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The effects of waste glass powder usage on polymer concrete properties

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HIGHLIGHTS

- The effects of waste glass powder usage on polymer concrete properties are investigated.
- Effects of resin amount in workability are examined.
- Waste glass powder increased the workability of polymer concrete.
- Waste glass powder increased the compressive and flexural strengths.
- The increases are directly proportional to the ratio of glass powder used in the mixture.

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ABSTRACT

In order to improve basic characteristics of the materials such as strength and resistance, macro-level combinations are carried out to gather superior properties of two or more materials in one material. Polymer concrete is a composite material which was supported by quartz sand as filler that hardens with resin and hardener in continuous polymer matrix. In this study, the effects of the amount of resin used for the production of polymer concrete and the workability of the concrete produced by replacing quartz aggregate powder used as filler with waste glass powder in the ratios of 10%, 20%, 30%, 40% and 47% and their effects on compressive and flexural strengths were investigated. As a result of the studies conducted, along with an increase in the amount of resin used in polymer concrete, an increase was also provided in compressive and flexural strength of concrete. As a result of waste glass powder replacement by keeping the amount of resin fixed, important amounts of increase were found out in compressive and flexural strength of polymer concretes.

1. Introduction

Concrete-polymer composites are materials that are obtained by replacing the entire or some part of the cement binder mixed with water in conventional mortar and concrete with polymer and by reinforcing cement based binder with polymer. The use of polymers in concrete technology can be divided into three main groups as polymer-Portland-cement concrete, polymer-impregnated concrete and polymer concrete. In the polymer-Portland cement concrete, a polymeric film was formed around the aggregates and some parts of capillary voids were filled [1]. In polymer-impregnated concrete, some parts of gel voids along with all capillary voids were filled with polymer. Polymer concrete is a composite material which was supported by aggregates that hardens with chemical reaction and which consists of resin and hardener in continuous polymer matrix. The aggregates can be silicates, quartz, crushed stone, gravel, limestone, calcareous, granite, clay, etc. In the composition different types of fine materials such as: fly ash, silica fume, glass fiber, carbon fiber, etc. can be used to improve the properties of polymer concrete [2–4]. Quartz sand can be added to resin or hardener before or it can be separately added as a third component. The matrix surrounding aggregates in polymer concrete is polymer; there is no cement [5]. Polymer concrete has higher mechanical properties compared to cement based concrete [6].

Polymer concrete is an ideal raw material mixture for the underground constructions with its chemical structure and water impermeability property. While cement-bound mortars cannot resist to chlorine based acidic solutions and the effects of sulfate, polymer-based mortars show resistance both as repair mortar or coating. Polymer concrete is a material that shows good resistance to water and has a high hydraulic capacity thanks to its smoothness. Their adhesion property is the most important property of these materials [7]. Therefore, polymer concretes are mostly used for repair and adhesion in practice. One of the most important properties of polymer concretes is that shrinkage cracks in normal

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concrete cannot be seen in the production of polymer concrete since water is not used. As a result of this property, polymer concretes are materials resistant to frost and chemical effects [5–8]. For this reason, these materials can comfortably be used for the buildings required to be resistant to chemicals. Another property of polymer concretes is that their weights are low according to their ultimate bearing capacities [9]. Polymer concretes whose flexural strengths are higher than normal concretes are used as an additive material for Portland cement concretes, for preventing abrasion on concrete surface, in structural and decorative construction panels, sewer pipes, underground tunnel equipment, drainage canals, for lining of carbon-steel pipes in geothermal applications and constructions like swimming pools.

Extensive research works have been conducted in determining the material characteristics of different types of polymer concrete [10–13]. In this study, the effects of the amount of resin used for polymer concrete production and the effects of the replacement of quartz aggregate powder used as filler with waste glass powder in various amounts on the workability of concrete produced and compressive and flexural strength were investigated. In the study, experiments were divided into two main groups. In the first group experiments, in order to determine the relationship between polyester percentage and strength, polymer concrete was added resin and quartz aggregate in the ratio of 37.5%, 40%, 42.5% and 45%, and its workability properties, compressive strength and flexural strengths were investigated. In the second group experiments, by taking the results of the first experiments into consideration, a test sample that provided ideal and economic properties was selected and the effects of its workability and mechanical properties on polymer concrete properties were investigated by replacing fine quartz aggregate with waste glass powder in the ratios of 10%, 20%, 30%, 40%, 47%.

