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Study on the Degradation Law of Physical and Mechanical Properties of Granite under the Action of Freeze-thaw Cycle

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Abstract

This study demonstrates the effect on the mechanical properties of granite through the freeze-thaw cycle test method, and investigates the mechanical property parameters and its changing law of the rock samples under different numbers of freeze-thaw cycles. The results show that with the increase of the number of freeze-thaw cycles, the physical property parameters such as mass and longitudinal wave speed of the samples show a tendency of attenuation. Mechanical property parameters such as peak strength and elastic modulus of the specimen also showed a trend of decay.

Keywords

Freeze-thaw Cycles; Physical Properties; Mechanical Properties.

1. Introduction

China has a variety of climate types and a vast area of cold regions. However, when engineering construction is carried out in cold areas, the problem of freeze-thaw cycle of the rock body has become the main problem restricting its safe construction due to the changeable climate and the big temperature difference between day and night. Due to the natural conditions and the geomorphological conditions in which the rocks are located, the internal moisture of the rocks freezes at low temperatures, resulting in the destruction of the rock structure and the creation of tiny pores, the temperature rises, the frost melts, and the moisture continuously penetrates into the new pores, and the cycle repeats itself, forming a process of freezing and thawing. As the internal cracks of rocks expand and increase due to the freeze-thaw action, resulting in the deterioration of physical and mechanical properties, it is easy to induce geohazard events. Therefore, it is of great significance to study the law of deterioration of physical and mechanical properties of rocks under the action of freeze-thaw cycle.

In recent years, many scholars have carried out different types of research in this area, and more systematically explored the effects of freeze-thaw cycles on various physical and mechanical properties of rocks.A.Momeni et al[1] chose three kinds of typical granite to study the deterioration of axial compression, tensile strength and other mechanical properties under the conditions of freezing and thawing; LI Jie-lin et al[2] applied different numbers of freeze-thaw cycles to the granite and conducted the unidirectional compression test to study the evolution of its strength; Gholamreza et al [3] selected five different types of sandstone, through the measurement of longitudinal wave velocity and porosity under different freeze-thaw cycles, the study showed that the longitudinal wave velocity decreases with the increase of the number of freeze-thaw cycles. Song et al[4].concluded through experiments that with the increase of freeze-thaw cycles, the uniaxial compressive strength, elastic modulus, and Poisson's ratio of limestone gradually decreased. Fu Hongyuan et al [5].carried out uniaxial compression tests of silty mudstone samples under different freeze-thaw cycles, obtained the influence of freeze-thaw cycles on the strength characteristics, failure modes and porosity of silty mudstone, and

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further discussed the strength deterioration mechanism of silty mudstone under freeze-thaw cycles.

Whether it is scientific research, or engineering construction, rock freezing and thawing is a common problem of engineering construction is more complex and difficult working conditions. Granite this hard rock is currently China's high-level waste geological disposal of the preferred rock body [6], the study of its physical and mechanical properties and microstructure, on how to safely and stably dispose of this type of rock body is of great significance. In this paper, granite from Xifeng County, Liaoning Province, was selected as the research object, and the freeze-thaw cycling effect on granite quality, longitudinal wave velocity was studied through repeated freeze-thaw tests at different times, uniaxial compression tests on the saturated-treated specimens. Uniaxial compressive strength and other physico-mechanical properties.

2. Materials and Methods

2.1. Specimen Preparation

Permian granite in Xifeng County, Liaoning Province was selected as the research object. The rock was prepared into a cylindrical sample with a height of 100 mm, a diameter of 50 mm, an error of no more than 0.3 mm, and an unevenness of the upper and lower end faces of no more than 0.05 mm. In order to further standardize the error caused by the material of the sample itself, the longitudinal wave velocity and other related physical properties of the sample were tested, and 15 samples with similar physical properties were selected and divided into 5 groups, and each 3 samples were a group for subsequent tests.

2.2. Granite Freeze-thaw Cycle Test Protocol

In this paper, on the basis of referring to the previous test scheme, in order to simulate the outdoor environment more realistically, the freezing temperature of the experiment was -25 °C, the melting temperature was 25 °C, and the number of cycles was set to 5 groups, which were 0, 10, 20, 40 and 60 times, and the freezing and thawing time of each group of samples was 12 h, and one freeze-thaw cycle was 24 h.

