Volume 8 Issue 5, 2022
DOI: 10.6919/ICJE.202205_8(5).0057

Research Status of Mechanical Properties of Ice

Huanhuan Hou

Henan Polytechnic University, Jiaozuo 454150, China

Abstract

The factors affecting the mechanical properties of ice are summarized, and the strength value can be calculated by selecting the size effect coefficient reasonably. By controlling the strain rate range, the peak strength of ice can be obtained, and the lower the temperature is, the higher the compressive strength will be. Adding corresponding materials into raw ice can improve the compressive and tensile strength. Finally, the development prospect of strengthened ice is forecasted.

Keywords

Compressive Strength; Tensile Strength; Sample Size; Strain Rate; The Temperature.

1. Introduction

In cold regions, ice is a natural engineering material, Tensile failure and compression failure of ice are the most concerned failure modes in the laboratory, In recent years, A great deal of experimental research has been done on the mechanical properties of ice, But its mechanical properties are complicated, Strength is affected by many factors, Therefore, many scholars have carried out experimental studies on it from various aspects such as temperature, strain rate and sample size. And the tensile strength of ice is much lower than the compressive strength [1].

2. Research Status of Influencing Factors of Ice Strength

2.1 The Influence of Sample Size on Strength

The size of the ice has a significant effect on compressive strength, Lin Zhi et al [2] used three groups of bohai sea ice with different sample sizes to conduct uniaxial compression tests (10 cm×10 cm×20 cm, 15 cm×15 cm×25 cm, 18 cm×18 cm×28 cm), And uses Weibull Theory [3], It is found that the smaller the cross-sectional area of ice is, the more obvious the size effect is, and as long as the size effect parameter α is chosen reasonably, the calculated results can approximate the experimental results better. Shen Wu et al [4] performed compressive strength tests on bayuquan sea ice samples (10 cm×10 cm×20 cm, 15 cm×15 cm×25 cm, 18 cm×18 cm×28 cm) and Huludao sea ice samples (φ 10 cm×25 cm, φ 8 cm×20 cm, φ 6 cm×15) Cm) at a strain rate of 3.0×10-3 s-1. It is found that the strength decreases with the increase of sample volume. Zhang Limin [5] believes that the influence of sample size on strength is indirectly reflected in the average particle size, combined with the uniaxial compression data of artificial frozen ice, reservoir ice and sea ice, the sample size effect and particle size effect are unified. It is found that when D (average equivalent diameter of grain) /A (diameter of ice sample) is less than 1.5, The compressive strength of ice decreases with the increase of D/A. Xu Y[6] believed that ice failure strength had significant size effect and predicted the impact of size effect on ice strength by using fractal dimension. Gharamti I E[7] conducted a large-scale laboratory test study on the size and rate effect of thermal columnar fresh water ice rupture, and the test results showed that the size effect and rate effect are mutual, and the size effect exists at low strain rate.

ISSN: 2414-1895 DOI: 10.6919/ICJE.202205_8(5).0057

2.2 Effect of Strain Rate on Strength

Ice is sensitive to strain rates, Zhang Limin [5] analyzed the relationship between the uniaxial compressive strength of ice and strain rate, It shows that ice has strain rate sensitivity and ductile-brittle transition characteristics under compression, There is a ductile zone at low strain rate and a brittle zone at high strain rate, and there is a ductile-brittle transition zone in which the compressive strength reaches its maximum value. Zhou Qing [8] analyzed the factors affecting the uniaxial compressive strength of ice. The results show that strain rate is an important factor in the compressive strength test, and the compressive strength value reaches its maximum value in the transition zone. Zi Linqin [9] conducted compressive strength tests on ice in different sea areas, and the results showed that the maximum compressive strength of ice in different sea areas was in the ductile-brittle transition zone. Wang Anliang et al [10] conducted compressive strength tests on sea ice in Bohai Sea, and the results showed that there was a linear relationship between sea ice strength and stress rate. Li Zhijun et al [11] used specific samples as an example to divide the strain rate values into ductile zone when the strain rate is lower than 3.0×10-5 s-1, transition zone when the strain rate ranges from 3.0×10-5 s-1 to 6.5×10-5 s-1, and brittle zone when the strain rate is higher than 6.5×10-5 s-1. Feng Xiaowei et al [12] conducted compressive strength tests on fresh ice with strain rates ranging from 10-2 s-1 to 10-4 s-1, and the results showed that the sample changed from brittle failure to ductile failure when the strain rate decreased to about 10-3 s-1. Yu Zhemin et al [13] conducted compression tests on sea ice, and the results showed that the strength of sea ice was greatly affected by strain rate and brine volume. Wang Qingkai et al [14] conducted compression tests on Yellow River ice at different temperatures and wide strain rates, and the results verified the strain rate effect of compressive strength. Chen Xiaodong [15] conducted compressive strength tests on sea ice, and the results showed that strain rate was the main reason for its ductile-brittle transformation. Wang[16] showed that the compressive strength of sea ice mainly depends on two parameters: porosity and strain rate; Deng[17] conducted compression tests on ice to study the failure mode and compressive strength characteristics of ice, and the results proved that the compressive strength value of ice reached its maximum value in the ductile-brittle transition zone. Zhang[18] studied the strain rate effect in the brittle failure process of ice under compression by numerical methods, and the test results showed that the failure mode and strength of ice were affected by the loading rate. Yang Q[19] conducted a uniaxial compression test on artificial ice, taking into account temperature, strain rate, water quality, air humidity, ice making method and other factors, and the results showed that strain rate and temperature had a great influence on strength.

