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# Interfacial tensile bond behavior of permeable polymer mortar to concrete

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## HIGHLIGHTS

- Impact factors of bond strength were explored through TBS test.
- Curing time, roughness, SCM, and repair position are the main impact factors.
- The failure of TBS fell into three modes.
- Calculation formulas for tensile bond strength have been proposed.

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## ABSTRACT

Permeable polymer mortar (PPM), in combination with high-strength stainless steel wire mesh, can be widely used to reinforce and repair concrete structures. However, debonding failure of reinforcing layer is one of the major failure modes for these reinforced structures. Therefore, a systematic study on the interfacial tensile bond behavior of PPM to concrete was conducted, and the impact factors of bond strength were explored through the tensile bond strength (TBS) test. Results indicate that curing time, interface roughness, strength of concrete and mortar, and repair position are the major impact factors of bond behavior. The bond failure modes differ if the strength ratio of concrete and mortar, interface roughness, and repair positions are different. Calculation formulas for TBS are proposed in this paper based on the test data.



## 1. Introduction

Permeable polymer mortar (PPM) is characterized with high strength and high resistance to fire and corrosion. Combined with high-strength stainless steel wire mesh, this PPM can be widely used to reinforce and repair concrete structures. This type of reinforcing material and the corresponding reinforcing technology have achieved good results when they are used in projects, including the Zhuangzai Bridge reinforcement project in South Korea, the floor reinforcement project of Fangxing Hotel in Beijing, the reinforcement and reconstruction project of Zheng Chenggong Memorial Hall of Xiamen, and the reinforcement project of Beijing Sanyuan Bridge [1]. In this reinforcing technology, load is transferred depending on the bond strength between PPM and concrete at the reinforcing interface. The existing studies [1–7] indicate that debonding failure of the PPM reinforcing layer is one of the major failure modes in these reinforced structures. Therefore, a study on the interfacial tensile bond behavior of PPM to concrete should be conducted.

The impact factors of the interfacial bond strength between PPM (a type of cement-based material) and concrete are similar to those between new and old concrete. Existing works believe that the surface roughness of old concrete is the most significant influencing factor of concrete bond behavior [8–11]. Surface treatment of old concrete considerably influences bonding quality [12,13], that is, the concrete, for which surface roughness treatment is carried out, exhibits better bond behavior than that without treatment. An interfacial agent is the second major influencing factor of interfacial bond strength [14–16]. Currently, commonly used interfacial agents include cement paste-based bonding agents, epoxy adhesives, and polymer binder. The bond behavior of new and old concrete is related to time because of the physical and chemical reaction; in addition, bond strength grows as curing time of new concrete increases [17,18]. Bond strength will rise with the increase in new concrete strength if the strength of old

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concrete remains unchanged; the bond strength will also rise with the increase in old concrete strength if the strength of new concrete remains unchanged [19–21]. During reinforcement and repair, the repair position exerts a certain effect on the bond behavior between new and old concrete, but no consistent conclusion has been reached to date [22,23]. Eduardo et al. [24] and Cleland et al. [25] indicated that the interfacial bond strength in the "natural drying state" and the "wet saturated drying state" is high, whereas that in the "non-natural drying state" and the "wet saturated state" is low.

Through the tensile bond strength (TBS) test at 243 test points, this paper will conduct a systematic study of the interfacial bond behavior of PPM to concrete, analyze their failure characteristics, and summarize the failure regularity based on the aforementioned impact factors.

## 2. Test introduction

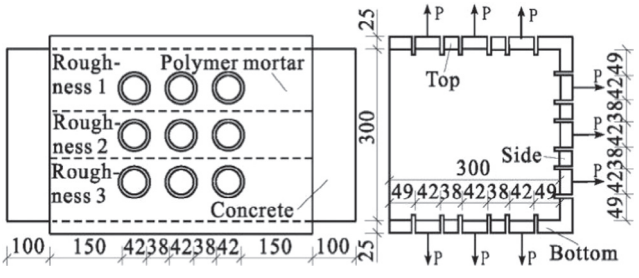
The effect of interface roughness, strength of concrete and mortar (SCM), curing time, and repair position on interfacial tensile bond behavior is studied by testing the interfacial TBS between PPM and concrete with pullout test apparatus. The PPM is RC-A0401, and its special interfacial agent is RC-A0404. Thus, the effect of interfacial agent on bond behavior is not considered in this study. Concrete is classified into C30, C35, and C40, and its cement is ordinary Portland cement 42.5. Repair positions are the side, bottom, and top, and the curing time is 7, 14, and 28 days. Finally, the surfaces are chiseled manually into three levels of roughness tested by sand-cone method. The test design and the specimens are shown in Figs. 1 and 2, respectively.

The experiment is performed in four steps. The first step is sample preparation, in which cubic concrete specimens are prepared. The second step is plastering the PPM on the surfaces of concrete cubes after curing. The surfaces are first chiseled manually, on which interfacial agent is plastered. Then, the PPM is plastered on the surfaces. The third step is drilling core sampling. Concrete drilling machine HZQ-150B is used to drill core samples (Fig. 2b). The fourth step is TBS test. Bond strength tester JS-10 is used to test the TBS of PPM, as shown in Fig. 2c.

## 3. Bond failure features

A total of 243 points were tested in the TBS test. Three points dropped out during the drilling process, so only 240 points were eventually tested. Table 1 provides the test data, and Fig. 3 shows the typical failure modes. Based on observations during the test, the failure of TBS fell into three modes.

Mode I is Concrete Failure. Failure occurs completely inside the concrete, and the fracture plane is on the concrete side of the bonded interface.

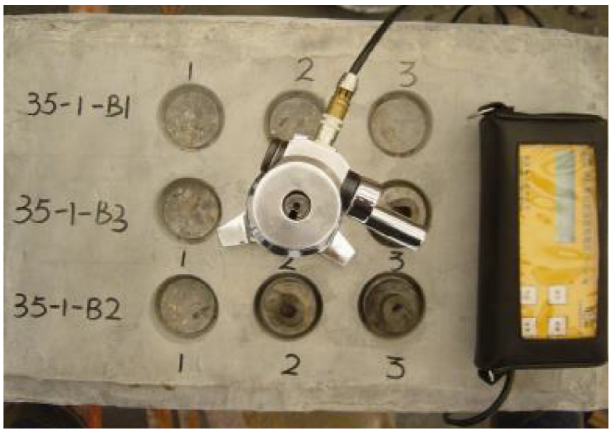



(a) Facade of specimen (b) Section of specimen

**Fig. 1.** Design of specimen for TBS test (unit: mm).

(a) Test specimen

(b) Drilling core sampling




(c) TBS test

**Fig. 2.** TBS test.

Mode II is Interlaminar Failure. Failure occurs on the bonded interface, and failure falls into two modes. On the one hand, the fracture takes place completely on the interface, called Interfacial Failure; on the other hand, the fracture surface is composed of the interface, some concrete or mortar, and is called Combined Failure (the combined failure composed of some interface and concrete is called Combined Failure I, whereas the combined failure composed of interface and mortar is called Combined Failure II).

Mode III is Mortar Failure. Failure occurs inside the mortar, and the fracture plane is on the mortar side of the bonded interface.