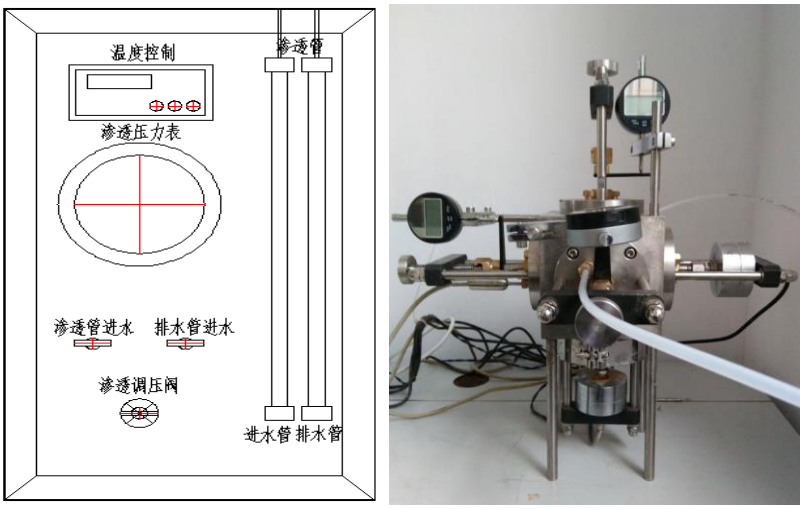

Fig. 3 Schematic diagram of system penetration and the main body structure of the instrument.

3. The characteristics and advantages of measuring instrument

The experimental instrument has the function of measuring the expansion stress of expansive soil and expansive rock, and the concrete analysis is as follows:

Expansion stress can be used to measure three-expansive soil and expansive rock under normal temperature conditions;

2.Swelling shrinkage can be achieved within the loop experimental apparatus of sample;

3..The use of high-precision load sensor and automatic data collection terminal, the three-dimension -al swelling stress of expansive soil's and expansive rocks' samples were expanded to intelligent measurement;

Using osmotic systems with the method of pressure injection mode to make the sample soaking quickly and equably, shorten experiment time, make water drainage easy as well as adjusting the pressure of water injection.

5.The load sensor is moved outside the instrument to prevent the load sensor from the influence of the water temperature environment, extending the service life and the accuracy of measuring of the load sensor.

6. Temperature can be controlled by heating devices to measure expansion stress of the sample under changeable degrees and study the relationship between expansion stress and temperature.

4. The main technical parameters

The main technical parameters of the instrument are shown in Table 1:

Table 1 The main technical parameters of the instrumen

Technical parameters Name	parameter
Body frame size	160mm×160×160mm
Sample size	40mm×40×40mm
Inlet and outlet holes	Aperture: Φ=4mm
Heating cup	R=55mm, L=345.58mm
Osmotic pressure head	0~1MPa
Control precision error	±0.4%F.S
Water penetration measuring Volume change sensor measurement accuracy error	0~50cm^3 ±0.1%F.S
Temperature range	Room temperature~90℃
Control error	±0.5℃（Secondary instrument digital display）
Vertical load σ_1	0~5KN
Load sensor measurement accuracy error	±0.2%F.S (Secondary instrument digital display)
Horizontal σ_2 Force	0~5KN
Load sensor measurement accuracy error	±0.2%F.S (Secondary instrument digital display)
Forward and backward σ_3 Force	0~5KN
Load sensor measurement accuracy error	±0.2%F.S (Secondary instrument digital display)
The vertical displacement amount σ_1	0~10mm
Dial gauge measurement resolution	0.001mm
The horizontal displacement direction σ_2	0~10mm
Micrometer resolution measurement uncertainty	0.001mm
Before and after the displacement direction to σ_3	0~10mm
Micrometer resolution measurement uncertainty	0.001mm

5. The specific operation steps of the instrument

Fig.4 Instrument working drawing

The working diagram of the instrument is shown in Figure 6. The specific operation steps are as follows:

1. Sample preparation lofting. The sample was made of the size of swelling rock 40mm * 40mm * 40mm small cube, opening the top of the sealing cover, put the sample in a specimen box. Then put permeable plate above the sample that is close to the sample, cover the sealing cover, tighten the bolt. Mobilize the adjusting bolt initial pressure (you can change initial stress, and investigate the relationship between initial pressure stress and swelling stress). Make the sample, waterproof pad, close contact between pressure and pressure on the piston. then adjust the pointer of displacement indicator to zero.

2. Measuring three-expansion stress. Through the infiltration system, make the device in the upper pipe outlet pipe, the lower pipe inlet pipe, use water injection pressure. Make the sample by water invasion and speed. Through reading instrument connected to the load sensor readout expansion stress of three directions. And record the size of the expansion stress and time. To study the relationship between the expansion stress and time, and then analyze the relationship between the expansion stress and the time in different directions.

