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Performance evaluation of repair systems under varying exposure conditions

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Abstract

This paper reports results of a study conducted to assess the performance of commonly utilized repair systems when exposed to some selected exposure conditions, such as marine, belowground, fire, acid, and sulfur fumes. The performance of the selected repair systems was assessed by exposing large-sized repaired concrete specimens to the selected exposure conditions in addition to thermal variations. After the completion of the exposure, the repaired specimens were visually examined for damage to the surface coating and presence of rust stains, salt scaling, etc. The bond of the coating with the substrate was evaluated and then the specimens were crushed to retrieve reinforcing steel bars that were examined for the extent of corrosion, if any. The data developed in this study were utilized to recommend repair systems suitable for the selected exposure conditions.

Keywords: Repair materials; Repair systems; Thermal variations; Reinforcement corrosion; Adhesion

1. Introduction

Reduction in the useful service-life of reinforced concrete construction is a major problem confronting the construction industry worldwide. Repair and rehabilitation of deteriorated concrete structures are essential not only to utilize them for their intended service-life but also to assure the safety and serviceability of the associated components. A good repair improves the function and performance of the structure, restores and increases its strength and stiffness, enhances the appearance of the concrete surface, provides water tightness, prevents diffusion of chloride, oxygen and carbon dioxide to the reinforcing steel, and improves the overall durability of the structure.

Several repair materials, particularly repair mortars, are marketed for repair of damaged concrete structures. The repair mortars are classified into different types, such as cement, epoxy resins, polyester resins, polymer latexes, and polyvinyl acetates. Cement-based or polymer-based materials are the most widely used repair mortars [1–3].

While several repair materials, both cement- and polymer-based are used in the repair and rehabilitation of deteriorated concrete structures worldwide, their performance in the hot weather environments, dominated by extremes of temperature and aridity, has not been thoroughly investigated. A few studies conducted at King Fahd University of Petroleum and Minerals, Dhahran Saudi Arabia [1,4–6], have evaluated the short-term durability of a limited range of commercially available repair materials. Dehwah et al. [4] and Basunbul et al. [5] evaluated the durability performance of some cement- and epoxy-based repair materials. Al-Gahtani et al. [6] evaluated the performance of epoxy resins. Al-Juraifani et al. [7] evaluated the performance of repair mortars under hot-weather conditions and performance criteria were

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suggested. Similar criteria were proposed by Vaysburd et al. [8]. Al-Dulaijan et al. [9,10] evaluated the performance of several generic types of surface coatings. Maslehuddin et al. [11] evaluated the performance of steel primers and suggested relevant performance criteria.

As discussed earlier, few studies [1,4–7,9–11] were conducted to assess the performance of repair materials, particularly repair mortars, surface coatings, and steel primers. However, the performance of a complete repair system needs to be evaluated.

This paper reports results of a study conducted to assess the performance of complete repair systems, particularly when exposed to conditions that are commonly encountered in the field, especially in industrial environments.

2. Methodology of research

The details of the ten repair systems and seven exposure conditions investigated are summarized in Tables 1 and 2, respectively.

2.1. Casting of reinforced concrete specimens

Reinforced concrete beam specimens, measuring $0.25 \times 0.25 \times 2.5$ m, with two 16 mm diameter steel bars at the top and bottom and 8 mm diameter stirrups spaced at 15 cm, were prepared for marine and below-ground exposures. Reinforced concrete slab specimens, measuring $1 \times 1 \times 0.15$ m, with two steel meshes of 12 mm diameter steel bars at 150 mm center to center and placed at the mid depth, were prepared for other exposures. Figs. 1 and 2 show the dimensions of the beam and slab specimens, respectively.

The concrete mixtures were prepared with a cement content of 370 kg/m^3 and an effective water–cement ratio of 0.40. ASTM C 150 Type I cement was utilized in the preparation of the concrete mixtures.

Prior to casting, wire leads were soldered to the top and bottom mesh of the reinforcing steel bars. These connections were utilized to measure the corrosion potentials. The steel bar-wire interface was coated with cement paste followed by an epoxy coating to avoid localized corrosion of reinforcing steel due to the galvanic effect. Electrode ports were also installed in both the beam and slab specimens prior to casting of concrete to measure corrosion potentials. The electrode ports consisted of 6 mm diameter Teflon tubes of short length that were inserted to the reinforcement level. The reference electrode was fixed in the electrode port to measure the corrosion potential near the steel level; thus minimizing the inaccuracies in the potential measurements due to the high resistivity of concrete, particularly in the

Table 1
Repair systems investigated

System	Repair mortar	Bond coat	Steel primer	Surface coating
1	Free flowing micro-concrete	Wetting only (saturated surface dry condition)	Single-component zinc-rich epoxy	Chloride/sulfate barrier
2	Pre-bagged acrylic modified mortar	3-Component epoxy resin and modified cement based slurry	Single component zinc-rich epoxy	Chloride/sulfate barrier
3	Portland cement mortar/concrete (max. w/c ratio = 0.38)	Wetting only	Composite cement epoxy	Chloride/sulfate barrier
4	Portland cement/micro-silica mortar (max. w/c + s = 0.38) (micro-silica = min 5% of total cement)	Portland cement/micro-silica slurry (proportions as mortar)	Composite cement epoxy	Chloride/sulfate barrier
5	Portland cement micro-silica mortar (max. w/c + s = 0.38) (micro-silica = min 5% of total cement)	Portland cement/micro-silica slurry (proportions as mortar)	Composite cement epoxy	Chemical-resistant epoxy
6	Resin mortar	None	Single-component zinc rich epoxy	Chemical-resistant epoxy
7	Shotcrete (dry mix) Portland cement (max. w/c = 0.38)	None	None	Chemical-resistant epoxy
8	Shotcrete (dry mix) Portland cement + micro-silica (max. w/c = 0.38) (micro-silica = min. 10%)	None	None	Chemical-resistant epoxy
9	Resin injection grout	None	None	Chloride/moisture resisting, i.e. polymer modified cement
10	Cement injection grout (max. w/c = 0.38)	None	None	Chloride/moisture resisting, i.e. polymer modified cement