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Analysis of mechanical-physical properties of cement-based mortar made with mineral materials and its usage for strengthening of RC beams

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ABSTRACT: The present study investigates the properties of cementitious mortars in which different portions of cement were replaced with mineral materials including electric arc furnace dust (EAFD), red mud (RM), marble powder (MP), and glass powder (GP). Compressive strength at ages of 7, 28, and 90 days, tensile strength at ages of 7 and 28 days, water absorption with durations of 30 minutes, 24 hours, and 72 hours after 90 days of curing, and chemical resistance against sulfuric acid tests were carried out on hardened specimens cured for 28 days. The results show that replacing 15% of cement with marble powder significantly increased the compressive strength of specimens cured for 7, 28, and 90 days. Furthermore, replacing cement with 5 and 15% glass powder or 5% of red mud increased the tensile strength. In order to investigate the performance of the repair mortars, one of them was chosen for strengthening RC beams. Three RC beams were manufactured and tested through 4-point bending scheme. The results indicate that the load-carrying capacity of the strengthened beam by CFRP sheet and repair mortar was the same as the specimen strengthened by CFRP sheet and epoxy resin, and was 60% higher than that of the un-strengthened specimen. It should also be highlighted that using the repair mortar instead of epoxy resin addresses some issues including low resistance to fire and poor connection of FRP with wet surfaces.

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1- Introduction

Several developed countries are working on restorative mortars to address the concrete deterioration issue and strengthening concrete structures. Recent studies show that some industrial by-products or some pozzolanic materials such as electric arc furnace dust (EAFD), red mud (RM), marble powder (MP), and glass powder (GP) can be utilized as a replacement for cement for making restorative mortars [1-4].

Strengthening of concrete structures with FRP materials is a practical, simple, and cost-effective approach. Within the past two decades, FRP materials have attracted a lot of attention for the strengthening of concrete structures, which in turn, has led to increase in their usage in both industry and research areas [5-8]. The main advantages of FRP materials are their lightweight, high strength and stiffness, high resistance against corrosion, and high flexibility [9-11].

2- Materials and Methods

The used materials for the current study to make a cement-based mortar are Mashhad Portland cement Type II, silica fume (SF), stone powder (SP), EAFD, RM, MP, GP, and water. The obtained results from the X-Ray Fluorescence test demonstrate that the cement composition is 61.4% calcium oxide (CaO), and 21.4% silicon dioxide (SiO_2). Furthermore, SF is composed of 90-95% SiO2, and SP has 54.2% CaO, and 16.2% Aluminum trioxide (Al_2O_3) in its composition. EAFD has 53.3% Ferric Oxide (Fe_2O_3), MP has 55.6% CaO, and GP has 61.6% SiO2. In the current study, cement powders are replaced with different minerals (EAFD, RM, MP, and GP) with 5 and 15% mass concentrations, making a total of 9 cement-based mortars.

In this research, the mechanical properties of specimens are evaluated by compressive strength, tensile strength and durability tests. The durability assessment of the specimens was performed by water absorption and sulfuric acid resistance tests. Cement-based mortars were made in a 30-liter mixer. Figure 1 shows the poured cement-based mortars in the forms to be used for compressive and tensile strength tests.

3- Experimental Results and Discussion

3- 1- Compressive strength

An increase in the compressive strength of cement-based mortars depends on the dosage of minerals as a replacement

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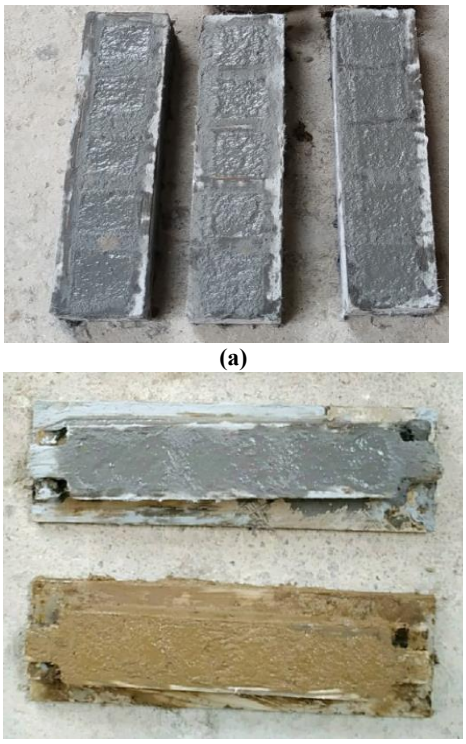

(a)

(b)

Fig. 1. Poured cement-based mortars in (a) compressive strength test form and (b) tensile strength test form

for cement powders, the type of minerals, and the age of the slurries. The best results, in terms of compressive strength, belonged to mortars with 5% and 15% by mass of cement replaced with MP and 5% by mass of cement replaced with GP. The results can be attributed to the void-filling effect and hidden pozzolanic reactions of minerals.

