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Thermal behavior of concrete with waste tire and glass powder as part of fine aggregate and cement

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ABSTRACT: One of the recycling approaches for waste materials like tires and glass is to use them in concrete. In this paper, the effect of the simultaneous use of waste rubber as partial substitution of fine aggregate and glass powder as partial substitution of cement, on workability and mechanical properties, in ambient temperature and after exposure to temperature of 600 °C, is investigated. In order to evaluate the effect of rubber particle size on workability and mechanical properties, two different rubber particle sizes of 0.15-1mm and 3-5mm were used. In total, 13 mixtures were prepared. Except for the reference mixture, the rest contained a combination of rubber particles replacing fine aggregate with the percentages of 5% and 10% by volume and glass powder replacing cement with percentages of 10%, 15% and 20%. First of all, the slump test was carried out. Moreover, compressive strength and tensile strength, before and after thermal exposure, were investigated. In order to have an understanding of waste material's behavior, scanning electron microscopy and energy-dispersive X-ray spectroscopy tests were conducted. the results indicated that 5% for rubber particles, 10% for glass powder and also rubber particle size of 3-5 mm presented the best results among mixtures containing rubber and glass powder, in terms of compressive and tensile strengths.

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1- Introduction

The large volume of non-biodegradable waste materials such as glass and rubber of waste tires has caused serious environmental concerns. Burying waste tires can be a cause of ecological threats due to the presence of toxic compounds. Although burning tire rubber is difficult to, there is always this risk and if it burns, it will produce toxic gases [1]. Also due to glass's non-biodegradability, Waste glass also causes many environmental problems.

In recent decades, researches has been conducted on the effect of using waste rubber as partial substitute for natural aggregate on the mechanical properties and thermal behavior of concrete. As an example, Mousavimehr and Nematzadeh [2] showed that less substitution of rubber caused less reduction in compressive and tensile strength and modulus of elasticity, also by increasing the temperature up to 800°C, loss of mentioned properties and weight in rubber-containing concretes was more than that in the reference concrete.

Researches have been conducted on the effect of using glass as a substitute for cement in concrete and its effect on the thermal behavior and properties of concrete. As an example, Elaqra et al. [3] showed that glass powder–containing concrete with particles smaller than 75 µm had a lower compressive strength, up to 28 days old, compared to the reference concrete, but after 90 days, the compressive strength of concrete with glass powder increased more than that of the reference concrete.

The Innovation of this research is the simultaneous use of rubber and glass powder as substitutions for fine aggregate and cement in concrete.

2- Experimental Program

Portland type 2 cement was used in this research. The used waste glass powder with the particle size of less than 75 µm. The reason was to prevent the alkali-silica reaction (ASR) of the glass powder as much as possible and to increase the pozzolanic reactivity of it.

The rubber particles used were obtained from crumbing of truck tires, which was in two sizes of rubber particles of 0.15-1 mm and 3-5 mm.

13 mixtures were used, which except for the reference mixture, in the remaining 12 mixtures, rubber particles were partially substituted with fine aggregate in ratios of 5% and 10% by volume, in two different particles sizes and glass powder was substituted instead of cement in ratios of 10%, 15% and 20% by weight.

After 28 days of curing, the intended specimens for thermal exposure were placed in the electrical furnace. Heating was conducted at the rate of 3 °C/min, until reaching a temperature of 600 °C and remained at mentioned temperature for one

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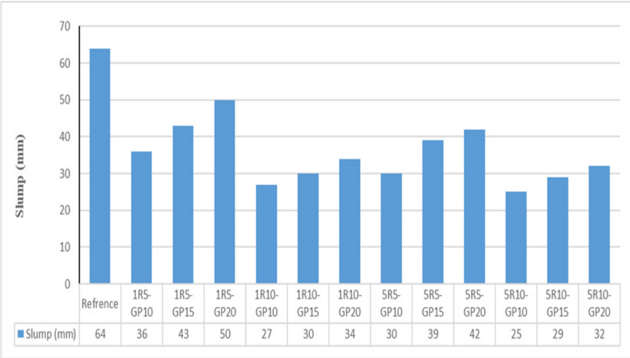

Fig. 1. Results of slump tests of mixtures

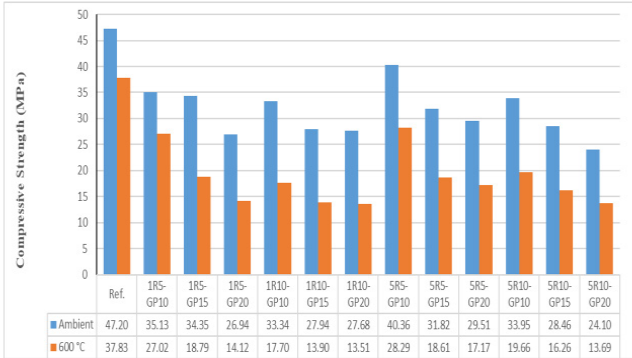

Fig. 2. Compressive strength of mixtures at ambient temperature and 600 °C

hour.

