Journal of Ferdowsi Civil Engineering, Vol.33, No.1, 2020.

Curing and Shrinkage Effect on the PMM/Concrete Bond, using Friction-transfer and Pull-off Methods

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1. Introduction

Enhancing the adhesion between repair mortars and substrate concrete is related to factors such as reduction of shrinkage, proper curing, and the use of modifying polymers. Nowadays, the use of polymers in cement-based mortars is increasing in order to improve some mechanical properties and increase the adhesion between repair mortar and concrete substrate. Many researches have been done on the effect of polymer on cementitious mortars. Some modifier polymers include latex styrene butadiene rubber (SBR), polyacrylic ester (PAA), and vinyl ethylene acetate (VAA). Different methods can be used to measure the adhesion between the concrete substrate and the repair layer. Assessing the adhesion strength between layers, depending on the stress state applied to the samples, can be in the form of tensile stresses, shear stresses, and a combination of compressive and shear stresses. Some of the adhesion determination tests are splitting test, slant shear test (However, Naderi in 2012 considered theoretically and practically, the results of the tests with compressive and shear stress to be unreliability), compound beam test, double shear plate, bending test, symmetrical sample test with gap and pull-off test. In this study, the effect of different percentages of latex styrene butadiene rubber on the adhesion between the repair mortar and the concrete substrate under different curing was investigated, using the friction-transfer and pull-off tests.

2. Experimental Program

In this paper, by employing in-situ and semi-destructive tests, including friction-transfer and pull-off methods, the effect of styrene-butadiene rubber latex on the shear and tensile bond strength between repair mortars and the concrete substrate was investigated. In the friction-transfer test, a partial core with a diameter of 50 mm is created at the test site surface. Then the metallic friction-transfer device is placed on the considered half-core and fixed. After fixing the friction-transfer device, a torque is applied to the metallic device, which transfers friction to the half-core, by an ordinary manual torque-meter so that the partial core fails (Figure 1).

Figure 1. Friction-transfer test

In pull-off test, which is one of the most comprehensive methods for evaluating the tensile strength between the substrate surface and the repair layer, a partial core, which continues into the substrate concrete, is first implemented on the surface of the repair layer by a core drilling machine. A circular steel disc is then glued to the core surface using epoxy resin adhesive, and a pull-off force is applied to it by the pull-off device to cause failure (Figure 2).

Figure 2. Pull-off test

In order to measure the effect of polymer on the adhesion between repair mortar and concrete substrate, styrene-butadiene rubber polymer was used in mortars in amounts of 10, 15, and 20% in relation to the weight of cement, and the results were compared with plain mortar. In order to evaluate the results, three different types of curing were used, including immersion in water, concrete curing compounds, and leaving in the open space. Also, the amount of shrinkage of plain mortars and polymer-modified mortars with different percentages of latex was determined, and the effect of the type of curing on shrinkage was studied. The results show an increase in shear and tensile bond strength between the repair layer and the concrete substrate with the addition of different percentages of latex. For example, the shear bond strength between repair mortars and concrete substrates can be seen in Figure 3.

The reason for the increase in bond strength between polymer-modified mortars and the concrete substrate is the formation of polymer films in the mortar. When the polymer and the Portland cement paste are connected through covalent chemical bonds or strong ion-covalent bonds, it gives greater coherence to the whole matrix and improves the properties of the mortar. Moreover, appropriate curing prevents excessive mortar shrinkage, which increases the adhesion between the repair mortar and the concrete substrate. Besides, the shrinkage of

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mortars cured in water is less than the shrinkage of mortars cured with curing compounds. Table 1 shows the effect of polymer addition on mortar shrinkage. Because hydrated cement contains capillary pores, there is water inside these pores. The loss of water inside the pores does not cause shrinkage, but as soon as the capillary water is lost, it causes the surface-absorbed water to vanish, and consequently, the shrinkage occurs. The curing compounds do not entirely prevent the mortar moisture from exiting. So this issue had increased the shrinkage of mortars when the curing compounds were used for curing compared to the curing in water.

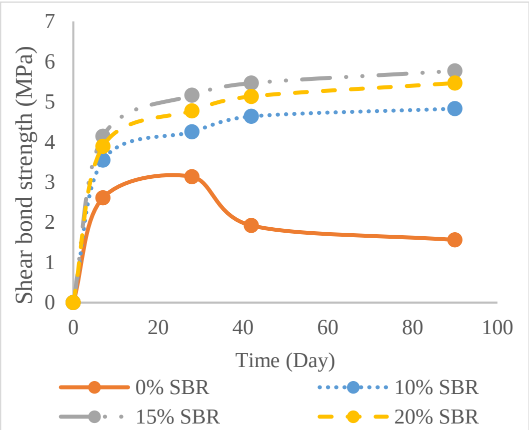

Figure 3. Shear bond strength

Table 1. Shrinkage of mortars

Mortars	(٪) Shrinkage			
	14 Days	28 Days	42 Days	90 Days
SBR 0%	0.0332	0.0662	0.0793	0.0872
SBR 10%	0.0223	0.0449	0.0513	0.0564
SBR 15%	0.0212	0.0406	0.0474	0.0512
SBR 20%	0.0192	0.0384	0.0438	0.0473

In order to display the cracks formed inside the mortars after the curing process, the mortars were photographed using a scanning electron microscope. It was observed that as long as the mortar is being cured, the shrinkage has not occurred yet and the mortar has not been cracked; however, in the case of mortar left in the open space, due to the exit of water through capillary pores in the mortar and also the loss of surface absorbed water, shrinkage occurs, which results in creating cracks in the mortar.

3. Conclusion

1. Because of the high correlation between the friction-transfer and pull-off methods, instead of using the expensive pull-off device, the simple, inexpensive, and domestic friction-transfer apparatus can be used.
2. The addition of styrene-butadiene rubber latex increased the shear and tensile bond strength between the repair mortar and the concrete substrate, in which the highest increase was observed when latex used in the amount of 15% in relation to the weight of cement.
3. Inadequate curing increases the shrinkage of the repair mortar, which causes shear stresses at the repairing mortar-substrate concrete interface and reduces the shear and tensile bond strength obtained by the friction-transfer and pull-off methods.
4. The 90-day bond strength between polymer mortars and the concrete substrate, on average, is more than two times the bond strength of ordinary mortars.
5. Increasing the amount of latex reduces the mortar shrinkage, so that the 90-day shrinkage of modified mortars containing 20% of polymer is, on average, 54% less than the shrinkage of ordinary mortars, which prevents bond strength from dropping.