Experimental Study on Thermal Expansion Property of Epoxy Mortar in Hydraulic Structure Repairing

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Abstract. The thermal expansion property of epoxy mortar has a significant effect on the repair effect. Experiments were carried out to study the thermal expansion coefficient of epoxy mortar by changing the type of curing agent, various sand binder ratios and sand etc. The results show that the curing agent has a remarkable effect on the thermal expansion coefficient of epoxy mortar. When the type and content of curing agent are fixed, the influence of sand binder ratio and sand type on thermal expansion coefficient of epoxy mortar is relatively small. It is an effective way to reduce the thermal expansion coefficient of epoxy mortar with excellent curing agent. The research conclusion can provide a reliable basis for hydraulic concrete repairing.

1. Introduction
The erosion wear damage of hydraulic structures is an important subject to be solved in water conservancy and hydropower construction. Concrete structures such as overflow dam, spillway, spillway, spillway, bottom plate of sluice gate, apron, stilling pier, bottom plate and side wall of drainage bottom outlet will be worn in varying degrees under the impact of high-speed sand bearing water flow and bed load impact, and maintenance is often required [1-2]. When the repair area or thickness is large, or when composite surface is under construction, it is very important to match the thermal expansion coefficient of the repaired concrete with the repair material. If the thermal expansion coefficients of the two materials are quite different, and the volume change with temperature is very different, it often makes the interface bonding lose effectiveness or makes the material strength of this part very low [3].

Epoxy mortar is one of the earliest materials for hydraulic concrete structure repairing. Although it has the advantages of high strength, low elastic modulus and large ultimate tensile strength, its thermal expansion coefficient is large [4, 5]. The epoxy mortar will be separated from the old concrete when the temperature changes sharply. Therefore, it is necessary to investigate the thermal expansion performance of epoxy mortar when it is used in the hydraulic structure repairing, so as to prevent the interfacial adhesion to fail in the engineering.

The thermal expansion property of epoxy mortar was studied in this paper by investigating the influence of epoxy mortar for two types of curing agents, various sand binder ratios and sand on the
thermal expansion coefficient.

2. Experimental Information

2.1. Experimental material

| Table 1. Technical indexes of epoxy resin |
|----------------------------------------|
| Model | Epoxy value (eq/100g) | Epoxy equivalent (g/eq) | Hydrolyzed chlorine (%) | Viscosity (mPa·s (25℃)) |
|-------|----------------------|------------------------|-------------------------|--------------------------|
| 0164  | 0.520~0.540          | 1985~192               | ≤0.050                  | 8000~14000               |

| Table 2. Performance parameters of curing agent |
|-----------------------------------------------|
| Model | Amine value (mg/KOH/g) | Viscosity (mPa·s(25℃)) | Toxicity |
|-------|------------------------|-------------------------|----------|
| 1085B | 200~250                | 200~300                 | LD50>10000mg/kg |
| T31II | 500±50                 | 1000~5000               | lesser    |

0164 epoxy resin (Wuxi) was selected for the test, and its physical properties are shown in Table 1, the curing agents are 1085B underwater curing agent (Changsha) and T31 II underwater curing agent (Changsha). Their physical properties are shown in Table 2. Sand with fineness modulus FM of 1.81 is used in the test. The sand types are quartz sand, limestone sand, granite sand and sandstone sand.

2.2. Experimental design and method

Different curing agents were used to solidify the adhesive in epoxy mortar, and the dosage was recommended by the manufacturer. Quartz sand, limestone sand, granite sand and sandstone sand are used respectively, and the sand-binder ratio is 4.5, 5.5, 6, 6.5, 7.

According to the Technical Specification For Epoxy Resin Mortar (DL/T 5193-2004), mixed the epoxy mortar evenly, and formed the specimen of 25.4mm×25.4mm×285mm, which was fixed Copper probe at both ends of it. The specimens were cured in curing room with temperature of 23 ℃± 2 ℃ and relative humidity of 50% ± 5%. After curing for 28 days, place the specimens in thermostat water bath of 0 ℃, 20 ℃, 40 ℃, 60 ℃ and 80 ℃ for 24 hours, measure the length of the specimens at each temperature and calculate the thermal expansion coefficient α.

3. Experiment results and analysis

3.1. Effect of different curing agents on thermal expansion coefficient of epoxy mortar

The coefficient of thermal expansion (CTE) is a measure of the length change characteristic of material with temperature. For a given temperature change, the expansion or contraction is completely determined by the thermal expansion coefficient.

