Research on Test Method about Coupling Effect of Ultra Low Temperature and Mechanic Force

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Abstract. This paper introduces the structure and application method of the self-designed ultra-low temperature mechanical loading test chamber, which can be used to study the coupling effect on building materials induced by temperature change and mechanic force. The results show that the lowest temperature in the chamber can reach to -169 °C, which can cool the building materials to any specified temperature within 20 °C and -169 °C. The chamber has the functions of accurately controlling the temperature in the chamber and changing the force on the specimen independently, so that the specimen can always be in the coupling effect induced by temperature change and mechanic force. And the coupling correlation between such two effects can be tested by the device outside of the chamber.

1. Introduction
With the rise of national LNG Development Strategy, higher building material requirements are needed to ensure adequate safety. The material of external tank of LNG storage tank is prestressed concrete. The temperature of LNG is -163 °C[1]. In order to prevent the leakage of LNG and avoid the serious harm to property and life, the concrete shall be supposed to bear ultra-low temperature without damage. At home and abroad, scholars have done a lot of research in ultra-low temperature environment at present. However, the loading and cooling are usually carried out separately. The change of mechanical properties of the specimen can not be estimated through this way[2-4].

The reason why there are few researches on the properties of building materials under ultra-low temperature is that the cost of ultra-low temperature test is high and the test parameters can not be changed flexibly due to the limitation of cooling loading conditions. Therefore, the problems of test equipment must be solved before the ultra-low temperature test. This paper will introduce a mechanical loading test chamber which can change the temperature and load parameters independently and form a coupling field during the cooling process.

2. Test Equipment
The test chamber is shown in Figure 1. The test chamber connects the specimen with the steel counterweight through the lower bolt and the pressure device. Thereby, the pressure is formed on the test piece. There are reserved holes in the center of steel counterweight. They can help the draw bar to pass through the counterweight. There are multiple threads at the bottom of the draw bar. Tighten the bolts to make the steel counterweight and the draw bar as a whole. The top of the draw bar is an inverted U-shaped head, and the bottom of the pressure device is a U-shaped head. Align two...
U-shaped heads, and connect the pressure device and the draw bar together with the sleeve rod. To sum up, connect the test piece and counterweight together. The steel counterweight transfers the gravity to the support ladder and then to the ground through the round steel. During the test, the force is transferred to the test piece once the round steel is drawn out. There are 8 levels of load, and the load can be controlled flexibly.

Figure 1. Ultra low temperature mechanical loading box
3. Device Functions
The ultra-low temperature mechanical loading box is a self-designed equipment, which uses liquid nitrogen to cool down. It achieves the aim of cooling through the thermal circulation of the air in the box. The test chamber is connected with a console, and the temperature of the control panel is set to control the injection rate of liquid nitrogen. In this way, the environment temperature can be freely controlled. Through the actual test, the lowest temperature can drop to -169 °C, the fastest cooling rate can reach to 1 °C / min, which can meet LNG's temperature boundary of -163 °C. The loading condition can be realized by drawing out the round steel and applying the weight of steel counterweight on the test piece through bolts. The counterweight is located outside the box. It will not be interfered with the change of the ambient temperature inside the box. Therefore, the temperature and force in the test chamber can be flexibly controlled, which can be applied separately or synchronously. In addition, the temperature can be measured by thermocouple, and the force is expressed by the weight of each grade of steel counterweight. Strain gauges and thermocouples are arranged on the surface of the specimen under test, and the data can be read by the test instrument.

4. Operation Steps
1) Put the test piece into the box. The test piece which has been cured and pre-embedded measuring device were put into the box. Put it near the test box. Open the test box through the console. After ensuring the safety of the box door, the test piece can be put into the test box manually by ladder. Because the test piece bears the pressure, it needs to be put on the support frame of the test box, and the pressure is applied to the test piece through the loading device.

2) Test system debugging. Draw out the corresponding wires through the test hole of the test box and connect them with the data acquisition system and data recording equipment. Level the bridge before loading, and debug the test system.

3) Preloading of mechanical force. Install the counterweight according to 80% of the loading force, lower the jack slowly until it is completely separated from the counterweight, and start loading. Keep loading for a while, then start unloading. First, raise the jack slowly until the counterweight rises for a short distance, so that the bolts at the bottom of the draw bar are not affected by forces, and unloading is completed. Repeat the step for 2-3 times to eliminate the gap between loading equipment and components. In the process of loading and unloading, pay attention to the test data of the strain gauge. When the data is repetitive, the gap between the loading device and the component is basically eliminated.

4) Mechanical force loading. Repeat the above steps, apply all the weight required by design to the instrument. Load the test component with mechanical force, and test the strain and temperature values of each test point during the loading process.

5) Preloading of temperature load. Before loading at the target low-temperature, connect the liquid-phase valve of liquid nitrogen tank with the cryogenic box. If the pressure of liquid nitrogen tank is not enough, unscrew the booster valve 5 to 10 minutes in advance. After the start of temperature loading, record the strain value at each measuring point at such time. Start to apply the pre-temperature effect on the test component. Turn on the power switch of the console of the cryogenic box. Press the start button to start the console, and set the loading temperature after the display operation interface appears. For the pre-load, the temperature is designed to be -100 °C. Click to run the system. After the fan of the cryogenic box is launched, slowly unscrew the outlet valve of liquid nitrogen and liquid phase. Test the data of the test piece every 5 minutes. In case of any abnormality during loading, press the emergency stop button on the console, and then close the liquid nitrogen tank. Let the temperature at the centroid of the specimen reach the predetermined temperature and remain stable for 30 minutes. Close the liquid nitrogen valve and booster valve. Stop the temperature load. Cool the component to normal temperature. Test the data of the test piece every 5 minutes. Let the temperature at the centroid of the specimen reach the ambient temperature and remain stable for 30 minutes. Analyze the test data. If the data has good repeatability, the test system is normal. Otherwise, the test system needs to be debugged.

6) Loading of temperature load. After confirming that the test system is correct, carry out formal temperature loading on the test system. First, connect the liquid-phase valve of the liquid nitrogen tank
with the low-temperature tank before low-temperature loading. If the pressure of the liquid nitrogen tank is not enough, unscrew the booster valve 5 to 10 minutes in advance. After the temperature loading starts, record the strain value at each measuring point. Set the loading temperature to -185 °C. Click to run the system. After the fan of the cryogenic box is launched, slowly unscrew the outlet valve of liquid nitrogen and liquid phase. Test the data of the test piece every 10 minutes. In case of any abnormality during loading, press the emergency stop button on the console, and then close the liquid nitrogen tank. Let the temperature at the centroid of the specimen reach the predetermined temperature and remain stable for 30 minutes. Close the liquid nitrogen valve and booster valve. Stop the temperature load. Cool the component to normal temperature and analyze the test data.

7) Results analysis. Process the test data and summarize the problems in the test process.

5. Conclusion
The mechanical loading box realizes the coupling of temperature and force, which is especially suitable for the research of material mechanical properties under extreme temperature. With the implementation of LNG strategy, the research under ultra-low temperature is directly related to the safety of the masses and property. So it is very important for us to do some research under ultra-low temperature, and more test data is needed to ensure sufficient safety.

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