3- 2- Tensile Strength

Using EAFD leads to a reduction of tensile strength compared to MP and GP. Further, the replacement of cement powders with 5% and 15% by mass with GP and 5% by mass with RM mineral will result in an increase in the tensile strength.

3- 3- Using cement-based mortars for strengthening of reinforced concrete beams

To achieve the research goals, three reinforced concrete beam specimens were made and tested under a four-point bending test. One of the specimens was without external strengthening, one was strengthened with CFRP sheets attached to the beam with an epoxy resin, and the last one was strengthened with CFRP mesh attached to the beam with a cement-based mortar.

Dimensions and longitudinal and transverse reinforcement arrangements of each specimen are demonstrated in Figure 2. As seen in Figure 2, steel rebars with 10 mm diameter were used as longitudinal reinforcement, and rebars with 8 mm diameter (with 70 mm spacing) were used as transverse reinforcement. The bottom and side concrete cover of

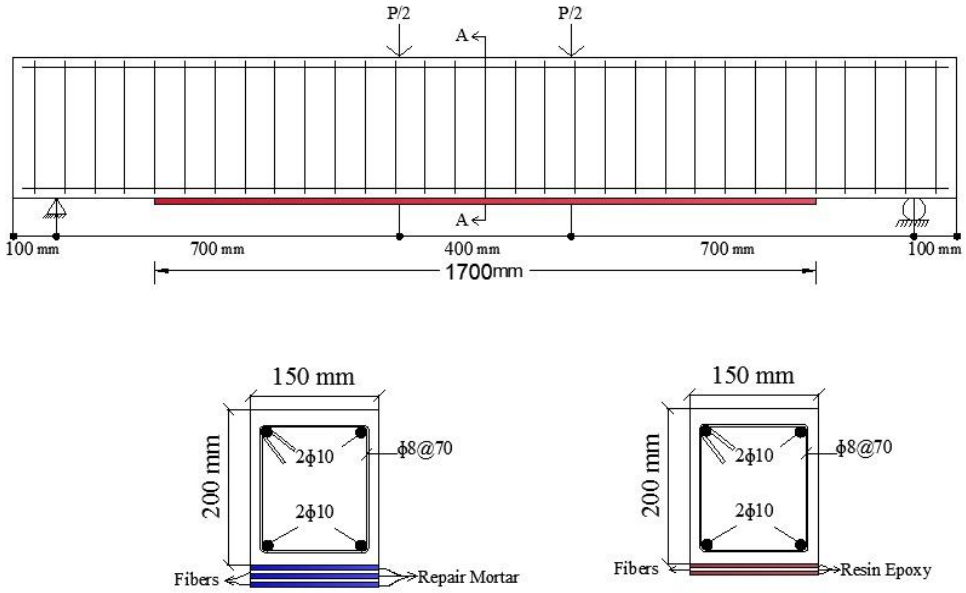

Fig. 2. The dimension, longitudinal and transverse reinforcement arrangement and the location of the applied loads (the dimensions are based on mm) of (a) the specimen strengthened with CFRP and epoxy resin and (b) the specimen strengthened with CFRP and cement-based mortar

specimens was 30 mm. The specimens were made of normal-strength concrete with 30 MPa compressive strength. The specimens were named as Ba-R/M; a indicates the specimen number, and R and M represent the type of epoxy resin and cement-based mortar, respectively.

4- Conclusions

In this study, in order to achieve a practical and cost-effective cement-based mortar for the strengthening of concrete structures, the effect of using some industrial by-products as a replacement of cement powders on compressive strength, tensile strength, water absorption, and sulfuric acid resistance is evaluated. Based on the experimental results, the following conclusions can be drawn:

Using MP as a partial replacement of cement with 15% replacement by mass increases the compressive strength at the ages of 7, 28, and 90 days.

Using EAFD with 15% replacement of cement by mass leads to a significant decrease in tensile strength and a drastic increase in water absorption.

The compressive strength of mortars cured in sulfuric acid for 28 days indicates that the strength of mortars with RM with 5% replacement, GP with 5% replacement, and MP with 5% and 15% replacement are higher than that of reference mortar (the mortar without any mineral as a partial replacement of cement).

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