Study on tensile mechanical properties of polymer cement composite joint sealant under negative temperature

Zhihang Wang1, Jinyu Xu1,2*, Xin Meng1, Zhe Huang1 and Wei Xia1

1School of Aeronautical Engineering, Air Force Engineering University, Xi’an, Shannxi, 710038, China
2College of Mechanics and Civil Architecture, Northwest Polytechnic University, Xi’an, Shannxi, 710072, China
*Corresponding author’s e-mail: wangzhihangafeu@163.com

Abstract. Tensile tests were carried out on polymer cement composite joint sealant(PCJS) after different negative temperature action time. By testing the tensile strength index, tensile deformation index and tensile energy consumption index of PCJS, the effect of negative temperature action time on the tensile mechanical properties of PCJS was studied. The results show that with the extension of the negative temperature, the tensile strength of PCJS continues to increase, the tensile elongation at break and the tensile toughness first increase and then decrease, the tensile peak strain and the tensile pre-peak toughness keep decreasing. After 1 d of negative temperature, the tensile elongation at break and the tensile toughness of PCJS were the largest.

1. Introduction
Polymer cement composite joint sealant(PCJS) [1,2] is a two-component polymer formed by polymer emulsion and cement as the main raw materials, adding fillers and additives to form a film through polymer curing and cement hydration. The material not only has the ability of organic polymer materials to reflect deformation, but also the ability of inorganic materials to resist deformation. In addition, it has the advantages of low cost, environmental protection and good adhesion to concrete structures [3,4].

At present, domestic and foreign scholars have carried out many researches on polymer cement composite joint fillers, mostly focusing on its mechanical properties, preparation methods, modification mechanism, construction technology, test methods and application research [5-8]. There are relatively few studies on its performance when used under negative temperature conditions. My country has a vast territory, and the temperature in some areas is low, especially in winter, when the temperature reaches below zero, which will have a serious impact on the performance of the joint filler.

Based on this, on the basis of existing experiments [1-2,4], this article puts PCJS in a negative temperature (-15°C) environment, and the influence of different negative temperature action time (1 d, 7 d, 15 d, 30 d) on the tensile strength index, tensile deformation index and tensile energy consumption index of PCJS was studied.
2. Experiment

2.1. Preparation of experiment materials and test pieces
The raw materials for preparing PCJS can be divided into two categories: solid components and liquid components. The solid components include cement and inorganic fillers, and the liquid components include polymer emulsions and functional additives. Polymer emulsion: Acronal S400F ap styrene acrylic emulsion and Celvolit 1350 type VAE emulsion. Functional additives: defoamers, dispersants, film-forming additives, plasticizers and silane coupling agents. Cement: Shaanxi Lantian Yaobai brand 42.5 ordinary Portland cement. Inorganic fillers: talcum powder and heavy calcium carbonate.

Prepare PCJS according to the mixing ratio shown in Table 1. The specific process is as follows: 1) Pour the styrene-acrylic emulsion, VAE emulsion and dispersant into the mixer and stir for 4 minutes, and then add defoamer, film-forming aid, and plasticizer in sequence Mixing agent and silane coupling agent for 4 minutes; 2) Dry mix cement, talcum powder and heavy calcium carbonate for 4 minutes until fully mixed; 3) Pour the solid component into the liquid component and stir at high speed for 10 minutes and then stir at low speed 5 min to obtain the mixture, and then co-cast the PCJS specimen as shown in Figure 1 with the cement mortar base material.

| Polymer emulsion       | Styrene acrylic emulsion | VAE emulsion | Cement | Talcum powder | Heavy calcium carbonate | Dispersant | Defoamer | Film forming aids | Silane coupling agent | Plasticizer |
|------------------------|--------------------------|--------------|--------|---------------|------------------------|------------|----------|------------------|-----------------------|-------------|
|                        | 1086.8                   | 585.2        | 234.1  | 217.4         | 217.4                  | 18.7       | 11.7     | 100.3            | 11.7                   | 16.7        |

Table.1 Mixture ratio of polymer cement composite joint filler (unit: Kg/m³)

2.2. Experiment method
Place the PCJS test piece to be tested in a low temperature test box with a test temperature of -15 ℃ (as shown in Figure 2) for continuous action for 1 d, 7 d, 15 d, 30 d, and take out the PCJS after the temperature continues The test piece is immediately subjected to a tensile test. Use HS-3001B electronic tensile testing equipment to perform tensile test on PCJS specimens. Load the prepared PCJS specimen into the tensile test fixture, and stretch the specimen to failure at a tensile speed of 5 mm/min. The corresponding load and displacement data during the tensile process are automatically recorded by the tensile equipment information collection terminal. Each group of experiments was carried out 3 times, and the results were averaged.

