Effect of temperature on tensile mechanical properties of GFRP bars with different diameters

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Abstract. Tensile mechanical properties of glass fiber reinforcement polymer (GFRP) bars under temperature effect is very important for engineering application. Based on three types of GFRP bars with different diameters under elevated and low temperature, change law of ultimate tensile strength and tensile elastic modulus in the temperature range of -20 °C to 300 °C were studied on GFRP bars. The results show that ultimate tensile strength decreases with the rise of temperature from -20 °C to 300 °C. Ultimate tensile strength and tensile elastic modulus decrease linearly below 100 °C. Above 100 °C, ultimate tensile strength decreases faster, temperature is higher. These

1. Introduction
GFRP bars have the advantages of light weight, high strength, corrosion resistance and good bonding performance, thus it can be used as an alternative or complementary for reinforced materials used in various kinds of structures, widely used and researched in the field of civil engineering [1, 2]. In buildings where these materials are exposed to high temperatures such as fire or low temperature during the winter months [3], and the loss of strength should be known. The effect of temperature on tensile strength and tensile modulus is based on the analysis of the temperature nodes taken by the investigators [4, 5]. Some researches were done at range of -50 °C to 500 °C [6-10], but the effect of high temperature on the tensile properties of GFRP bar was consistent, that is, as the temperature increased, the tensile strength and tensile modulus decreased and decrease rate was different. Low temperature state has different conclusions. There is no extensive research on the relationship between the performance changes caused by different temperature change modes. In this paper, studies have focused on the influence of temperature effect on tensile mechanical properties of GFRP bars in the aspects of the diameter size and temperature, revealing the changing rules of tensile mechanical properties when GFRP bars are affected by the temperature, which provides a theoretical basis for the further study of GFRP bars structure application in the harsh environment.

2. Experiments program

2.1. Experimental materials
The test material was composed of vinyl ester glass fiber composite material (GFRP) with the density of 2.05g / cm³, diameter of 16mm, 22 mm and 25 mm. The effective length of the specimen was 400
mm, of the steel sleeve, the specimen length of 800mm. GFRP component content as shown in Table 1.

| Diameter | Mass content of Resin (%) | Mass content of Fiber (%) | Volume ratio of Fiber (%) |
|----------|---------------------------|---------------------------|---------------------------|
| φ16      | 13.0                      | 87.0                      | 68.6                      |
| φ22      | 15.8                      | 84.2                      | 65.7                      |
| φ25      | 16.7                      | 83.3                      | 63.7                      |

2.2. Experimental project
In order to study tensile mechanical properties and strength mechanism of GFRP bars under temperature effect, this test should make sure that the GFRP bars should not be damaged by excessive high temperature, or the goal can’t be got. Therefore, this test chooses the temperature range from -20°C to 180°C and temperature gradient is 20°C to make tensile tests on φ16, φ22, φ25 GFRP bars to acquire their mechanical performance at each different temperature status. After cooling to a specified temperature, the time should be recorded down and kept the same temperature for 30 min and then the specimen should be wrapped with the insulating materials of the same temperature to be tested. Set heating-preserving parameters by thermostat, when the temperature reached the required value, kept the temperature for 40 min and then began tensile test. Tensile tool was computer-controlled electro-hydraulic test machine(model: WAW-1000), the tests were loaded with displacement loading mode, the loading rate was 2 mm/min.

3. Results and Analysis

3.1. Experimental phenomenon
During the tensile test of GFRP bars, the color of the surface of the specimens changed little from -20 °C to 20 °C, and the damage state of the bars was not significantly different from the GFRP bars. The whole process of body destruction was very close to 20 °C. When the GFRP bars were heated to a temperature of 100 °C, the tensile failure test was carried out, and the bars were in a bundle-like burst failure state, accompanied by the scattering of many fine fibers. 120 °C ~ 180 °C, the bar tensile failure state above, but accompanied by a small amount of floc-like fiber yarn, the color of broken part was changed into a lighter coke yellow color; When temperature was between 180°C to 280 °C, in the process of stretching the test piece was not accompanied by sound until it was destroyed into floc fluffy, specimens’ color changed from coke yellow into carbon black gradually. After the temperature reached 320°C, the color of the specimen surface almost became black, as shown in Fig 1.

![Fig 1. Failure modes of GFRP bars in different elevated temperature conditions](image)

3.2. Effect of temperature on tensile properties of GFRP bars
The relation curve of ultimate tensile strength and temperature of bars is shown in Fig 2. Ultimate tensile strength (fu) of the GFRP bars decrease with temperature rise, the descending rate of the φ25 bar is the fastest, and the descending rate of φ16 bar and φ22 bar below 60°C are almost equal. When the temperature is higher than 60 °C, tensile strength of φ22 bar decreases gently. The relation curve of
ultimate tensile strength and temperature of φ16 bar is located above those of φ22 bar and φ25 bar, which shows fu of φ16 bar is the maximum one. When the temperature is below 60 °C, ultimate tensile strength of φ22 bar is lower than φ25 bar’s. But when the temperature is higher than 60 °C, ultimate tensile strength of φ22 bar is higher than mate tensile strength of φ25 bar’s, besides, with temperature rise, in the same temperature conditions, the diameter is bigger, ultimate tensile strength is smaller. At the temperature of 180°C, ultimate tensile strength of the three kinds of bars decrease by 33.64%, 36.30% and 51.84%. Ultimate tensile strength of φ16, φ22, φ25 GFRP bars increase by 7.8%, 8.9% and 11.5% at -20 °C.

Fig 2. The relationship curves of ultimate tensile strength of GFRP bars and temperatures
It can be seen from Fig 3. that elastic modulus and temperature of GFRP bars are larger than 20 °C, the values are almost the same. When the temperature is above 20°C, the elastic modulus decreases slowly with the increase of temperature, and the decreasing range is more stable, elastic modulus of GFRP bars of φ16, φ22, φ25 increased by 6.9%, 7.2% and 4.5% at -20 °C. Elastic modulus of GFRP bars at φ16, φ22 and φ25 are almost negligible when the temperatures are 80 °C and 20 °C, and the change trend of the three kinds of diameters are almost the same.

Fig 3. The relationship curves of elastic modulus of GFRP bars and temperatures

4. Conclusion
(1) Ultimate tensile strength of GFRP bars increase under the low temperature of 20 °C, and the different diameter bars have different changes. Ultimate tensile strength of φ16 bar, φ22 bar, φ25 bar increase by 7.8%, 8.7%, 11.5%. at -20°C than that of 20°C. In the sustained low temperature process, ultimate tensile strength gradually reduce with the time, but the change is small, which can be ignored.
(2) Ultimate tensile strength and elastic modulus of GFRP bars tend to decrease with temperature rise. When the temperature rises, the descending trend of φ16 bar, φ22 bar are basically the same, showing the parallel state, and φ25 bar’s descends faster. At 180 °C, ultimate tensile strength of three kinds of the bars decrease by 33.6%, 36.3% and 51.8%. Elastic modulus of GFRP bars decreases slowly with the temperature rise. Elastic modulus of three kinds of the bars at 100 °C are about 3% lower than that at 20 °C, and the change trend of three kinds of the bars is basically the same.

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