Linear coefficient of thermal expansion

\[ \alpha = \frac{\Delta L}{L \times \Delta T} \]

In the formula:

\( \alpha \)— Average linear coefficient of thermal expansion per degree centigrade, 1/℃;

\( \Delta L \)— Change in length of specimen due to heating or cooling, mm;

\( L \)— length of specimen at Reference temperature (\( \Delta L \) and L are tested in the same unit);

\( \Delta T \)— The temperature difference that causes the length change of the specimen, ℃.

Other things equal, (limestone sand, sand binder ratio is 5.5), 1085B curing agent and T31 II curing agent were used respectively to cured epoxy resin for the preparation of epoxy mortar. The \( \Delta L/L \) ratio varied with temperature as is shown in figure 1. By calculation, the thermal expansion coefficient of 1085B epoxy mortar is about \( 57 \times 10^{-6} \) 1/℃, the thermal expansion coefficient of T31II epoxy mortar is about \( 17 \times 10^{-6} \) 1/℃. The thermal expansion coefficient of T31 II-epoxy mortar is less than 1085B-epoxy mortar, and is closer to the thermal expansion coefficient of concrete (5~12 \times 10^{-6} \) 1/℃).
Thus, in the process of preparing epoxy mortar, the type of curing agent has a great effect on the thermal expansion coefficient of epoxy mortar. The thermal expansion coefficient of epoxy mortar can be effectively reduced by choosing appropriate curing agent type.

3.2. Effect of different cement sand ratio on thermal expansion coefficient of epoxy mortar

Other things being equal in the experiment (use limestone sand), sand-binder ratios were 4.5, 5, 5.5, 6, 6.5, 7 to prepare epoxy mortar. The change of thermal expansion coefficient $\alpha$ with sand binder ratio is shown in figure 2.

It can be seen from figure 2 that the thermal expansion coefficients of the two types of epoxy mortar decrease with the increase of sand binder ratio. This is because the thermal expansion coefficient of sand is smaller than that of epoxy resin, and the higher the proportion of sand in the mortar, the smaller the thermal expansion coefficient of epoxy mortar. However, it can be seen that although the increase of sand binder ratio in epoxy mortar can reduce the thermal expansion coefficient of epoxy mortar, the extent of reduction is not great from the experimental data. Therefore, the influence of sand binder ratio on thermal expansion coefficient of epoxy mortar is not obvious.

3.3. Effect of different type of sand on thermal expansion coefficient of epoxy mortar

Other things equal (use 1085B curing agent, and sand binder ratio is 5.5), granite sand, quartz sand, limestone sand and sandstone sand are selected respectively to prepare epoxy mortar. The test results are shown in figure 3.

![Figure 1. The change of $\Delta L/L$ with temperature](image1)

![Figure 2. Change of thermal expansion coefficient with sand binder ratio](image2)

![Figure 3. Change of thermal expansion coefficient with the type of sand](image3)

Figure 3 shows that among the epoxy mortar prepared with four types of sand, the thermal
expansion coefficient of granite sand is the largest, while that of quartz sand is the smallest. This is related to the difference of thermal expansion coefficient of sand itself. Generally, the thermal expansion coefficient of sand is about $3\sim 12 \times 10^{-6} \degree \text{C}^{-1}$, while that of quartz sand is about $1 \times 10^{-6} \degree \text{C}^{-1}$. The thermal expansion coefficient of quartz sand is the smallest among the four kinds of sand, which corresponds to the smaller thermal expansion coefficient of epoxy mortar. Therefore, the thermal expansion coefficient of epoxy mortar can be reduced by $2\sim 5 \times 10^{-6} \degree \text{C}^{-1}$ by using quartz sand with low thermal expansion coefficient instead of other ordinary sand. Accordingly, selecting sand with low thermal expansion coefficient to prepare epoxy mortar cannot effectively reduce the thermal expansion coefficient of epoxy mortar.

4. Conclusion

During the repair of hydraulic structures, many hydropower stations are located in areas with poor natural conditions. Usually, the temperature difference between day and night is large or the temperature changes violently when discharging water. So, there are specific requirements for the thermal expansion coefficient of repairing materials.

The research results of the influencing factors on thermal expansion coefficient of epoxy mortar show that: changing the ratio of sand to mortar or the type of sand can change the thermal expansion coefficient of epoxy mortar to some extent, but its influence degree is small, which is not the main factor affecting the thermal expansion coefficient of epoxy mortar. But the selection of curing epoxy resin with different curing agent types has a great influence on the thermal expansion coefficient of epoxy mortar. Accordingly, under the premise of ensuring the strength requirements, select the appropriate epoxy and change the properties of the epoxy resin by selecting a curing agent with excellent properties or by other means in order to reduce the thermal expansion coefficient of epoxy mortar and make it match the thermal expansion coefficient of repaired concrete as far as possible to meet the requirements of engineering repair.

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