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Evaluation of Flowable High Strength Concrete Used as Repair Material (Review Study)

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Abstract: The use of fibers in concrete or mortar is well known for their potential to enhance the flexural toughness, the energy dissipation and the impact resistance for many structural applications especially in building repairs and other Civil Engineering works. The use of fibers in flowable concrete provides great advantages in arresting cracks and enhancing the flexural rigidity of the composite material. Hence, this study investigates the procedure of tests required to determine the conductivity of the repair material by adoption of some combined systems of repair materials with concrete and the bond action of this repair material (Flowable high strength system).

Key words: Fibers, flowable concrete, repair material, performance, bond strength

INTRODUCTION

The inclusion of fibers within concrete or mortar is well proven to increase the toughness, the energy absorption and the impact resistance in applications like slabs, floors, shell domes, rock slope stabilization, refractory linings, composite metal decks, seismic retrofitting, repair and rehabilitation of atructures, fire protection coatings and concrete pipes (Nataraja *et al*., 1999).

The application of fibers in concrete was regarded to be difficult in the past due to insufficient workability of fiber reinforced mixtures. The development of superplasticizer significantly improved the workability of fiber reinforced concrete. Fibers can have rheological and mechanical synergistic effects in concrete or mortar and the optimized fiber combinations can provide better mechanical performance while maintaining adequate flow or workability properties (Nehdi *et al*., 2004; Ramli and Dawood, 2011a, b).

The repair material may contribute to the mechanical strength of the concrete structure and a high fluidity is required to completely fill cracks and pores. At the same time, a repair material is sensitive to the displacements and must have an elastic modulus as close as possible to that of the concrete substrate. Hence, a repair material with a high fluidity and a relatively high compressive strength is preferred. One of the greatest challenges of repair materials to perform well is their dimensional behavior relative to the substrate. Relative dimensional changes cause internal stresses within the repair material and the substrate. High internal stresses may result in cracking, loss of load carrying capability and structural deterioration. Particular attention is required to minimize these stresses and to select the optimized material to properly address relative dimensional behavior (Liu and Huang, 2007).

PROBLEM STATEMENT

Many structures, especially those made of reinforced concrete, suffer from severe degradation after their construction due to many environmental causes (deicing salts, freezing and thawing, aggressive environment like earthquake etc.) and a drastic increase of live loads. One of the major problems of today is how maintain and retrofit these structures? (Liu and Huang, 2007; Dawood and Ramli, 2009, 2010).

In many instances, epoxy resins were used as repair materials to maintain concrete infrastructures. Epoxy resins are very expensive as a repair material. In addition, thermal aging is accelerated when epoxy resins are exposed to high temperature and humidity. Especially, in countries like Malaysia this results in a drastic increase of costs for the maintenance of concrete structures. Hence, alternative repair materials that are economic while possessing good thermal resistance compared to epoxy resins are needed (Lee *et al*., 2007; Ramli and Dawood, 2008).

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THE PERFORMANCE OF REPAIR MATERIALS

The strengthening, the maintenance and the repair of concrete structures have gained more recognition in the field of Civil Engineering. The selection of repair materials for concrete structures requires an understanding of the material behavior in uncured and cured conditions for the anticipated service life and exposure (Lee *et al*., 2007).

Hassan *et al*. (2000) investigated the compatibility of cementitious, polymer and polymer-modified (PMC) repair materials. They concluded that the high shrinkage strain of cementitious repair mortars affects their compatibility with concrete and indirectly increase the permeability at the interface of the combined system. They also reported that the mismatch between the elasticity modulus of concrete and the epoxy mortar was found to reduce the load carrying capacity of the combined system. For the design of an efficient repair, it was recommended that the repair material should have a higher modulus (>30%) than the concrete substrate.

Dawood and Ramli (2010) have studied the performance of high-strength flowable mortar and high-strength flowing concrete reinforced with steel fibres as repair materials. They evaluated them by adoption of some combined systems of repair materials with substrate concrete to determine the bond action of this repair material (flowable high-strength system). The author concluded that the high-strength flowing concrete has an excellent performance in terms of compressive strength for the repaired system. On the other hand, the high-strength flowable mortar improves significantly the tensile strength of the repaired system.

David *et al*. (2005) have identified the characteristics of successful repair materials. They performed tests on a number of repair materials currently in use across the USA and compiled information for the selection of a repair material. Material types included in these tests were the following: Three magnesium phosphates, one rapid setting cement, three polyurethane polymers, one epoxy polymer, one thermosetting vinyl-polymer and one polymer-modified bitumen. Several tests on the time of setting, compressive and flexural strengths, modulus of elasticity, shrinkage, Coefficient of Thermal Expansion (CoTE) and tensile bond strength were conducted at 40, 70 and 100°F. The following conclusions were drawn from the study:

- The different repair materials have different stiffnesses and were grouped in three categories: rigid, semi-rigid and flexible, with magnesium phosphates representing the most rigid material. While polymer concretes have a lower modulus of elasticity, the ultimate compressive strengths could only be determined for rigid materials and the flexural strength could only be obtained with rigid and semi-rigid materials
- A series of compatibility property tests consisted of experiments on the modulus of elasticity, shrinkage and CoTE. The CoTE increased at decreasing E-modulus. The shrinkage values depended on the type of material and the temperature change during curing. In general, rigid materials resulted in lower shrinkage values while semi-rigid and flexible materials caused high shrinkage values
- Thermal cycling of simulated spalls caused no degradation of the repair materials. Tests on the tensile bond values were performed with each of the repair materials after the cycling but the results were variable which might be partially due to the nature of the test and the variation of the bond surface. Certain types of rigid as well as flexible materials were found to bond well
- Spall repair materials should be selected with consideration and by taking into account the material properties. Based on the bond strength and whether it fits the standard of engineers' specified bond strength, a material should be selected. The overall utility includes the consideration for future repair and the ability of the spall repair material to bond with the overlay

CONCLUSION

The study flowing concrete reinforced with fibers is so important especially due to its application in the repair and rehabilitation of damaged structure field. The experimental tests and the adoption of combined system of proposed repair material and substrate concrete are so needed to understand the performance of the repair material in this regards. One of most important property of the repair material is the bond strength with the substrate concrete. Therefore, the experimental tests for the combined system of the repair material and substrate concrete should be subjected to compression and tension forces to study the performance of this repair material.

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