Amirkabir Journal of Civil Engineering

Amirkabir J. Civil Eng., 52(1) (2020) 47-50
DOI: 10.22060/ceej.2018.14707.5726

An Investigation of Factors Affecting The Moisture Sensitivity of Warm Mix Asphalt (WMA)

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ABSTRACT: looking for of increased pollution and environmental concerns, as well as rising fuel and energy prices, the Warm Mix Asphalt (WMA) technology, has been introduced as an environmentally friendly technology, and nowadays the direction of the pavement industry has become more widely used. WMA asphalt technology, despite the reduction in production and compaction temperature and other advantages compared to Hot Mix Asphalt (HMA), has a weakness in moisture damage, which is one of the main concerns of this technology, and the use of Anti-stripping additive is one of the most widely used methods to reduce this damage. Asphalt mixtures of WMA are composed of different materials such as bitumen, aggregate and WMA additives. The study on the effect of each of these materials on the reduction of moisture sensitivity less attention has been investigated. Therefore, in this study in order to aware of road engineers to improve this problem with this type of asphalt mixture will be discussed. Studies showed that the type of aggregate (characteristics of acidity or alkalinity), the type of WMA additive, and mixing and compaction temperature were among the most important factors affecting the WMA asphalt mixture resistance, which indirectly affected the pavement.

Review History:

Received: 7/14/2018
Revised: 8/21/2018
Accepted: 8/29/2018
Available Online: 9/22/2018

Keywords:

Warm mix asphalt (WMA)
Moisture sensitivity
Aggregate
Bitumen
Compaction temperature

1- INTRODUCTION

The use of hot mix asphalt due to the compaction and mixing high temperature increased the amount of energy and fuel consumed and, it poses a serious risk to the environment by releasing pollutants and toxic gases. By increasing environmental pollution, rising fuel, and energy prices, the trend to use of WMA asphalt technology has become more and more universally accepted worldwide. The WMA compared to conventional asphalt mixtures have different advantages and disadvantages. The main advantage of this new technology is to reduce the asphalt production temperature by 20-40 °C, and this reduction in temperature is considered as an effective way to reduce air pollution. Environmental considerations, less aging, lower energy consumption and increased runtime throughout the year are the benefits of this kind of asphalt mixture. On the other hand, the cost of special additives, the cost of refining, equipping asphalt factories and the weakness of the pavement against moisture damage are its disadvantages. The sensitivity of the asphalt mixture to moisture is one of the main concerns of WMA technology that results from the destruction of the bonding between bitumen and aggregate or the failure of the bitumen structure. The presence of moisture in the pavement layer due to the destruction of the bonding between bitumen and aggregate, and during the traffic loading, the structure of the asphalt ruptures and occurs in failures such as rutting and raveling [1]. The moisture sensitivity of asphalt mixture is due to various factors, which in this study other effective factors such as aggregate, bitumen, and various WMA additives are discussing.

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2- INTRODUCTION OF MOISTURE DAMAGE MECHANISM

Although several factors occur simultaneously, causing Anti-stripping, all researchers have reached the consensus that the main factor that causes this phenomenon is the water. In order to accurately assess the mechanisms of damage caused by moisture, it is necessary to identify the sources and routes for its entry and exit in the pavement system. As shown in Figure 1, moisture enters through the pavement structure in different ways [2].

Anti-stripping is a complex phenomenon that affected by various factors, and some of these factors are not known, but some of them, such as pore pressure, detachment, displacement, emulsion, and environmental conditions are accepted as mechanisms of this phenomenon.

3- MATERIAL INFLUENCES OF MOISTURE SUSCEPTIBILITY

Asphalt mixtures consist of various components of aggregates, bitumen, and additives, which each of it has a significant effect on the asphalt mixture properties, Therefore, in order to better investigate the asphalt mixture, it is necessary to examine all the chemical and physical properties of its components. In this research, the effects of aggregates, bitumen, and additives (WMA additive and anti-stripping

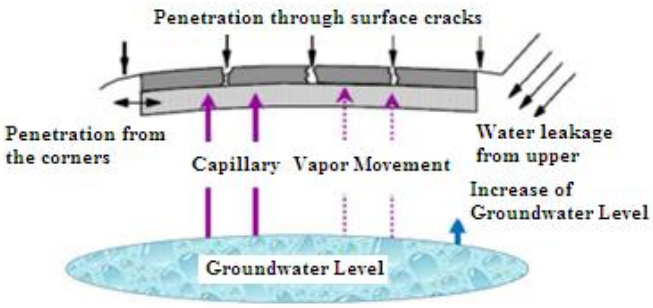

Fig. 1. Possible ways of penetrating water into the pavement [3].