In the process of freeze-thaw cycle, the basic physical property parameters of granite samples were obtained by testing the physical properties of quality, longitudinal wave velocity and other related physical properties. The granite specimens undergoing freeze-thaw cycles were placed in a uniaxial compression testing machine (YAW-2000), and the load was increased at a rate of 0.05 mm/min until the specimen was destroyed, the load was removed, and the relevant data were recorded.

3. Results and Analysis

3.1. Changes in Physical Properties

3.1.1. Mass Changes

Figure 1 shows the variation of the average mass of granite samples with the number of freeze-thaw cycles. As can be seen from the figure, with the increase of the number of freeze-thaw cycles, the mass change first increases and then decreases, and the mass decreases when the number of freeze-thaw cycles reaches 40. However, when the freeze-thaw cycle increases sequentially, the mass loss rate decreases first and then increases. This results show that under the action of freezing and thawing, the pores and fractures inside the rock penetrate and expand gradually due to the continuous freezing and expansion of internal water, which leads to the increase of water absorption of the rock, the increase of its mass and the decrease of mass loss rate. With the increase of freeze-thaw times, after reaching 40 cycles, the surface of the rock is more prone to particle detachment and spalling, and the surface spalling amount of the rock

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gradually exceeds its water absorption, resulting in the reduction of rock quality and the increase of its mass loss rate.

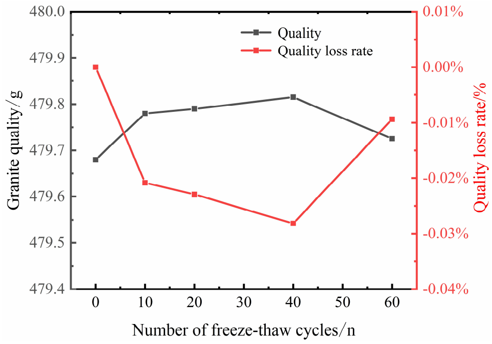

Figure 1. Mass changes

3.1.2. Longitudinal Wave Velocity Variation

Figure 2 shows the longitudinal wave velocity of granite with different freeze-thaw cycles. It can be seen from the figure that the longitudinal wave velocity trend is concave and decreasing, and the decreasing amplitude is gradually slowing down with the decreasing longitudinal wave velocity of granite with the number of freeze-thaw cycles. This is due to the decrease of the gelatinous force between the mineral particles inside the rock under the action of frost heave, and the decrease of the internal compactness, which makes the microstructure of the rock change greatly, and the pores, fissures and other defects inside the rock continue to develop and penetrate, and form a complex fracture grid inside the rock. The ability of water to transmit sound waves is already stronger than that of air, and due to the freeze-thaw effect, more and more water fills the developing pores and fissures, making the sound wave rebound more slowly. The wave velocity of the rock sample gradually stabilized with the increase of the number of freeze-thaw cycles, and its attenuation rate also tended to be flat.

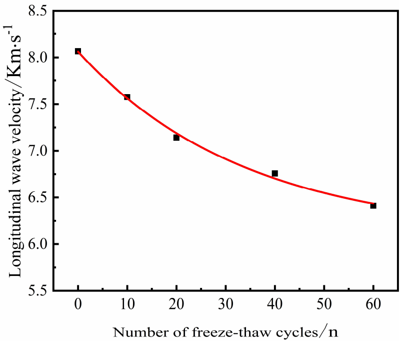

Figure 2. Longitudinal wave velocity variation

3.2. Changes in Mechanical Properties

3.2.1. Stress-strain Curve Analysis

As can be seen from Figure 3, the stress-strain relationship curve of granite under different freeze-thaw cycles includes four stages: compaction, elastic deformation, crack propagation and post-peak failure. The stress-strain relationship between rock samples with different freeze-thaw cycles in the figure during uniaxial compression test is analyzed as follows:

(1) Stage I (compaction stage): The axial pressure increases, and the curve shows the characteristics of upward upturning. In terms of stage significance, this stage is most significant when the number of freeze-thaw cycles reaches its highest.

(2) Stage II. (elastic deformation stage): As the axial pressure continues to increase, it enters the elastic deformation stage, and the curve is basically linear. Because the freeze-thaw action

weakens the characteristics of the specimen itself, and only a small amount of stress is required to cause the deformation of the specimen, the slope of the specimen decreases gradually with the increase of the number of freeze-thaw cycles in the curve.

