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The effect of rock carbonate types on fatique performance of asphalt mixtures in carbonate rocks of the central Alborz zone

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Abstract

Central Alborz Zone (CAZ) comprises a range of industries and a high concentration population (about one-fourth of the country's population), essential to provide material resources and create the necessary infrastructure for this massive population. The CAZ has a large variety of rock formations and facies, which causes extensive expansion in rock materials and resources. One of the major materials in the CAZ is the existence of a wide variety of carbonate rocks (Elika, Dalichai, Lar, Tizkuh, Ziarat, and Kond formations). This study aims to investigate the geological and engineering geological characteristics of six carbonate formations in the CAZ and to classify carbonate rocks based on their material and their performance in asphalt mixtures. Therefore, by sampling these formations and performing various lithological and engineering geological experiments, six studied formations have been classified, and have been used to evaluate their performance in asphalt mixtures. Selected formations include Elika, Dalichai, Lar, Tizkuh, Ziarat, and Kond. The studied carbonate rocks were classified based on the lithology and performance of their asphalt mixtures in fatigue and cracking test. This classification includes the best performance to the weakest performance, respectively, including Mudstone (Elika Formation), Bioclast Grainstone (Kond Formation), Bioclast Packstone (Dalichai Formation), Bioclast Packstone (Tizkuh), Packstone-wackestone (Ziarat Formation) and Dolostone (Lar Formation).

Keywords: *Central Alborz zone, Carbonate rocks, Fatigue, SCB, Cracking*

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Extended Abstract:

1. Introduction

The Hot Mix Asphalt (HMA) is considered the most widely used construction material for pavements. The HMA is a heterogeneous mixture of materials consisting of aggregates, bitumen, mineral fillers, and air voids. The effects of aggregate properties on the mechanical properties of HMA are essential in designing a high-quality pavement, so requires aggregates of multifunctional characteristics to meet various demands. Cracking is a predominant distress that frequently drives the need to rehabilitate asphalt pavements because of irreversible deficiencies, higher maintenance cost, and shorter serving lifespan (Yan et al. 2020; Liu et al. 2021). Fatigue cracking is caused by loss of adhesion between aggregate particles and asphalt binders or loss of cohesion in asphalt mixture or a combination of both mechanisms (Tan and Guo 2013; Taherkhani 2016; Cong et al. 2017; Kavussi and Naderi 2020; Sadeghi er al. 2022). Basic aggregate such as limestone shows the weakness of binder cohesion which may cause microcracking in the pavement course and acid aggregate shows in such case weakness of adhesion that causes washing-up binder from aggregate and grain raveling (Birgisson et al. 2003). The SCB has been the most widely adopted due to its simplicity of sample preparation and the repeatability of test results (Fan et al. 2018; Ferjani et al. 2019).

2. Materials and methods

The first phase of the study involved the aggregate selection based on the geological and engineering geological test results. In the second phase, mix design was conducted based on the phase one results and Marshall tests. In the last phase of the study, in order to evaluate the performance properties, SCB test was conducted. Six different carbonate aggregate types were obtained from the carbonate formations of the CAZ area (Fig. 1) and considered in this study: micrite (Elika), dolostone (Lar), bioclast packstone (Dalichai), bioclast packstone (Tizkuh), packstone-wackestone (Ziarat), and bioclastic grainstone (Kond). At the reconnaissance stage, thin sections of each rock type were examined and identified under the microscope. Also, in order to determine the type of rock, the mineralogy was evaluated by the X-ray diffraction method. Aggregate gradation specifications were selected according to the Iranian Highway Asphalt Paving Code Number 234 (IHAP (Iran Highway Asphaltic Pavements) 2010). The selected aggregate gradation skeleton with the maximum nominal aggregate size (NMAS) of 19 mm consists of 54% coarse aggregates, 41% fine aggregates, and 5% filler. The asphalt binder PG 64–22 (60/70 penetration) was used as a virgin asphalt binder produced by Pasargad Oil Company to produce asphalt specimens.

The SCB test is a laboratory mechanical test that uses semi-circular bending specimen geometry to evaluate the fracture resistance of asphalt mixtures at an intermediate temperature. The SCB test was carried out by following the procedure of AASHTO TP124. The provisional standard test method calls for specimens with a diameter of 150 mm, a thickness of 50 mm, and a constant load-line displacement rate of 50 mm/min. The notch is 1.5 mm in width and 15 mm in length. SCB tests were conducted at 25 °C using a servo-hydraulic loading device, SANTAM UTM, which is equipped with a temperature-controlled chamber. The flexibility index (FI) was developed based on calculations of the measured fracture energy, which represented asphalt mixture capacity to resist cracking-related damage, and load-line displacement curve post-peak slope (m) values using Eq. (1):

$$FI=\frac{G_F}{abs(m)} \times A \quad (1)$$

Where FI = flexibility index, GF = fracture energy (J/m2), m = absolute value of post-peak load slope m (kN/mm), and A = unit conversion and scaling coefficient taken as 0.01.

3. Results

The obtained results indicated the load–displacement curves, which used for calculating the fracture energy, post-peak slope, and flexibility index. According to the curves, the Ziarat Formation shows the highest peak load and the lowest deformation which indicates brittle behavior. On the contrary, the Elika Formation has the highest deformation and more viscoelastic behavior. Also, the Elika Formation shows higher fracture energy, which can be attributed to the strong bonding between limestone aggregates. Although the other formations have a different composition, they have relatively similar values of fracture energy. According to the flexibility index, the best performing HMA mix is the Elika Formation with a flexibility value of 40.2 followed by Kond, Dalichai, Tizkuh, Ziarat, and Lar Formations from the highest to lowest values, respectively. The Elika Formation specimens have the lowest water absorption and porosity in their structure, so it is evident that has better viscoelastic behavior than other formations due to having enough binder film which may prevent cracking. The Lar and Ziarat Formations show higher water absorption than other formations that cause the higher bitumen infiltration into aggregate pores by selective absorption. With selective absorption, bitumen molecules are scattered inside the aggregate particles, which changes the material from a homogeneous to a heterogeneous material and turns the mechanical properties of limestone aggregates into viscoelastic materials from elastic materials.

4. Conclusion

The purpose of this paper is to establish a relationship between geological parameters of different types of carbonate rocks and hot mix asphalt (HMA) performance.

Specimens with lowest water absorption and porosity in their structure has better viscoelastic behavior. The higher percentage of SiO2 leads to the higher strength of aggregates, elastic behavior and negligible viscoelastic properties. The mineral’s grain-boundary microcracks absorb bitumen which reduces the thickness of bitumen film and viscoelastic behavior. In aggregates with higher water absorption and selective absorption, materials change from homogeneous to heterogeneous and from elastic materials to viscoelastic materials. Aggregate pores absorbed smaller molecular sizes by selective diffusion and left behind larger molecular species, so asphalt becoming brittle and accelerate cracking.

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