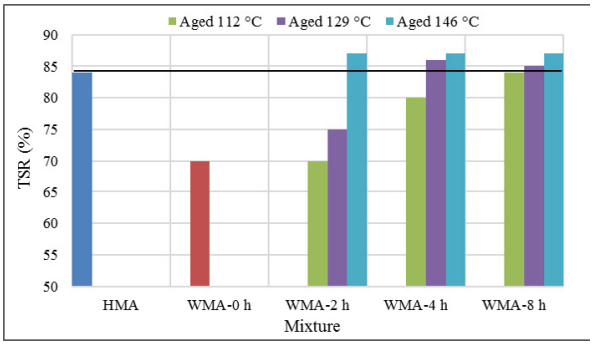

Fig. 2. Effects of temperature and aging time on changes in asphalt moisture resistance [5].

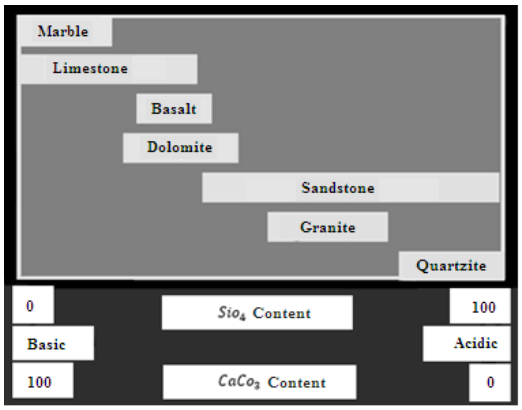

Fig. 3. Composites of various aggregates in terms of alkali-acid properties [6].

materials) was investigated.

3.1. Chemical properties of bitumen

The bitumen structure is complex and its chemical structure is not fully known. Bitumen chemical compounds and their structure depending on the oil and the processes used to produce it. Additives have a significant role in strengthening the chemical structure of bitumen and cause different bitumen behavior, so adding anti-stripping in bitumen with increasing polar groups increases the adhesion between bitumen and aggregates in the presence of water[4].

3.2. Bitumen aging

During the aging process, the physical and chemical properties change, resulting in different bitumen performance in the production of asphalt mixtures. Bitumen moisture resistance is very important and little research has been done in this regard. According to Figure 2, the aging time at low temperatures has a significant effect on the moisture sensitivity of the asphalt mixture.

3.3. Aggregate type

The aggregates have different chemical properties, which results in the different performance of the asphalt mixture against moisture. Aggregates are according to their source of extraction, as well as siliceous or limestone minerals. The aggregates that are mostly silica have their acidic surface, known for their hydrophilic aggregates, and also the limestone aggregates whose surface is alkaline and known as hydrophobic materials. Figure 3 shows the properties of aggregates, and it is observed that the aggregates of acidity possess significant amounts of silica (Sio_2) in their structure, and as materials are high in calcium carbonate ($Caco_3$), the materials are mainly limestone.

4- EFFECT OF ANTI-STRIPPING ADDITIVES

Moisture damage is one of the major failures in the WMA technology, which is due to poor bonding between bitumen and aggregate in the presence of water, this bonding is broken. One of the solutions to this problem is the use of anti-stripping additives to change the properties of aggregate surface and compatibility and improve adhesion between bitumen and aggregates. The effect of some anti-stripping agents on the moisture resistance of the WMA asphalt mixture was mentioned below.

