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Durability and microstructure properties of SBR-modified concrete containing recycled asphalt pavement

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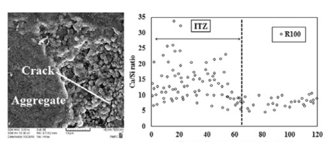
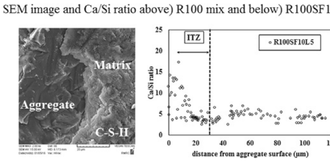
HIGHLIGHTS

- Mechanical properties reduced by replacement of recycled asphalt pavement (RAP).
- The toughness index improved remarkably by replacement of RAP.
- Durability increased by the addition of SF and SBR latex.
- Silica fume and latex reduced the thickness of ITZ significantly.

GRAPHICAL ABSTRACT



SEM image and Ca/Si ratio above) R100 mix and below) R100SF10L5



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ABSTRACT

The road and building industry are the largest material consumers of the earth and the largest producer of solid waste. Recycling and reusing waste materials such as construction and asphaltic waste is one of the practical remedies in order to reduce the consumption of mineral materials. In this study, the effect of silica fume, styrene butadiene rubber (SBR) latex, and recycled asphalt pavement (RAP) on the mechanical properties (compressive, flexural and splitting tensile strength, module of elasticity and toughness), permeability characteristics (water penetration depth, rapid chloride ion penetration, electrical resistivity) were assessed. Additionally, microstructure properties were investigated via scanning electronic microscopy (SEM) and energy-dispersive X-ray spectroscopy (EDX). In this regard, 33, 66 and 100 wt% of coarse aggregates were replaced by RAP. Furthermore, three different curing methods were applied to evaluate the mechanism of latex effect on compressive strength of mixtures. The results showed that the replacement of SBR latex and silica fume led to a significant increase in mechanical properties and reduction of the permeability of concrete mixtures. The interfacial transition zone (ITZ) between the cementitious matrix-aggregate using SEM images indicated that mixtures containing SBR latex and silica fume had a uniform structure at the cementitious matrix-aggregate interface. EDX analysis also indicated the reduction of ITZ thickness and the calcium to silica ratio. It was also found that the compressive strength of the concretes cured in high temperature condition increased remarkably, which exhibits the heat contribution to the formation of a polymer membrane in specimens with latex.

1. Introduction

Concrete is the most important material in the construction of a wide range of structures such as buildings, bridges, platforms and

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underground structures such as tunnels and concrete pipelines. On the other hand, the construction industry is the largest consumer of materials and material removals from the ground [1,2]. It is also the largest producer of solid waste which has been caused concerns in global assemblies about the widespread production of wastes and created challenges [3–5]. In this regard, recycling and reusing waste materials such as construction or asphaltic waste is one of the convenient ways to reduce the consumption of materials [6]. Recycling these materials not only eliminates and solves environmental problems caused by their disposal or burial, but also reduces the consumption of natural basic materials and increases the lifespan of resources and mines [7–9].

Waste asphalt aggregate (WAA) is the reconstruction/exfolia tion-derived of asphalt pavement which forms a large proportion of waste materials. Many of these materials are discarded annually in a lot of countries. Recycling this materials is often dependent on the technical and economic efficiency of transportation to move the recycled materials to the asphalt factory. Various studies have been conducted to evaluate the impact of recycled asphalt crushed materials in conventional concrete mixtures [10–12]. Over the past decades, 100 million tons of recycled materials have been produced annually from rehabilitation and repairing projects of pavements in the United States. More than three billion tons of waste materials are also produced in European countries annually which about 40% is construction waste [13–15].

Although the use of recycled materials in concrete products and cement-based composites has some negative impacts on mechanical properties including compressive strength, it can improve deformation, toughness and absorbed energy and has cost-effectiveness [16]. WAA can be consumed in two forms of fine-grained (sand) or coarse-grained (gravel) which has been covered with a layer of asphaltic material including bitumen, etc. with a thickness of 6–9 μm. In concretes made with recycled asphalt aggregate, the asphaltic coating around aggregates prevents the re-distribution of crack in the interfacial transition zone (ITZ) of concrete that causes toughness improvement.

