A study on micro-morphology and impacts of curing temperature on bond strength of interfacial transition zone through scanning electron microscope

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Abstract. The influence of curing temperature on the bond strength of ITZ was studied in this paper. It is found that, Increasing curing temperature can improve the bond strength of ITZ in the early age, but it will significantly decreases the growth trend of the bond strength. The micro-morphology characteristics were examined by the method of scanning electron microscopy. It was found that, the higher the curing temperature is, the more uneven the hydration products distribution of ITZ is, and also the looser the ITZ structure is.

Keywords: Interfacial transition zone; Curing temperature; Bond strength; Scanning electron microscopy; Concrete;

1. Introduction
Mass concrete structure is widely used in the construction of hydraulic engineering. In the early age of pouring, The temperature history has a great impact on the performance of concrete. The interfacial transition zone (ITZ) is the weakest link in concrete, which determines the performance of concrete to a certain extent [1-4]. At present, plenty of researches on ITZ have been carried out [5-10], however, few of them considering the effect of curing temperature. In this paper, the effect of temperature on the bond strength of interfacial transition zone is studied by the method of three point bending and SEM.

2. Experimental
2.1. Materials and Mix proportion
Portland cement (P. O 42.5) was used in all mixes, and the chemical composition are shown in Table 1. Granite (from Fujian Province, China) was used as coarse aggregate (water absorption 0.31%). Water/cement ratio of paste was 0.50.

Table 1. Chemical composition of Portland cement (wt.%).

|    | CaO | SiO₂ | Al₂O₃ | Fe₂O₃ | MgO | SO₃ | K₂O |
|----|-----|------|-------|-------|-----|-----|-----|
|    | 53.28 | 25.97 | 9.34  | 3.10  | 1.35 | 1.09 | 1.03 |
2.2. samples
The size of specimen for bond strength testing is shown in Fig.1, for SEM observation is shown in Fig.2. All these specimens were cast in the metal molds which were specially made. When demolded, Specimens would be kept in water at different temperatures for curing until reaching curing age. The curing temperatures were set to 20℃, 40℃, 60℃, 80℃. The age of bond strength testing was set to 7, 14, 28, 56 days, age of SEM observation was set to 28 days.

![Fig 1. Size of three point bending specimen](image1)

![Fig 2. Size of SEM observation specimen](image2)

2.3. Methods of testing

2.3.1. Bond strength and compressive strength. According to GB/T 17671 (Chinese Standard), three point bending method was used in bond strength testing. After bond strength test, pick the paste for compressive strength test.

2.3.2. SEM. By the means of JEOL-JXA-840A scanning electronic microscopy, the micrographs of ITZ was observed. After reaching the curing age, specimens should be kept in anhydrous alcohol to prevent further hydration. Then, separated the two halves at the interface for SEM observation.

3. Results and discussion

3.1. Effect of curing temperature on bond strength
The test results of bond strength at different curing temperature are shown in Fig.3. As it shown in the figure, in the early age, the increase of curing temperature can significantly improve the bond strength. As curing age increases, the growth trend gradually disappears, when the age reaches 56 days, it is
obvious that, the bond strength at high curing temperature is already lower than the one at low curing temperature.

![Graph showing bond strength of ITZ vs. age and temperature](image)

**Fig 3. Bond strength of ITZ**

![Graph showing b-c ratio vs. age and curing temperature](image)

**Fig 4. Ratio of bond strength to compressive strength**

Ratio of bond strength to compressive strength is shown in Fig.4, it can be found that, in the early age, increasing curing temperature can increase bond/compressive ratio, which means, in early age, the effect of temperature on ITZ is more significant than that of paste. When the age reaches 56 days, the changing rule of ratio is just opposite to that in early age.

### 3.2. Effect of curing temperature on micro-morphology

Fig.5 shows the micro-morphology of ITZ (fracture surface of SEM sample) at different curing temperature, in this figure, we can get clear more specifically how the curing temperature affects ITZ, the structure of hydration products at high curing temperature is more loose and distribution is more uneven than that at low curing temperature.
Although high curing temperature can speed up the hydration reaction rate in the early age (thereby increase the bond strength), it will lose the structure and uneven the distribution of the hydration product, as a result, the strength at high curing temperature is lower than that at normal curing temperature in late period.

4. Conclusions
The follow conclusions can be drawn from this study:
(1) Increasing curing temperature can improve the bond strength of ITZ in early age, but it will significantly decreases the growth trend of bond strength.
(2) Increasing curing temperature can increase the bond-strength/compressive-strength ratio in early age.
(3) The structure of hydration products at high curing temperature is more loose and distribution is more uneven than that at low curing temperature.

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