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Mechanical Properties of High-Performance Concrete Reinforced with Basalt Fibers

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Abstract

Knowledge of the concrete properties such as strength, elastic modulus, thermal expansion, heat generation, shrinkage and creepand durability, are important in the pavement designing. High-performance fiber reinforced concrete (HPFRC) is currently being used in the construction of airport runway and highway pavements but mostly it is used forrapid cure patching and where the early opening of the pavement is required. The reason for less use of HPFRC is its high cost as it employs higher cement content whichresults in thermal contraction problems due to high heat release during setting. In this study, material properties of an economical HPFRC containing Basalt fibers are determined which include compressive strength, elastic modulus and tensile strength. Basaltfibers are relatively cheaper and newfibres for concrete whichare recently investigated by a few researchers. In this study, influence of addition of 1, 2 and 3% Basaltfiber volume fraction in three different mixes of high-performance concrete (HPC) is investigated. The first mix was prepared by using 100% cement and other two mixes were prepared by replacing 10% cement content with silica fume and locally produced met kaolin. Experimental results showed that the addition of Basaltfibersup to 2% fiber volume together with mineral admixtures improved the compressive strength. The improvement in the strains corresponding to maximum compressive strength and splitting tensile strength results was observed at all fiber volumes, whereas there is a negligible influence of the fiber addition on the elastic modulus.

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Keywords: high-performance fiber reinforced concrete; Basaltfibers; silica fume; metakaolin; compressive strength;elastic modulus; splitting tensile strength.

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1. Introduction

Alteration and stabilization of airport and highway pavement slabs using fiber reinforced concrete (FRC) is well established. Typically, FRC is used when the pavement is expected to heavywear and tear; therefore, addition of fibers in the concrete mix, due to a uniform distribution, offers substantial benefits including enhanced impact and fatigue resistance [1], increased flexural strength [1], increased toughness and tensile strength [1, 2], ductility [1] as well as shrinkage cracking control [1-3]. A few examples of FRC pavements are shown in Fig.1.

The most commonly used fiber in FRC pavement construction is steel fiber which though performs quite satisfied for a longer period of time, but in tropical countries like Malaysia, use of steel fiber may not be appropriate due to possibility of surface corrosion [1]. Therefore, it is necessary to look for alternate construction materials offering substantial applications in Pavement Engineering.

During the last decade, Basaltfiber is investigated by few researchers [4-8] due to its characteristics which include good mechanical characteristics particularly high strength, high elastic modulus, high thermal and chemical stability [9], good sound insulation and electrical characteristics [10]. The first use of Basaltfiberin normal strength concrete was reported in 1998 in a report published for Highway Innovations Deserving Exploratory Analysis (IDEA) Project 45 [11] in which performances of 3-D Basalt fiber reinforced concrete (using fiber volume as 0.1, 0.25, 0.4, and 0.5%) and Basalt rod reinforced concrete were investigated. The prominent features endorsed to Basalt fiber reinforced concrete included higher energy absorption capacity after attaining the optimum load and increased ductility. Beside this, it is also mentioned in [11] that Basalt fibers easily disperse in the concrete mix without segregation and lose their shape due to flexibility unlike other fibers which cause difficulty in handling and therefore form balls such as steel and Polyvinyl Alcohol PVA fibers. Similar conclusions are also mentioned in other studies [5, 7] which showed encouraging effect on the concrete strength and its cracking resistance [9]. So far, the optimum Basalt fiber dosage used to produce best mechanical properties is reported as 0.1% in a study [6] (after using 0.1 to 0.3% of Basalt fiber volume) and 0.3% in a study [8] (after using 0.1 to 0.5% of Basalt fiber volume [8]) in the concrete mix. However, the use of higher volume of Basalt fibers in either normal or HPC is not reported in the literature yet. Other than concrete pavements, bridge deck slabs are mostly subjected to reverse cyclic loading and in the study [6], the dynamic behavior of Basalt fiber reinforced concrete is investigated, which showed good results. Therefore, use of FRC incorporating Basalt fibers is one of the good substitutes of conventional steel fibers.

Certainly, to investigate the influence of several important new engineering material parameters on the long-term performance of pavement, it is essential to have sufficient knowledge about material properties including compressive strength, flexural strength, elastic modulus, tensile strength, as well as the coefficient of thermal expansion [12]. Therefore, in this study, the authors used higher fiber volume of Basalt fiber ranging from 1 to 3% in three different HPC mixes to determine the material properties included compressive strength, modulus of elasticity and splitting tensile strength.The first HPC mix was prepared using 100 percent cement content, and other two mixes were prepared by using 10% silica fume and 10% locally produced met kaolin as partial cement replacing materials.

a.Concrete floor,driveway and warehouse built by Macro polymeric Synthetic FRC [13]

b. Pavement with Steel FRC [1]

c. Concrete pavement grade replaced by FRC at Hex ham, Australia [14]

Fig. 1. Examples of the use of FRC in the pavement slabs