The concrete containing various percentages of recycled asphalt aggregate and fly ash investigated by Hassan et al. [17]. The results showed that the presence of recycled asphalt aggregate reduces the compressive strength but improves the performance of concrete in the post-peak zone and ductility. Ibrahim et al. [18] examined the impact of replacement of 25% and 50% by weight of recycled asphalt aggregate on rheological, mechanical properties and durability of self-compacting concrete. The results showed that splitting tensile strength fell down in high values of recovered asphalt aggregate. In addition, 25% aggregate replacement was recommended. The coarse-grained recycled asphalt impact production on the mechanical behavior of high strength concrete was investigated by Capson and Sorensen [19]. It was reported that though the replacement of recycled aggregates up to 50% by weight results in the reduction of compressive strength by 44%, the tensile strength increased by 8% with the replacement of 30% recycled aggregates.

Over the last decades, cement-based materials containing polymers have received meticulous attention by researchers. Polymer-modified concrete products in comparison to that of unmodified concrete improve some of the engineering properties including bending strength, tensile strength (direct or splitting), toughness, dimensional stability and durability. Also, the inclusion of polymer materials in concrete not only have a decent performance in concrete exposed to freeze and thaw cycles, but also have suitable durability against severe environmental conditions such as acidic, sulfate, chloride environments and carbonation. In addition, such materials can be employed as repair materials and compensate substrates. Polymer-modified composites provide a good bond at the cementitious matrix-reinforcement/fiber interface which increases the potential tensile strength for their application.

The suspended styrene butadiene rubber (SBR) and various acrylics (AC) are among the most commonly used latexes. In SBR, the styrene to butadiene ratio is one of the important parameters determining the polymer's property in which suitable balanced rate is usually 60%–65%. Higher styrene dosages would develop the compressive strength and tensile strength but reduce bound performance and raise the minimum film-forming temperature [20–22]. Barluenga and Hernandez's [23] investigated the rheology and mechanical properties of mortars containing SBR latex modified. It was reported that the presence of latex would increase the workability and improve the compressive strength and flexural strength.

The primary contribution of this paper, however, lies in the examination of the hardened characteristics of polymer-modified concretes incorporating containing waste asphalt and, most importantly, the examination of the ITZ of concretes containing waste asphalt. To the best knowledge of authors, although many studies on polymer-modified concretes have been performed, there is no research currently available exploring the ITZ characteristics of concretes with polymer and waste asphalt. The study in this paper seeks to address this important gap in the existing literature by exploring the hardened properties of SBR latex-modified concretes incorporating with silica fume and recycled waste asphalt.

2. Experimental program

2.1. Materials

In this study, type I 42.5 ordinary Portland cement and silica fume (SF) according to ASTM C150 and ASTM C1240, respectively was used as cementitious materials (Fig. 1a). The physical properties and chemical composition of cementitious materials have been shown in Table 1.

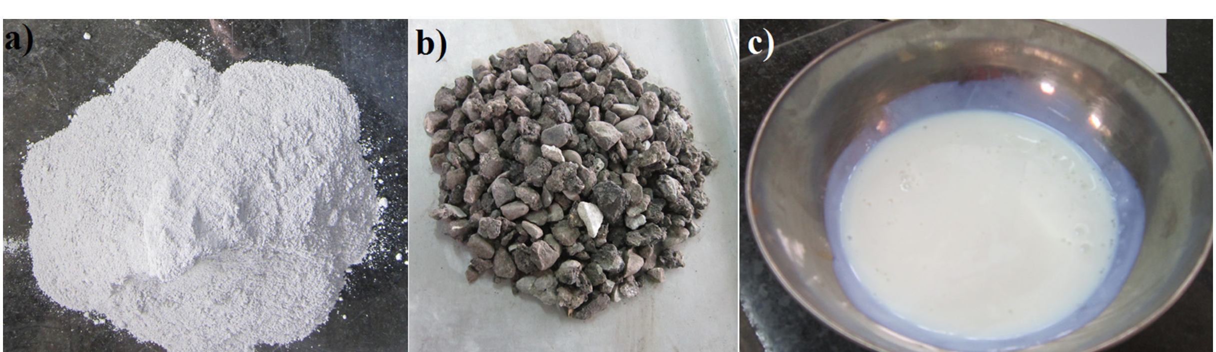

Fig. 1. Raw materials appearance; (a) Silica fume (b): Recycled asphalt pavement and (c) SBR latex.