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A Study on Mechanical Properties, Water Absorption, and Microstructure of Cementitious Mortar containing Recycled Admixtures

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ABSTRACT: Economic concerns and environmental issues have led to increased use of recycled materials in cementitious mortars. To mitigate the adverse effects of cement, it can be partially replaced with recycled materials. In this paper, cement was partially replaced with iron, rubber, glass, and eggshell powders (IP, RP, GP, and EP) by 7, 14, 21, and 28%. Then, compressive and tensile strength, water absorption, and microstructure of the specimens were assessed. The strength tests, as well as microstructure analysis, were conducted at the age of 28-day and the water absorption was tested at the ages of 7, 28, 56, and 90 days. Based on the results, the use of all powders by 14%, enhances the compressive strength up to 14%. Moreover, it was found that up to a replacement ratio of 28%, the tensile strength is greater than that of the control specimen although, in the case of 7% admixtures, maximum tensile strength is achieved. In addition, water absorption of the specimens containing GP and EP up to 35% replacement ratio, is less than that of the other specimens, which was well observed in the SEM analyses.

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1- Introduction

In recent decades, most countries are seeking strategies to efficiently recycle waste materials [1-5]. Based on the review of the latest studies, the wastes could be used for industrial requirements through which the technical, economic, and environmental demands are fulfilled. Today, the rapid development of the industry has accentuated the need for energy production and in turn, the environmental challenges have increased subsequently. Accordingly, to avoid depletion of the natural aggregates and adopt an eco-friendly solution, waste materials could be recycled and reused in construction and building projects [6]. In this respect, waste materials have received significant attention to be partially used as a replacement for aggregates in the concrete, by which the concrete properties could be ameliorated as well [7,8].

2- Methodology

The specimens were prepared in two different forms to conduct the compressive and tensile strength tests. In this respect, standard cube specimens with a size of 50×50×50 mm were constructed for testing the compressive strength and the standard dogbone-shaped briquettes containing iron, glass, rubber, and eggshell powder (with a particle size of 50 to 60 μm) with replacement ratios of 7, 14, 21 and 28%, were prepared to carry out the direct tension tests. In addition, the water absorption test was performed in conformation with the relevant standard at the ages of 7, 28, 56, and 90 days.

Noteworthy, before using the waste materials into the concrete mixes, they were kept in the electric furnace with a temperature of 100°C for 24 to 48 hours so that their humidity is completely lost. In the next step, these materials were crushed by special mills and then, ground into powders with the required size of particles.

It is worthwhile that the wastes to be used in the concrete mixes are taken from the places special for depositing such materials outside the city. The wastes employed in our tests include powders of glass, iron, eggshell, and rubber that are recycled from glass pieces, iron filings, eggshells, and car tires. To prepare the powders, first, the materials with large pieces were collected and then, powdered by the electric grinder. For this purpose, the grinder blades were adjusted to produce particles of the size ranging from 50 to 60 μm.

Table 1 shows the concrete mix designs in detail. The water-to-cement (W/C) ratio is taken equal to 0.4.

3- Results and Discussion

3.1. Compressive Strength Test

The trend of variations in the compressive strength versus an increase in the replacement ratio of the pozzolans has been illustrated in Fig. 1. As observed in Fig. 1, the strength of the control specimen (A) is equal to 15.6 MPa which is set as a criterion for further evaluations. According to Fig. 1, at a replacement ratio of 7%, EP, IP, and RP enhance the strength by 18, 26, and 17%, respectively. As observed, the inclusion

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of 7% GP has reduced the compressive strength up to 5% compared to the control specimen. However, as the GP content goes up, the strength improves by 15 and 36% following an increasing trend compared to the other specimens.

3.2. Tensile Strength Test

In general, except for RP in which the strength is improved only when the replacement ratio does not exceed 7%, the other pozzolans could desirably increase the strength up to the replacement ratio of 28%. Attention should be paid to the point that the size of particles greatly affects the results and thus, to preserve the margin of safety and decreasing trend of variations in tensile strength of some of the specimens, it is recommended to restrict the use of IP, EP, RP, and GP by the replacement ratio of 14% (Fig. 2).

4- Conclusion

- It was observed that by replacing the cement with 7% eggshell, iron, and rubber powders, the compressive strength of the mortar improved by 18, 26, and 17%, respectively. However, the compressive strength declined by up to 5% in the specimens containing the GP which then, raised by 36% as the GP content increased. Generally,

Table 1. Summary of the Mix Designs (kg/m3)

Mix ID	Sand	Cement	Water	Pozzolan (%)				
				0	7	14	21	28
A	1287	770	308	-	-	-	-	-
EP-7%	1287	716	308	-	54	-	-	-
EP-14%	1287	662	308	-	-	108	-	-
EP-21%	1287	608.5	308	-	-	-	161.5	-
EP-28%	1287	554.5	308	-	-	-	-	215.5
GP-7%	1287	716	308	-	54	-	-	-
GP-14%	1287	662	308	-	-	108	-	-
GP-21%	1287	608.5	308	-	-	-	161.5	-
GP-28%	1287	554.5	308	-	-	-	-	215.5
IP-7%	1287	716	308	-	54	-	-	-
IP-14%	1287	662	308	-	-	108	-	-
IP-21%	1287	608.5	308	-	-	-	161.5	-
IP-28%	1287	554.5	308	-	-	-	-	215.5
RP-7%	1287	716	308	-	54	-	-	-
RP-14%	1287	662	308	-	-	108	-	-
RP-21%	1287	608.5	308	-	-	-	161.5	-
RP-28%	1287	554.5	308	-	-	-	-	215.5

