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Experimental investigation of the effect of using different aggregate types on WMA mixtures

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Abstract

In recent years, production of warm mix asphalt (WMA) mixtures with the help of chemical additives has been developed due to obvious advantages, such as reduction of pollution emissions, construction temperature and the possibility of carrying asphalt in long distances. Various additives can have positive or negative effects on the performance characteristics of WMA mixtures made from different types of aggregates. Although, effects of different types of aggregates have been more investigated on the performance of hot mix asphalt (HMA), the effects on WMA have been less studied. Therefore, in this study, three types of aggregates including: limestone (Li), siliceous (Si) and slag (Sl) from the metal production factories together with Sasobit and Zeolite additives were provided to be used for the WMA mixtures. After constructing the asphalt samples and determining the optimum binder, Marshall Stability, indirect tensile strength tests and resilient modulus test and the durability parameter determination were performed. Test results indicated that WMA-Sasobit mixtures have the greatest impact on reducing consumed percentage of binder in slag and siliceous aggregates compared to limestone aggregates. For both additives, WMA mixtures containing limestone aggregates showed higher resilient modulus and siliceous aggregates showed lower resilient modulus. Moreover, the results of indirect tensile strength of specimens containing limestone aggregates showed the highest value and siliceous aggregates showed the lowest one. TSR in the limestone and slag aggregates was improved using both additives, but Zeolite additives reduce TSR in the siliceous aggregates.

Keywords: Type of aggregate; Warm mix asphalt; Sasobit; Zeolite; Performance characteristics; Moisture susceptibility

1. Introduction

The warm mix asphalt (WMA) industry follows technological developments, which not only do not change its workability and the physical–mechanical properties of mixtures but also reduce the high mixing temperature of HMA mixtures [1].

The goal of WMA technologies is to obtain required strength and durability which is equivalent to or even better than HMA pavements [2,3]. In addition to have executive and environmental benefits WMA mixtures have some disadvantages such as the asphalt production cost and higher sensitivity to the stripping phenomenon due to reduced mixing temperature and the possibility of a reduction in bonding strength between binder and aggregates [4].

Since aggregate characteristics play a fundamental role on the performance of asphalt mixtures and features of pavement construction, previous studies recommended to use crushed limestone (LS) aggregates due to its advantages. However, siliceous aggregates may have resistance equal to or greater than limestone aggregates [5]. By improving and modification of properties of bitumen, it could take advantage of the vast part of siliceous aggregate

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mines, both in terms of quality and economic. In some areas such as melting factories and slag production with good resistance, this type of aggregate can also be used. Two of the most widely used additives in the production of warm mix asphalt are Sasobit and Zeolite [6,7]. Sasobit additives in WMA can lead to reducing the temperature by 18–54 °C rather than those of HMA [8]. Literature review of the WMA production showed, the most commonly used additive is Zeolite, which contains 0.3% by the weight of total mix, and it has the possibility to reduce mixing temperature by 30 °C [8]. Resilient Modulus (MR) has been used in AASHTO Guide for Design of Pavement Structures (1993) and in Mechanistic-Empirical Pavement Design Guide (MEPDG) [9]. Topal et al. by comparing the properties of WMA mixtures containing limestone aggregates including natural and synthetic Zeolite, indicated that Resilient Modulus of WHA mixtures is higher than HMA mixtures at different temperatures [10]. Ameri et al. (2013) compared the behavior of WMA made from different aggregates and concluded that mixtures contained limestone aggregates (coarse limestone) have a better resistance performance than the steel slag aggregates [11].

Binder-aggregate stripping is a complex which depends upon many variables, such as the type and application of mix asphalt, the bitumen properties (viscosity), the aggregate characteristics and anti-strip additives which are used in blend. Investigating aggregate change effects on the mechanical performance and durability of asphalt mixture is important though complicated. Valdés-Vidal et al. investigated the changes in mechanical behavior of twelve different asphalt mixtures including several types of aggregates and two types of bitumen. They found out that type and surface texture of aggregates have an influence on stability and cracking resistance [12]. Several studies investigated the effect of aggregate type on durability and the moisture susceptibility, especially the effect of adhesion of bitumen to three aggregates (limestone, marble and granite), which showed acid aggregates (granite) have the lowest value of adhesion and resistance to moisture damage [13]. The stripping phenomena may occur naturally, even without the presence of moisture on some aggregates, this phenomenon has been found in some areas with very warm and dry climates like Saudi Arabia and Iran [14]. One of the main mechanisms of moisture damage is the loss of adhesion or molecular absorption at the interface between dissimilar objects which has the task of maintaining bond between mixtures [15].

Adding lime or cement to the aggregates, using of the hydrophobic aggregates or anti-strip additives are some methods to strengthen the adhesion properties of bitumen and aggregate. Kavussi et al. (2012) demonstrated that mixtures containing 3% Sasobit doesn't have negative effect on the durability of WMA which is measured by tensile strength ratio (TSR) [16]. They also showed Sasobit additive besides reducing the mixing temperature improves the workability of asphalt mixture and causes internal lubrication [17]. Shu et al. (2012) found that WMA mixtures containing recycled asphalt pavement (RAP) according to TSR criteria often met the minimum standard of 75% [18]. Ai et al. (2015) the moisture susceptibility of WMA mixtures was tested by boiling water test and the results showed the approximate value of 20% while its minimum value index is 15% [19]. Some filed researches claimed no difference between WMA mixtures compared to HMA ones in terms of rutting performance. Moreover, some practical researches showed improvement on asphalt mixture fracture resistance when WMA technology was used. However, WMA mixtures showed same tensile strength ratio (TSR) results compared to HMA ones. Based on Louisiana WMA mixture investigations, pull-off cohesion and adhesion property test results claimed that Sasobit additive can reduce the cohesion strength [20,21].

So far, simultaneous evaluation of the impact of aggregate type and additive type on the durability and the performance characteristics of WMA has not been concerned. Evaluating the effects of the different aggregate types may even help to understand the negative effects of additives on some aggregate performance. In this research, the most commonly used additives such as Sasobit and Zeolites (synthetic) was used to reduce the mixing temperature and WMA density. In order to evaluate the effect of additive type on the selection of aggregate type, three of the most widely used types of aggregate (limestone, siliceous and slag) were used. Then, tests of Marshall Stability, resilient modulus and moisture susceptibility were carried out to compare WMA mixtures. This research pursues two main objectives: (1) evaluating the effect of different types of aggregates on the performance of WMA mixtures and (2) economic evaluating of the effect of using various aggregates on changing the thickness of warm asphalt layer compared to a conventional one.

2. Materials and laboratory test

Three conventional aggregate types, Limestone, siliceous, and steel slag, were used in this paper. The materials employed in this research were obtained from commercial sources. This section presents the primary materials and test methods included in this study.

2.1. Aggregate

Limestone and siliceous aggregates were prepared from mountain minerals and steel slag from Alloy Steel Plant of Yazd. These aggregates are used to replace natural materials and to avoid waste production and also to observe environmental issues. The used filler is selected from the same aggregates because the effects of chemical properties of aggregate become completely identical and the impact of different filler material does not turn into an effective and new variable in this paper. Steel slag filler material due to its high stiffness was produced by ball mill circulating. Fig. 1 shows the appearance and microscopic image of mineralogy natural aggregates used in this study.