2. Materials

2.1. Resin

Polyester resin was used as resin. Unsaturated isophthalic polyester resin, one of the polyester resin types found in the market in various types with a trade name of isophthalic polyester, was selected. It is designed for packed casting applications particularly like artificial marble with its good filler acceptance and low tensile properties and it can also be used in applications that do not require fast curing and high thermal endurance and in CTP applications. Its most distinct properties are that it helps to take more quantities since it wets fillers better in artificial marble applications, and it also enables to produce more natural castings with its clean color. Polymer concrete produced from isophthalic polyester is hard, rigid and has a high mechanical strength. Additionally, this resin was preferred since it was cheaper than the others. However, in very thick block castings, it has the risk of cracking due to internal stresses [14]. Polyester is comprised of resin, hardener (as a solution in methyl ethyl ketone peroxide; dimethyl phthalate) and accelerator (cobalt).

2.2. Quartz Sand

Quartz is one of the minerals that is most commonly found on earth and refers to the compound SiO_2 with a mohs hardness of 7, a specific gravity of 2.85 g/cm^3, and a melting temperature of 1785 °C. Quartz sand, which is found in nature as transparent or opaque, colorless or in various colors such as white, red, pink, blue, purple, consists of at least 80% SiO_2 in its raw form (See Fig. 1). Quartz sand can be increased to the ratio of 99.9% SiO_2 by washing, sieving and if needed, enriching by flotation. It is an important raw material that is needed in various fields of industry and is consumed in high amounts. Quartz aggregate was preferred since it provided rigidity and high strength to polymer concrete in which it was used in its production due to its high hardness [15]. Quartz aggregate was divided into three groups depending on its particle size as fine particle (0.5–1 mm), medium-size particle (1–3 mm) and coarse particle (3–5 mm).

2.3. Glass powder

Glass powder is a waste material and it becomes granulated by sieving by means of sieves after they are crushed in the breaker and milled. It is used for surface treatment by blasting, reinforcement of synthetic resins, and path lines. While the use of glass powder along with reinforcing fillers in the processing of polymers enhances the mechanical properties of polymers, it also reduces production costs [16]. The glass powder used in this study is sold in packed of 25 kg after they are milled and sieved (see Fig. 2). Sieve analysis related to quartz aggregate and glass powder used in the experiments was given in Table 1.

3. Preparation of polymer concrete samples

In both experimental groups, hardener was added into the polyester in the ratio of 65% of polyester by weight and accelerator was added in the ratio of 35% of polyester by weight. In order to investigate the workability of polymer concrete, a slump cone was used in the form of a truncated cone with an upper diameter of 50 mm, lower diameter of 100 mm and a height of 150 mm [17]. Easily mixing of fresh concrete, its transportability without any segregation, its placement, compactability and leveling its surface are defined as workability property of concrete. Workability of polymer concretes depends on polymer/aggregate ratio, aggregate granulometry, polymer/filler ratio, the form and viscosity of aggregate. Workability property gets affected by any compounds in concrete and any conditions during production. Slump test is used to determine the consistency of fresh concrete and gives an important idea about workability.

Polymer concrete was filled in the moulds coated with a mould release agent by using a "desk-type vibrator" in order to obtain a compact structure by eliminating the air gaps before hardening occurred. 6 prismatic samples were prepared for each group in the sizes of 40 × 40 × 160 mm for compressive and flexural strength tests (Fig. 3). A cure was applied in the oven at 80 °C for 1 h in order for polyester resin to be completely polymerized and they were kept at the room temperature for 20 days for the tests.

4. Experimental studies

The effects of the amount of resin used for the production of polymer concrete and the workability of the concrete produced by replacing quartz aggregate powder used as filler with glass powder in the rates of 10%, 20%, 30%, 40% and 47% and their effects on compressive and flexural strengths were investigated. In the first group experiments of the study, which was divided into two main groups, in order to determine the relationship between polyester percentage and strength, polymer concrete was added resin and quartz aggregate (Table 2) in the ratio of 37.5%, 40%, 42.5% and 45% and its workability properties, compressive strength and flexural strengths were investigated. In the second group experiments, by taking the results of the first experiments into consideration, a test sample that provided ideal and economic properties was selected and the effects of its workability and

Fig. 1. Quartz aggregate.