3. To study the effect of strain on the expansion stress. By adjusting the screw on each direction, change displacement in the direction of the touch panel, each direction corresponds to the displacement can be tested by the amount of displacement of the dial gauge, then observe the displacement corresponds to the expansion of the force changes, and record results. The test data are sorted out, and the relationship between stress and strain is obtained. Then, the relationship between the stress and strain in different directions is compared and analyzed.

4. To study the effect of temperature on the expansion stress. In the case of other environmental conditions are the same and heat the equipment. Using the temperature control system, through the heating ring, setting the sample heated to design temperatures. To observe and record the change of the samples on each direction expansion stress, Changing the temperature settings, repeat the above steps. Collecting test data and concluded that the relationship between the expansion stress and temperature, as well as the relationship between the expansion stress and temperature in different directions to compare analysis. So we completed the expansion of the expansion of rock stress determination.

5.Stop the test. After the test, the device is placed in a cool ventilated environment, natural cooling process was carried out on the heating ring, then remove the top and a lateral sealing cover, taking out the expansion of rock sample. Cleaning and dry the equipment, installing a cover gasket to ensure the instrument is dry and clean.

6. Test Example

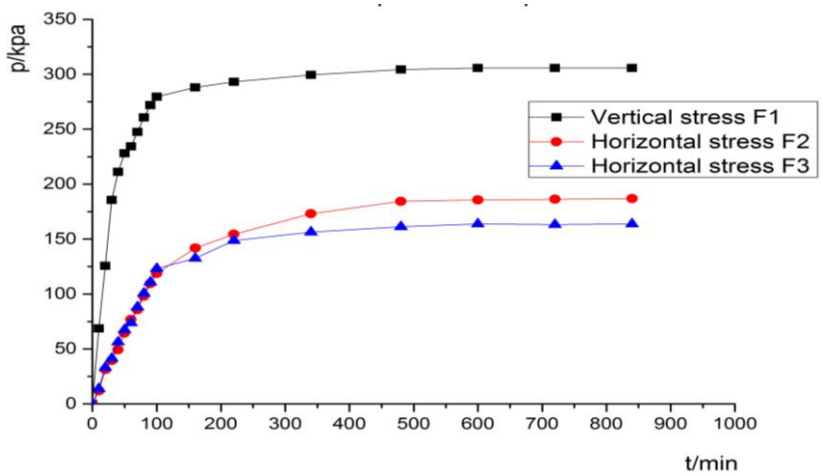

Fig 5 The curve is a relationship about expansion stress and time

The test soil was taken from the slope of Tao Cha diversion channel of the Middle Route Project of the south to North Water Transfer Project. Soil samples is allocated by water content of 16%,dry density of 1.7g/cm^3 soil samples, and sample preparation. When the water pressure is applied to 0.1Mpa, the results can be observed in Figure 5:

1.The expansion of the expansive soil strength increased fastly in the first 100 minutes, reached about 80% of the total expansion force;100 minutes to 500 minutes expansion force slightly lower growth rate, inflation force continue to increase. Roughly after 500 minutes of expansive force gradually achieved stability, and achieved the maximum value. The reason is that in the initial test, the specimen was infiltrated by water and expansion of potential rapid growth, due to the change of the sample volume is restricted, swelling power cannot release, so it was transformed for the rapid growth of the expansion force, expansion force had a linear relation with time. Then, the expansion potential and the expansion force decreased, and the structure of the expansive soil tend to be stable. After a few hours, the samples were basically saturated, the expansion potential and the expansion force were not changed any more, the structure of the soil reached a stable state.

2.Vertical expansion stress in the water after the growth rate slightly faster than the horizontal direction of the expansion stress, both of them reached the steady state roughly at the same time. Eventually the vertical expansion stress was larger than the horizontal stress. The above test results are same with the previous expansion soil test of scholars such as Yun Xie, Zheng Han Chen, Shu Guo Sun [7] , the measured data showed that the instrument has high reliability.

7. Conclusions

The new development of the rock and soil expansion stress measuring instrument is safe and convenient, and the design is fine, with high accuracy, and can ensure the reliability of the remeasurement results. It can be used to measure thermal expansion stress of sample under hot environment. By using high precision load sensor and the high precision displacement gauge, it can accurate measure expansive soil and expansion of rock sample to expand parameters such as stress and strain. The relationship between initial water content, initial stress, strain, temperature, and three - to - expansion stress can be studied by using this device, also the theoretical basis can be provided for the design of expansive rock and expansive soil in the future.

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Study on the characteristics and mechanism of the smooth layer oxidation and acid etching of black shale (41472256)

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