3. Results and analysis

3.1. Tensile strength index
The tensile strength index of PCJS is the tensile strength, and the tensile strength is the corresponding stress value when the PCJS specimen reaches the peak stress in the tensile test, which directly reflects the tensile performance of the material. The influence of negative temperature action time on the tensile strength of PCJS is shown in Fig. 3. It can be seen that the tensile strength of PCJS continues to increase
with the extension of the negative temperature action time at an ambient temperature of -15 °C. After 1 day of negative temperature, the tensile strength of PCJS increased rapidly, which was 70.81% higher than that before negative temperature. Then with the extension of the negative temperature action time, the tensile strength of PCJS continued to increase slowly. After 7 days, 15 days, and 30 days of negative temperature, the tensile strength of PCJS increased by 76.25%, 81.48%, and 88.24%, respectively. It can be seen that the tensile strength of PCJS can continue to increase in a negative temperature environment.

Figure 3. The effect of negative temperature on the tensile strength of PCJS

3.2. Tensile deformation index
The tensile deformation indexes of PCJS are the tensile elongation at break and the tensile peak strain. The tensile elongation at break represents the ratio of the displacement of the PCJS specimen during tensile failure to the initial width of the PCJS, and the tensile peak strain represents the tensile strain at the peak stress reached by the PCJS in the test. The influence of negative temperature action time on PCJS tensile elongation at break and tensile peak strain is shown in Figure 4. It can be seen that with the extension of negative temperature action time, the tensile elongation at break of PCJS first increases. And then after 1 day of negative temperature, the tensile elongation at break of PCJS is the largest, which is 4.36% higher than that before negative temperature. Then the tensile elongation at break of PCJS is smaller than that before the negative temperature. After 30 days of negative temperature, the tensile elongation at break decreased by 13.69%. The tensile peak strain of PCJS decreases with the extension of the negative temperature. After the negative temperature was applied for 1 day, the amplitude of the decrease was the largest, which was reduced by 63.52%. After 30 days of negative temperature, the tensile peak strain of PCJS finally decreased by 77.04%. It can be seen that, as a whole, the tensile deformation index of PCJS will be reduced in a negative temperature environment.

Figure 4. The effect of negative temperature action time on PCJS tensile elongation at break and tensile peak strain

Figure 5. The effect of negative temperature action time on PCJS tensile toughness and peak tensile toughness
3.3. Tensile energy consumption index
The tensile energy consumption index of PCJS is tensile toughness and tensile peak toughness. The influence of negative temperature action time on the tensile toughness and peak tensile toughness of PCJS is shown in Figure 5. It can be seen that with the extension of the negative temperature action time, the tensile toughness of PCJS first increases and then decreases Small trend. After 1 d of negative temperature, the tensile toughness of PCJS was the largest, which increased by 58.06% compared with that before negative temperature. Then the tensile toughness gradually decreases, but it is still greater than before the negative temperature. With the extension of the negative temperature action time, the tensile peak toughness of PCJS continues to decrease. After 1 d, 7 d, 15 d, and 30 d of negative temperature, the tensile peak toughness of PCJS decreased by 41.86%, 55.71%, 56.93%, and 60.12%, respectively. It can be seen that the tensile toughness of PCJS increases and the pre-peak tensile toughness decreases in the negative temperature environment.

3.4. Mechanism analysis
Through the analysis of the test results, it is known that the negative temperature action time has a significant effect on the tensile mechanical properties of PCJS, which is mainly due to the effect of negative temperature on the polymer molecular chain. When the ambient temperature is reduced from 25 °C (normal temperature) to -15 °C (negative temperature), the thermal motion of polymer molecules is inhibited due to the less energy in the negative temperature environment, which causes the polymer macromolecular chains to be frozen and condensed. The force between them is increased, and the flexibility of PCJS is reduced. Therefore, it takes more external force and longer time to realize the stretching and displacement deformation. Therefore, after 1 d of negative temperature, the tensile strength of PCJS, Tensile elongation at break and tensile toughness increased significantly, and peak strain decreased significantly. With the extension of the negative temperature action time, the degree of freezing and coagulation of the polymer molecular chain is further intensified, and the intermolecular force continues to increase, resulting in further inhibition of the movement and stretching of the polymer molecular chain. Therefore, PCJS continues to act at the negative temperature Later, it showed that the tensile strength index continued to increase, and the tensile deformation index and stretching energy consumption index gradually decreased.

4. Conclusion
(1) With the extension of the negative temperature action time, the tensile strength of PCJS continues to increase.
(2) With the extension of the negative temperature action time, the tensile elongation at break of PCJS first increases and then decreases, and the peak tensile strain continues to decrease. After 1 d of negative temperature, the tensile elongation at break of PCJS is the largest.
(3) With the extension of the negative temperature action time, the tensile toughness of PCJS first increases and then decreases, and the peak tensile toughness continues to decrease. On the whole, the tensile toughness of PCJS is larger than that before the negative temperature, and the maximum tensile toughness appeared after 1 day of negative temperature.

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