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Laboratory investigation of the effect of temperature on frictional properties of concrete pavements containing crushed glass

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Abstract

In this research the effect of temperature on skid resistance of concrete pavements has been evaluated. An experimental approach has been used for this purpose and concrete mixtures containing crushed glass as fine aggregate with different surface textures were tested at different temperatures using British Pendulum Tester, so that concrete mixtures containing crushed glass with 3 different surface textures with different patterns of contact surface (smooth, brushed, grooved) were evaluated at temperature range from 0 °C to 50 °C. The optimum amount of crushed glass in concrete mixtures was determined using the compressive strength test and the mixtures produced by virgin lime aggregates were taken as control mixture. The results indicated that the skid resistance of concrete mixtures with brushed surface had the highest amount compared to other surface textures. Crushed glass aggregates had a positive effect on compressive strength, flexural strength and skid resistance of concrete pavements. It was also found that the skid resistance of all mixtures decreased with an increase in temperature.

Keywords: Skid resistance; British Pendulum Test; Concrete pavement; Glassy concrete; Surface texture

1. Introduction

In the last few decades a lot of fatalities and injuries have occurred due to car accidents. Although the majority of these accidents are related to driving faults, highways have a significant effect on this high percentage of traffic accidents. Skidding on wet pavements contributes to 13.5% of fatal and up to 25% of all accidents and a substantial part of the overall highway toll [2]. Skid resistance is the force developed when a tire that is prevented from rotating slides along the pavement surface [7]. In addition to increasing stop distance while breaking, loss of skid resistance reduces steer controllability and affects driver's ability to control vehicle and slippery roads may cause irreparable damages to inexperienced drivers [10]. Thus providing adequate skid resistance is paramount and one of the best ways to reduce skid related accidents.

The objective of constructing pavements is to prepare a smooth and safe surface for vehicles to commute. In recent years concrete pavements have been widely used throughout the world because of its high strength, good service and long durability [4]. However, as the skid resistance of untextured concrete pavement may endanger road safety, providing surface texture is necessary for improving the friction of concrete pavements. There are two primary functions of textures, providing paths for water to escape from beneath the tires of aircraft or other vehicles and

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providing enough sharpness for the tire to break through the residual film remaining after the bulk water has escaped [12]. Therefore, different textures were provided in this study in order to evaluate and compare the skid resistance of concrete pavements with different textures.

Glass is widely used in our lives and each year about 10 million tons of waste and crushed glass is produced in large cities world-wide, which compose about 3–5% of all household wastes [18]. Recycling waste material can save a lot of energy. One of the alternatives of recycling crushed glasses is using them in different sections of industry [6]. Waste glass has been used as aggregate in highway construction in many countries recently [9,14]. Hence, it would be a good idea to use them in concrete pavements. This paper aims to evaluate the frictional properties of concrete pavement containing crushed glass as aggregate.

There are many methods for measuring the skid resistance of surfaces of which British Pendulum is one. This technique involves measuring the force required to drag a non-rotating tire over a wet pavement [3]. The British Pendulum is used in this study as it can measure the frictional properties of surfaces in laboratory scale. The skid resistance is known to be the function of many factors such as tire type, surface porosity, polishing of surface aggregate, tire wear, inflation pressure, vehicle speed, whether the wheel is rolling or locked and whether the pavement is wet or dry. Therefore all the factors must be fixed or clearly defined during measuring skid resistance of surfaces [7,3].

Temperature is one of the factors that affects the frictional properties of road pavements. Researchers have found that the interactions between pavement surface and tires were affected by climate related factors such as temperature and rainfall [5]. Therefore, the effect of temperature on concrete pavements was investigated in this study.

Many researchers have investigated the skid features of different surfaces and the parameters affecting them. LUO [13] investigated the effect of temperature on frictional properties of Hot-Mix asphalt. For this purpose the skid resistance of asphalt surfaces was measured under different environmental conditions. He illustrated that the skid number decreased by increasing temperature of surface at low speed. However, at high speed, the effect was reverted and pavement friction tended to increase by increasing pavement temperature [13]. Khasawneh and Liang [11] investigated the effect of temperature on skid properties of HMA. They showed that the friction of asphalt surface decreased by increasing the temperature. They also introduced a method for agencies who desire to record skid number (SN) at a reference temperature for a long-term monitoring purpose [11]. Wang and Flintsch [17] investigated the frictional properties of asphalt surfaces in terms of temperature and time. For this purpose they studied the surface characteristic of different sections of Virginia Smart Road pavement facility over a 6-year time period. They confirmed that temperature had a significant effect on the seasonal and multi-year variations of pavement surface friction [17]. The effect of pavement temperature on skid properties of HMA pavement surfaces was also investigated by Flintsch et al. (2003). A total of seven HMA surfaces were periodically evaluated using an ASTM skid trailer with both ribbed and smooth tires over two and half years. The analysis showed that pavement temperature had a significant effect on pavement frictional measurements [5,13].

In this study the skid resistance of concrete surfaces containing fine crushed glass and virgin lime stone aggregates was investigated in terms of temperature and surface texture. For this aim a laboratory study has been conducted on 2 different concrete mixtures with 3 different textures (smooth, brushed and grooved). Compressive strength tests were carried out in order to find the optimum amount of crushed glass and British Pendulum Test were conducted in different temperatures from 0 °C to 55 °C to compare the frictional properties of surfaces.

2. Material and methods

The main procedure of this study was divided into three steps. At first different percentages of crushed glass were replaced in concrete mixtures as fine aggregate (from 250 μ to 600 μ) in order to find the optimum amount of crushed glass. The optimum amount of crushed glass was chosen based upon the maximum compressive strength of concrete which was carried out in accordance with ASTM C39 [6]. After the optimum amount of crushed glass in mixtures had been chosen, compressive strength and flexural strength tests were conducted for all of the specimens at the end of 1th, 3rd, 7th, 28th and 90th days of moist curing. After that British Pendulum Test was conducted to compare the frictional properties of concrete surfaces with different textures and at different temperatures.

Crushed limestone was provided from quarries around Tello (located in north east of Tehran) which are mainly used for highway construction. In order to find out the properties of limestone aggregates, specific gravity (ASTM C127-07, ASTM C128-12), Los Angeles abrasion resistance test (ASTM C131-12) and water absorption test (ASTM C127-12) were conducted on limestone aggregates. Crushed glasses were obtained from Rashid recycling company of Tehran and the physical properties of crushed glass and limestone aggregates (LA) are shown in Table 1. Both types of aggregates met the grading requirements of ASTM

Table 1
Physical properties of crushed glass and LA aggregates.

Physical properties	Lime aggregate	Crushed glass
Specific gravity (fine agg.)	3.87	2.54
Water absorption	0.4	0.34
Specific gravity (coarse agg.)	2.63	-
Los Angeles abrasion (%)	24.1	-