4.1. Gilsonite

Gilsonite (natural bitumen) as a mineral material has a significant effect on the moisture properties of the warm mix asphalt. The presence of significant asphaltenes, as well as the nitrogen components in gilsonite, has caused the material to form a strong adhesion between bitumen and aggregate. In the Sobhi and Hesami research, the percentages of this additive were added to the asphalt mixture of WMA. Results showed that due to increased viscosity, the presence of calcite and dolomite in itself, as well as high percentage of asphaltenes, it has very good adhesion to silica aggregates and causes an improvement of bitumen-aggregate bonding. Also, it causes a significant reduction of moisture deterioration in WMA mixtures [2].

4.2. Hydrated Lime

Extensive research has been done on the effect of hydrated lime on the moisture resistance of asphalt mixtures, which shows that lime as an anti-stripping material changed the mechanical properties of the mixture and it increases the moisture resistance of the asphalt mixture.

4.3. Zycotherm and zycosil

Zycotherm, as a silicon nanotechnology additive, improves the moisture sensitivity of asphalt mixtures due to its strong chemical bonding between bitumen and aggregate. The performance of this anti-stripping agent is based on two

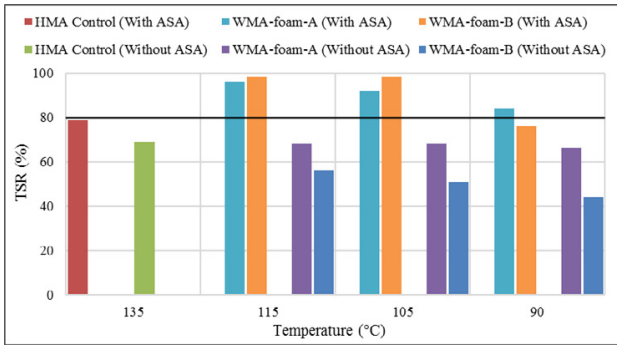

Fig. 4. Effect of compaction and mixing temperature on moisture sensitivity of asphalt mixtures [9].

organic and inorganic phases that interact with the formation of a covalently bond between bitumen and aggregates [7].

5. COMPACTION AND MIXING TEMPERATURE

The compaction and mixing temperature of the warm mix asphalt is the main and key factor in the amount of compaction mixture and coating bitumen and aggregate. The compaction of asphalt mixture cause to reduce the volume and its voids and thus increases the strength of the mixture against moisture damage[8, 9]. According to Figure 4, by reducing compaction temperature the amount of Asphalt mixture moisture sensitivity increases. In general, it can be concluded that the compaction and mixing temperature along with other factors are the most important parameters in determining the amount of resistance of the mixture to moisture.

6. CONCLUSIONS

Asphalt mixture moisture sensitivity is a structural failure and one of the potential failures in the asphalt pavement of WMA, which plays an important role in the mechanical performance of asphalt mixtures. Therefore, this requires more study and attention to extending the pavement life. This study was conducted to better understand the factors affecting the moisture sensitivity of WMA technology, some of which are as follows:

1) The type of aggregates used in asphalt mixes based on the acidity theory in terms of their acidity and alkalinity has a significant role in the formation of the bond between bitumen and aggregates. Generally, aggregates of alkali (calcareous aggregate) have a stronger bond with bitumen than acidic aggregates and have higher moisture resistance.

2) Neat bitumen generally has acidic properties and modified bitumen with WMA additive (Sasobit) increases the acidity of bitumen, in which case aggregate bitumen forms a stronger bond to acidic aggregates.

3) Due to the structural similarity, slag (steel and copper) and limestone are alkaline properties, and its use in the WMA asphalt mixture, together with the improvement of other failures, leads to increased resistance in the moisture content of the asphalt mixture.

4) The mixing and compaction temperature of the asphalt mixture of WMA is the main and key factor in the amount of asphalt mixture compaction and bitumen and aggregate coating that is directly related to the moisture resistance of the mixed mixture.

5) Aging on the moisture resistance of the asphalt mixture has a positive effect and increases the TSR. Also, the aging time of bitumen at low temperatures reduces moisture damage, and this effect decreases with increasing temperature, and decreasing the aging time will increase the sensitivity of moisture

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HOW TO CITE THIS ARTICLE

S. Sobhi, A. Yusefi, S. Hesami, M. Ameri, An Investigation of Factors Affecting The Moisture Sensitivity of Warm Mix Asphalt (WMA), Amirkabir J. Civil Eng., 52(1) (2020) 47-50.

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