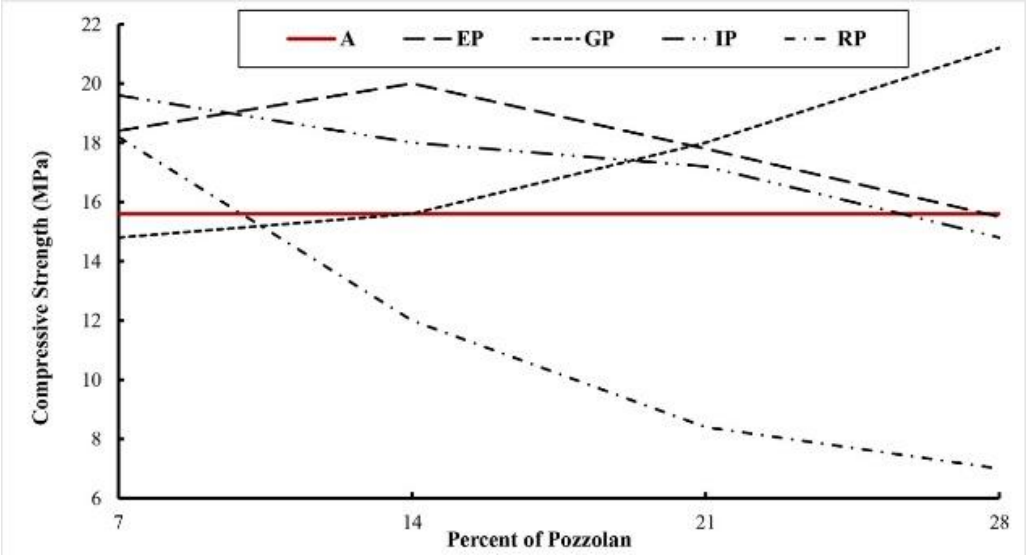

Fig. 1. Compressive Strength Diagram

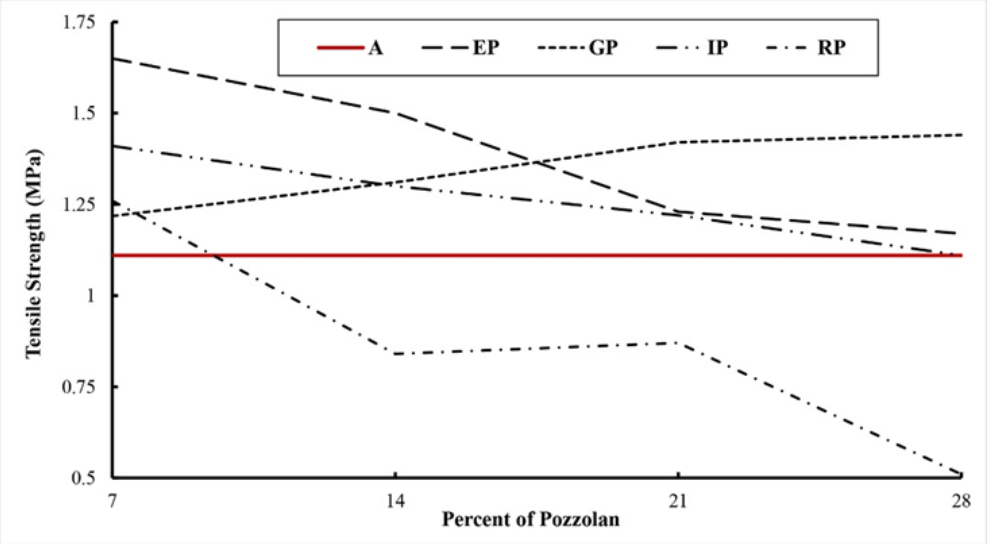

Fig. 2. Tensile Strength Diagram

for the other specimens, an increase in the content of the powders has been followed by a decreasing trend in the compressive strength whose value remains greater than that of the control specimen yet. It was found that the maximum decline in the strength pertains to the cases containing the RP which experienced up to 60% loss of strength that is most likely attributed to the insufficient adherence of the rubber, cement paste, and aggregates. As a general conclusion, the use of 14% pozzolanic wastes in the cementitious mortars desirably affects the compressive strength.

- The tensile strength could improve up to the replacement ratio of 28% except for the specimens containing the RP for which only 7% replacement is recommended. Quantitatively, the tensile strength of the control specimen and the specimens containing 28% glass, eggshell, and iron powders are equal to 1.11, 1.44, 1.17, and 1.11MPa, respectively. In general, the use of 7% of the powders, enhanced the tensile strength of all specimens.
- From the age of 7 to 28 days, the water absorption has significantly varied and on the contrary, at the ages of 28, 56, and 90 days, the water absorption has slightly changed. Accordingly, it was found that the EP and IP reduced the water absorption by 15 and 13% compared to the control specimen in which water absorption is about 19.5%. Moreover, it was observed that as per the increase in the GP content, water absorption decreases by 19%.

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