In this research, glass powder as well as, rubber particle sizes of 0.15-1 mm and 3-5 mm, are known as GP and 1R and 5R, respectively.

3- Tests

The slump test was performed for all mixtures according to ASTM C143 [4].

The compressive strength test was performed for all mixtures, using cubic specimens of 150×150×150 mm^3 size, according to the BS EN 12390-3 [5], and the results for each mixture in each thermal condition were obtained as the average of the test results.

Splitting tensile strength test was performed for all mixtures, using cylindrical specimens of 150 × 300 mm^2 size, according to the ASTM C496 [6] and the results for each mixture were obtained as an average of test results.

4- Results and Discussion

The slump of all mixtures containing rubber particles and glass powder was reduced compared to the reference mixture. With increasing rubber replacement rate in both rubber particle sizes, slump decreased. The reason for this change can be attributed to the roughness of the surface of rubber particles. In terms of rubber particle size, it was found that larger particle size, can causes lower slump values. Also, in constant values and particle sizes of rubber, with the increase of glass powder replacement, the slump increases. The replacement rate of 5% rubber and 10% glass powder as well as 1R rubber size provided the highest slump values in the combined mixtures. Slump test results of all mixtures can be seen in Figure 1.

At ambient temperature, the compressive strength of all composite mixtures was lower than the reference mixture. In both particle sizes of rubber and for constant amounts of glass powder, with the increase of rubber content, compressive strength decreased. Moreover, in content amounts of rubber and glass powder, with the increase of particle size, compressive strength generally increased. According to SEM images, there is a gap along the boundary between the rubber and paste matrix which can help to accelerate concrete failure, and this problem increases by increasing the replacement of rubber.

In constant amount and particle size of rubber, with the increase of glass powder content, compressive strength decreased. After heating exposure to 600 °C, the results were almost like results at ambient temperature, but, for constant amount of glass powder and for both rubber particle sizes, with the increase of rubber replacement, a decrease in compressive strength compared to the reference was observed. The intensity of this decrease at elevated temperatures was greater than that at ambient temperature. Which is due to the burning of significant amounts of rubber. Compressive strength at ambient temperature and at 600 °C can be seen in Figure 2.

At ambient temperature, the amount of replacement of glass powder and rubber and the size of rubber particles were effective in splitting tensile strength. At a constant amount of glass powder and for both rubber particle sizes, tensile strength generally decreased with the increase of rubber content from 5% to 10%. In a constant replacement rate of glass powder and rubber, with the increase of the rubber particle size from 1R to 5R, tensile strength increased. With the increase in the size of the rubber particle, the tensile strength, which was always lower than the reference mixture for all combined mixture with 1R size, in some mixtures with 5R size, even with the presence of glass powder, tensile strength was higher than the values for the reference mixture. Moreover, at ambient temperature, with the amount and size of rubber particles being constant, the tensile strength decreased with the increase in the amount of glass powder.

After applying heat, the tensile strengths of the combined mixes were lower than the reference mix. By increasing rubber content, in both particle sizes and constant content of glass powder, due to the burning of more rubber, the tensile strength decreased. Splitting tensile strength at ambient temperature and at 600 °C can be seen in Figure 3.

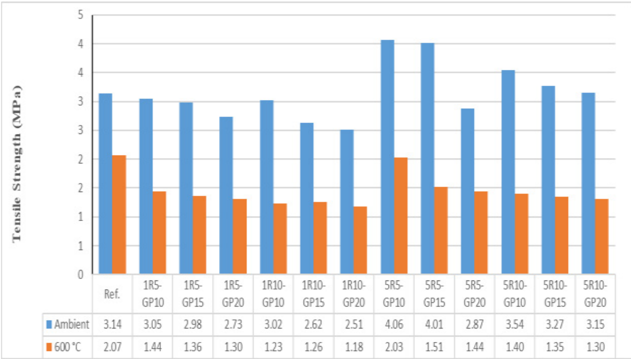

Fig. 3. Splitting tensile strength of mixtures at ambient temperature and 600 °C

5- Conclusions

1. The slump value in all of the mixtures containing rubber and glass powder was less than that in the reference mixture. In terms of workability, the replacement rate of 5% of rubber and 20% of glass powder are the optimal values.

2. In both thermal conditions, the compressive strength of mixes with rubber and glass powder was lower than that of the reference mix. The replacement rate of 5% of rubber and 10% of glass powder were optimal values.

3. In both thermal conditions, the splitting tensile strength decreased with the increase of replacement of rubber particles and glass powder. Optimal values were the same as compressive results.

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