(3) Stage III. (crack propagation stage): The axial pressure continues to increase, and the external force on the specimen gradually reaches the limit that it can bear, and the specimen shows a large plastic deformation, and the strength gradually reaches the maximum value. However, as the number of freeze-thaw cycles increases, the compressive strength decreases.

(4) Stage IV. (post-peak failure stage): When the stress level of the sample reaches the peak, the stress begins to decrease gradually, showing the characteristics of brittle failure, resulting in all the stress being released, and the rock finally loses its strength and fails.

Based on the above analysis, it is found that there is an obvious hysteresis effect at each stage of the stress-strain curve of granite samples under different freeze-thaw cycles. Among them, the most prominent is the compaction stage, which is mainly due to the influence of freeze-thaw action, the pores and micro-cracks in the rock continue to increase, so that the original cracks are connected, and at the same time there will be a small number of new cracks, and it is necessary to go through a larger strain to compact the fractures that have experienced more cycles, resulting in the compaction stage of 60 freeze-thaw cycles to be extended.

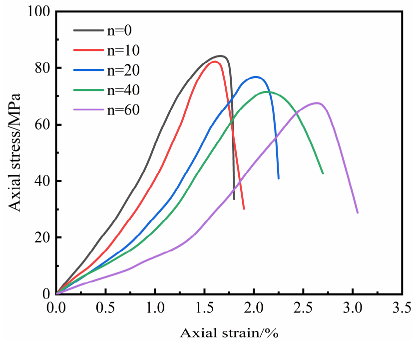

Figure 3 Stress-strain curves

3.2.2. Compressive Strength and Elastic Modulus Deterioration Analysis

Fig. 4 shows the variation of the elastic modulus and compressive strength of granite with the number of freeze-thaw cycles. The elastic modulus of granite was 8.29 GPa before freeze-thaw cycles, and decreased by 6.76%, 17.25%, 25.93% and 37.88% after 10, 20, 40 and 60 freeze-thaw cycles, respectively. The results show that with the increase of the number of freeze-thaw cycles, the elastic modulus of the sample also decreases.

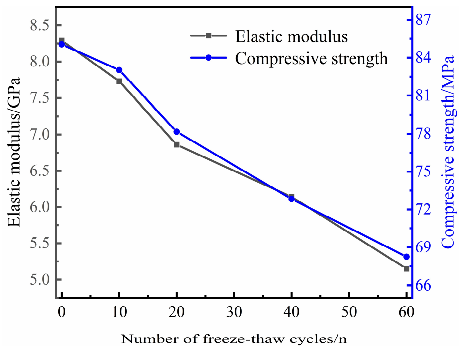

Figure 4. Changes in modulus of elasticity and compressive strength

The uniaxial compressive strength of granite before freeze-thaw cycles was 85.05 MPa, and when the freeze-thaw cycles of granite reached 10, 20, 40 and 60 times, the rock strength decreased to 83.02, 78.16, 72.83 and 68.25 MPa, respectively, and the corresponding strength losses decreased by 2.39%, 8.10%, 13.19% and 19.75%, respectively. Obviously, there is a significant negative correlation between its strength and the number of freeze-thaw cycles. It is not difficult to see that the deterioration process of the two is also corresponding, that is, the degree of damage generated in the rock will continue to intensify due to the increase of the number of freeze-thaw cycles, and eventually the macroscopic mechanical properties of the rock will deteriorate.

4. Conclusion

In this paper, the granite samples were tested with different freeze-thaw cycles and uniaxial compression. The influence of freeze-thaw cycles on the physical and mechanical properties and microstructure of granite is discussed, and the following conclusions are drawn:

(1) With the increase of the number of freeze-thaw cycles, the mass of granite specimens also gradually increases, and after the number of freeze-thaw cycles reaches a certain number, the number of cycles continues to increase, and the quality of the specimens gradually decreases. However, the longitudinal wave velocity of the sample decreases due to the influence of the internal microstructure of the rock.

(2) Through the analysis of stress-strain curves, it is concluded that due to the influence of freeze-thaw cycles, the end time of the four stress-strain stages of granite has a lag phenomenon, and the lag of the compaction stage is the most obvious.

(3) The changes of mechanical parameters under different freeze-thaw cycles were analyzed, and it was found that with the increase of the number of freeze-thaw cycles, the peak strength and elastic modulus showed a gradual attenuation law.

Acknowledgments

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