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Experimental evaluation of the effect of mix design ratios on compressive strength of cement mortars containing cement strength class 42.5 and 52.5 MPa

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Abstract

Cement mortar is one of the major cement-based construction materials and its mechanical properties perform an important role in the strength of structures. The effect of different mortar mix design parameters on its compressive strength has always been of great significance. Specifically, this research investigates the simultaneous effect of cement strength class and sand-cement (S/C) and water-cement ratios (W/C) on the compressive strength of mortars containing with cement strength class 42.5 and 52.5 MPa. For this purpose, an extensive experimental plan with 540 cubic 50 mm specimens made with 36 different mix designs. The results showed that the compressive strength of specimens increased with age and was strongly influenced by cement strength class, S/C and W/C ratio. The optimal mix design in terms of compressive strength is the with S/C ratio of 2.75, W/C ratio of 0.3, and cement strength class of 52.5 MPa.

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Keywords: Cement mortar; Compressive strength; Cement strength class; Water-Cement ratio; Sand-Cement ratio.

1. Introduction

The evaluation of concrete structures from different aspects of the laboratory, optimization, and modeling has attracted the attention of researchers [1-4]. Hence, cement mortar is an important heterogeneous composite used in

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construction. Cement mortar is tasked with provision of uniform stress distribution and thermal deformation, and plays an important role in conjunction resistance properties of structure [5-7]. The significant variables that affect the behavior of fresh and hardened mortar include the water-cement ratio (W/C), the sand-cement ratio (S/C) and cement strength class.

The role of W/C and cement type on the various properties of cementitious materials such as concrete and cement mortar has been extensively studied [8-10]. For example, the effect of changes in water and temperature on deformation of cement and concrete pastes [11], cement content and W/C ratio on the early hydration process [12] and cement type and additives materials on the properties of cement materials [13, 14] have been researched. In another research, Body and Mindess [15] performed an experimental study on the effect of two W/C (0.45 and 0.65) and two types of cement (ordinary and sulphate resistant) on strength and sulphate resistance of concrete at different ages. The results showed that W/C has a greater effect on the sulfate resistance than the type of cement has, and that compressive strength test is more sensitive than tensile test in detecting internal damages, especially at an early age. Also, Kim et al. [16] found that increasing the W/C from 0.45 to 0.6 increases the porosity of cement mortar by 150% and decreases its compressive strength by 75.6%.

Typically, water-cement ratio is the most important mix design parameter for cementitious materials such as cement mortar. Studies on concrete have shown that compressive strength is inversely proportional to the W/C. It should however be remembered that mortar and concrete are more precisely different materials with different structure and composition. Few studies, the effect of mix design factors such as W/C and S/C on the properties of cement mortar have attracted. One of the studies on the effect different materials and mix designs on mechanical properties of mortars have reported that Abram's law applies on mix designs with W/C ratios of higher than 0.4 [17]. Researchers have also expressed the effect of W/C ratio on the compressive strength of cement mortar with a relationship similar to the Abram's law. It has been found applying more parameters to this law will allow it to be used for cement mortars [18].

Research has shown that aggregates have a significant effect on rheology and mechanical properties of cement mortar [19]. So the impact of gradation and sand type on properties of cement mortar has been the subject of many studies [20, 21]. Schutter and Poppe [22] have shown that the type of sand has a significant effect on the properties of cement mortar, as gradation-based geometric parameters of aggregate such as fineness modulus are associated with water demand of the aggregate and dry density of mortar. In a study by Haach et al [23] on the effect of aggregate and W/C on workability and compressive strength of cement mortars, the results show that an increase in W/C weakens the mechanical properties and improves the workability of cement mortar. Reddy and Gupta [24] have studied the effect of sand gradation on tensile strength. The results show the strength is reduced with the change in fineness modulus of sand from 3.21 to 1.72. They have also reported that to make a mortar with a given consistency with fine sand, 25 to 30% more water need to be added to the mix design. There are only a few studies on the combined effects of cement strength class, and S/C and W/C ratios, and their interaction on the mechanical properties of cement mortar. In one of these studies by the same authors, the effects of various cement categories have been investigated by the neural network method. The results showed that cement type is one of the important parameters in predicting the compressive strength of cement mortar [25].

The aim of this research was to determine a wide range of mix design parameters that are required to achieve balanced mechanical properties in the cement mortar. To achieve this purpose, the simultaneous effect of mix design factors such as type of cement strength class, W/C and S/C was investigated through an experimental program. Mixture design was conducted on 540 cubic specimens made with 36 cement mortar mix designs composed of six different W/C, three different S/C and two different types of cement strength classes (42.5 and 52.5 MPa). Compressive strength test was performed to determine the combined effect of factors, and the mix designs with the best mechanical properties were determined.

2. Experimental study

A typical cement mortar is the mixture of sand that acts as the filler material, cement that acts as the binder and water that triggers the hydration process. The basic composition and characteristics of each of these components affect the ultimate compressive strength of the resulting cement mortar.