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The impact of surface preparation on the bond strength of repaired concrete by metakaolin containing concrete

Reza Mirmoghtadaei, Masih Mohammadi *, Nasibe Ashraf Samani, Seyedreza Mousavi

Shahid Ashrafi Esfahani University, Department of Civil Engineering, Isfahan, Iran

HIGHLIGHTS

- The influence of surface preparation types on the bond strength is assessed.
- Six different types of surface textures are applied through the study.
- Metakaolin is replaced with partial percentages of cement for overlay concrete.
- Physical properties of the interface as well as chemical reactions are considered.
- The highest bond strength at all ages is related to grooved-acid etched specimens.

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ABSTRACT

The article is stemmed from an experimental program in which the influence of various types of surface preparation on bond strength of repaired concrete is evaluated. Six different surface textures are studied: as-cast; wire brushed; acid etched; grooved; grooved-wire brushed; grooved-acid etched. According to ASTM C882, 144 half-specimens as substrate concrete are cast. To form full-specimens, metakaolin containing repair concrete is poured on half-specimens. The bond strength of all specimens is measured through the slant shear method at the ages of 7, 28, and 90 days and compared with one another. According to the results, grooved-acid etched led to the highest bond strength in comparison to other types of surface preparation. On the other hand, proper percentage of metakaolin replacement with cement could improve the bond properties of samples.

1. Introduction

Concrete has been utilized as the major construction material in concrete structures, pavements, offshore structures, water and sewage structures, dams, and so on. Many factors might affect the performance of concrete structures which can be categorized according to physical, chemical, and mechanical changes during its service life. Therefore, concrete structures need regular repairing and rehabilitating in order to have proper level of serviceability, as their main design goal. In recent decades, owners of concrete structures and buildings show a preference to repair the damaged structures instead of reconstructing them.

Several practical articles which addressed growing needs for repairing techniques, materials and factors affecting this field of study are available. For instance, the grouting and sealing of cracks in the scroll cases of the Chkhorotsku hydroelectric plant by means of polymer compositions at the GruzNIIÉGS [1], column injection with cracks less than 1 mm wide [2], the use of resins in road and bridge construction and concrete repair works [3], utilization of epoxy resin and cementitious materials in underwater repair of offshore structures [4]. The importance of the repair has been extended today; the investigation of the problem of building decay in Hong Kong [5]; the repair of a practical case – "Kajima Corporation Minaminagasaki Dormitory", one of the oldest high-rise reinforced concrete buildings in Japan [6]; practical concrete pavement patching specifications for the Virginia Department of Transportation (DOT) [7].

There are several methods for measuring the bond strength between substrate concrete and overlay concrete [8,9]. In a simple process, the effectiveness of a repair material in sealing cracks was evaluated by means of two testing techniques [10]. Core pull-out technique was employed for assessment of the bond strength with an emphasis of minimizing the effect of stress concentrations [11]. Some researchers have used slant shear method for their reports; the bond durability of reactive powder concrete was examined

* Corresponding author at: Department of Civil Eng., Ashrafi Esfahani Uni., Ghaem Blvd., Sepahan Shahr, Isfahan, Iran. Tel.: +98 913 319 81 66; fax: +98 313 650 29 25.

E-mail address: masih.mohammadi@gmail.com (M. Mohammadi).

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Table 1
Chemical properties of binders.

Constituents (% by mass)	Cement	Metakaolin
SiO_2	39.8	49.5
Al_2O_3	6.2	40.25
Fe_2O_3	3.9	2.5
MgO	0.18	1.02
CaO	64.5	2.2
Na_2O	0.18	0.11
L.O.I	1.53	1.9

[12]; focusing on epoxy-repaired concrete, the bond strength of samples was investigated under wetting and drying conditions in Persian Gulf [13]; different methods, including slant shear, were used to study the adhesion of polymer-modified mortars [14]; a series of slant shear, rebar pull-out and tensile strength tests were performed to evaluate the performance of reactive powder mortar in comparison to epoxy resin [15]. Today, Arizona slant shear [16] has been modified and adopted by some codes [17,18]. Some have reported that employing of slant shear test has led to the consistent results [19]. On the other hand, researchers believe that real stress states in structures can be represented well by slant shear in comparison to other techniques [20,21]. The slant shear test uses a cylindrical sample made of two similar half-specimen. Each part has a diagonal surface of 30° to the vertical. Prepared samples are tested under axial loading. The bond strength is evaluated under combined compressive and shear stresses.

The bond strength is dependent on two main reasons: (I) chemical reactions between repair materials and the substrate surface; (II) physical property of the interface surface which influenced by the surface roughness. The surface roughness can be taken into account as one of the most important parameters in achieving proper bond strength between substrate and overlay. It has been proved that slant shear test works well for its sensitivity to the surface roughness [22]. Extensive researches have been done in the surface preparation [23–26]. Pedro et al. introduced the surface preparation as the most important agent in the behavior of interface surface between new and old concrete [27]. Among some studies which have been conducted in the field of the impact of surface roughness on the bond strength of repair materials to the substrate [28–30] and various methods which have been carried out for quantifying the surface roughness, some researchers presented numerical criteria [31], while others adopted quantitative measure of surface preparation [32]. The use of pozzolans in concrete repair works and estimate the bond strength has been studied in recent years [23,26,30]. Using metakaolin as a supplement is not an exception [33]. Metakaolin is an amorphous material which can be produced by the thermal decomposition of kaolin [34].

The objective of this research is to study the influence of various types of surface preparation on the bond strength of new to old concrete. In order to the above investigation, the effect of partial replacement of cement in repair concrete with metakaolin in various states of preparation is examined and compared. Substrate specimens are cast according to ASTM C882 and their surfaces are prepared by the methods of wire brushing, acid etching, grooving, grooving followed by brushing, grooving followed by acid etching. Results were conducted by means of slant shear test and compared with results of as-cast specimens, samples which were tested without surface preparation.

Fig. 1. Dimension of semi-specimens according to ASTM C882.

2. Materials

Following materials are utilized throughout the investigation:

2.1. Cement

Type II Portland cement is used. The chemical properties of the cement are presented in Table 1.

2.2. Aggregates

The grading of aggregates satisfies ASTM C33. Quartzitic gravel as coarse aggregate with the maximum size of 10 mm, relative bulk specific gravity of 2.6 is used. Natural river sand as fine aggregate with relative bulk specific gravity of 2.57 and water absorption of 4.5% is used.

Table 2
Mix proportion of substrate concrete.

Type	Water $\left(\frac{kg}{m^3}\right)$	Cement $\left(\frac{kg}{m^3}\right)$	Course aggregate $\left(\frac{kg}{m^3}\right)$	River sand $\left(\frac{kg}{m^3}\right)$	Metakaolin $\left(\frac{kg}{m^3}\right)$	Super plasticizer $\left(\frac{kg}{m^3}\right)$	Slump (mm)
SC	180	443	738	1067	–	4	44

Table 3
Mix proportion of overlay concrete.

Type	Water $\left(\frac{kg}{m^3}\right)$	Cement $\left(\frac{kg}{m^3}\right)$	Course aggregate $\left(\frac{kg}{m^3}\right)$	River sand $\left(\frac{kg}{m^3}\right)$	Metakaolin $\left(\frac{kg}{m^3}\right)$	Super plasticizer $\left(\frac{kg}{m^3}\right)$	Slump (mm)
OCM0	180	443	738	1067	–	45	138
OCM10	180	396.7	736	1067	44.3	45.4	139
OCM15	180	376.5	736	1067	66.45	45.7	139