2.3 Influence of Temperature on Strength

Temperature affects the microstructure of ice, which in turn affects the compressive strength of ice [20]. Xu Zijun [21] conducted uniaxial compressive strength tests on Wuliangsuhai Lake ice at different temperatures, and the results showed that, at the same strain rate, the strength increased with the decrease of temperature. Guo Yingkui et al [22] conducted compressive strength tests on samples at different temperatures, and the results showed that the strength increased with the decrease of temperature. Luo W et al [23] conducted uniaxial compression tests on artificial fresh water ice at different temperatures, and the results showed that there was an approximate linear relationship between temperature and compressive strength. Xu Hongyu et al [24] carried out triaxial test and obtained the stress-strain curve of ice under different temperatures and confining pressures and the relationship between compressive strength and temperature, and analyzed the influence of test temperature and confining pressure on strength by using Mohr-Coulomb strength criterion. Shan Renliang et al [25] carried out uniaxial and conventional triaxial tests on fresh water icicle at different temperatures, and the test results showed that the confining pressure had a greater impact on the strength of the sample than the temperature. Zhang Yongkang et al [26] conducted compression tests on polycrystalline ice at different temperatures, and the results showed that ice strength increased with the decrease of temperature. Yuan Baojiang [27] conducted uniaxial compression tests on artificial ice, and the results showed that ice strength and slope of elastic section both increased with

ISSN: 2414-1895 DOI: 10.6919/ICJE.202205_8(5).0057

the decrease of temperature. Farid H[28] believed that the compressive strength of ice was strongly correlated with temperature, strain rate and porosity. Potter R S[29] believed that ice compressive strength was closely related to density and was a function of density, which could be described by linear relationship.

3. Research Status of Ice Enhancement

In order to improve the compressive and tensile strength of raw ice, many scholars tried to add fibers, wood chips, crushed bark and other materials to the raw ice for compression and tensile tests. Wu Y et al [30] conducted uniaxial compression tests on raw slurry fiber reinforced ice (FRI) with different dosage, and the test results showed that the strength of FBI was about 4 times that of raw ice. Xla B et al [31] mixed different contents of fibers into raw ice and conducted tensile tests on raw ice and fiber-reinforced ice at different loading rates, and the results showed that the tensile strength of fiber-reinforced ice was 2-3.5 times higher than that of raw ice. Lou, X[32] conducted shear mechanical properties tests on sulfuric acid bleached cork pulp fiber reinforced ice (BSSP) with different additives, and the results showed that the increase of fiber improved the energy absorption capacity and load carrying capacity of ice in the shear process. Glockner[33] added glass fiber to raw ice to make a dome. The experimental results show that reinforced ice can be used as a building material. Relatively, there are few studies on this field at home and abroad.

4. Conclusions and Prospects

This paper summarizes the experimental research on the factors affecting the mechanical properties of ice, Sample size, temperature and strain rate are the main factors affecting the compressive strength of ice. The specimen height remains unchanged, and the greater the cross-sectional area, the lower the compressive strength, It can also be understood that the larger the size, the more initial defects of the sample. The lower the temperature, the greater the compressive strength value, which can be interpreted as: the lower the temperature, the denser the ice. According to the strain rate, it is divided into three zones, Ductile zone, Ductile brittle transition zone, Brittle zone, The maximum value of compressive strength is reached in the transition zone.

A great deal of experimental research has been done on the mechanical properties of ice, And achieved remarkable results, But there are still some problems, Considering the actual situation and the available test results, Further efforts should be made in the following areas: There is literature to support the use of reinforced ice as a building material, but there's not a lot of research on it, research in this area should be strengthened; Research can be carried out on new composite materials, the ice can be used as the inner core ice, and the outer boundary is restrained by the composite material, Further promote its development.

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