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Study of the amine-based liquid anti-stripping agents by simulating hot mix asphalt plant production process

Ebrahim Hesami [a,b,*], Gholamreza Mehdizadeh [c]

[a] Babol University of Technology, Babol, Iran
[b] ÅF Infrastructure AB, Stockholm, Sweden
[c] Islamic Azad University, Tehran, Iran

HIGHLIGHTS

- The effects of liquid antistripping additives on moisture sensitivity of hot mix asphalt is experimentally studied.
- The plant production condition is considered in the experiments.
- The plant and lab samples are extensively compared.
- The presented methodology is highly efficient for the HMA production plants.

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ABSTRACT

Stripping is one of the major distresses threatening the longevity of hot mix asphalt (HMA) pavements. Numerous types of liquid anti-stripping agents have been introduced to reduce moisture susceptibility of the Asphalt in HMA pavements. However, laboratory findings on the asphalt binder samples might be quite different with the actual conditions of mixing processes in asphalt plants. In HMA production plants, HMA mixtures and/or asphalt stored in asphalt storage tanks, are kept at high temperatures for hours, which drastically reduces the effectiveness of liquid anti-stripping agents. In this study, it is intended to simulate the HMA production conditions and then investigate the impacts of two types of liquid amine-based anti-stripping agents on the performance of HMA using the tensile strength ratio (TSR) and semi-circular Bending (SCB) tests. Results of this study indicated that effectiveness of these additives was significantly decreased after long-term being heated for HMA production. It is recommended that use of the manufacturer's suggested percentages of liquid anti-stripping additives, should be carefully reexamined with regard to production conditions.

1. Introduction

Moisture damage usually occurs in flexible pavements due to the separation of asphalt binder from the surface of the aggregate in the presence of water. This phenomenon is responsible for occurring stripping and other premature distresses individually or simultaneously. Moisture damages in the asphalt mixture cause serious problems such as loss of strength and durability, increasing costs of the repair and maintenance of flexible pavements. The disintegration of asphalt binder-aggregate, raveling and pothole development and cracking, are some of the damages caused by moisture [1]. Pavements made with hydrophilic aggregates, due to greater affinity to water rather than asphalt are highly vulnerable to stripping. There are diverse methods to prevent moisture damage, such as adding hydrated lime [2], cement or limestone powders as filler [3], liquid anti-stripping additives [4], nanomaterial [5,6] and different polymers [7–10] These methods have been chosen based on their effects on asphalt mixtures, which also can be added to aggregate or asphalt binder.

Laboratory and field studies have shown that use of hydrated lime consistently improved the resistance to moisture damages in the HMAs compared to other available approaches [1,3,11–13]. However, most agencies and contractors are more interested to use liquid anti-stripping additives, in the form of cationic surface-active agents, generally amines, due to easier and safer application rather than hydrated lime powder. Amines are organic

* Corresponding author at: Babol University of Technology, Postal Box: 484, Babol 71167-47148, Iran and ÅF, Infrastructure Division, Frösundaleden 2, 169 99, Solna, Sweden.

E-mail addresses: hesami@kth.se, Ebrahim.hesami@afconsult.com (E. Hesami), smehdizadeh31@yahoo.com (G. Mehdizadeh).

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compound in which functional group contains a Nitrogen atom with a pair of electrons. Several researchers have studied the performance of liquid anti-stripping additives on the reduction of moisture damages in asphalt mixes, showing the positive role of these materials in reduction of moisture and being more economical compared with other options in some cases [14].

There are several procedures to add liquid anti-stripping in asphalt plants. Adding additives to the HMA can take place during mixing or by using dosing pumps, which directly pumps a very precise flow rate of additives to the asphalt binder in an asphalt weigh bucket prior to delivery to the hot mix plant. Fig. 1 is illustrating the two possible places for adding additives to asphalt binder in asphalt plants, i.e. hot asphalt cement storage and asphalt weigh bucket.

In practice, regardless of the method used, the asphalt mixture produced with the modified asphalt binder will be maintained at approximate production temperature (for storing, loading, transportation, laying and compaction) for several hours, which has adverse effects on additives.

From the literature, it can be concluded when a liquid-treated mixture is exposed to long-term heating, the amount of additives is decreased in the asphalt mixture. A study later showed that the lighter amine compounds of liquid anti-stripping additive were evaporated, and heavier particles remained after being heated, showing no anti-stripping effects. In this research, it was observed that the values of the indirect tensile strength (ITS) ratio of the mixes with liquid amine anti-stripping additives, failed the permissible value only after six hours of heating. Moreover, the results showed that heavier compounds of liquid anti-stripping additives, which have remained in the mixtures after prolonged heating, were not effective on reduction of moisture sensitivity of the mixture. Chemical changes which occur during heating process of liquid amine anti-stripping additives are adversely effective on the bonding between asphalt and aggregate [15].

In another research, liquid anti-striping agents were mixed with asphalt binder and placed in oven at 163 °C for 3 days. These binders were used to prepare asphalt mixture samples. These samples were kept in water for 1, 28 and 90 days. It was observed that keeping binders with liquid additives in the oven reduced the anti-stripping effects of liquid additive. Therefore, stripping in mixtures can be due to aging of asphalt binders which have been stored for 3 days in oven at 163 °C [16].

Usually when liquid amine chemical based additives are added to asphalt binder at 140–190 °C, nitrogen groups of these additives reacts with polar groups of asphalt binder to form compounds with no anti-stripping property [17].

This paper presents a discussion on the effects of liquid amine anti-stripping additives on the moisture sensitivity of the HMA by simulating the production process in the HMA plants and considering reasonable time intervals between production and implementation of asphalt mixture. The study is consisted of the following variables:

(i) Three types of liquid amine anti-stripping additives;
(ii) Time when the modified asphalt binder remains in asphalt binder flax;
(iii) The time asphalt mixture is stored before laying down at the approximate temperatures of asphalt production.

2. Experimental design

2.1. Materials

2.1.1. Aggregates

The mineralogy of the aggregates is reported in Table 1. The major mineral part of the aggregates is silica, which made the aggregates hydrophilic. Physical properties determined by different tests, are given in Table 2 [18–29].

Aggregate gradation used for preparing asphalt mixtures samples are given in Table 3, which is selected the average value of upper and lower limits of AASHTO T11&T27 grading for producing dense asphalt mixtures.

2.1.2. Asphalt binder

In this research, 60–70 grade asphalt binder was used for producing samples. According to ASTM-D1559, 4.7 was selected as the optimum binder content for producing asphalt samples. Asphalt binder properties are given in Table 4.

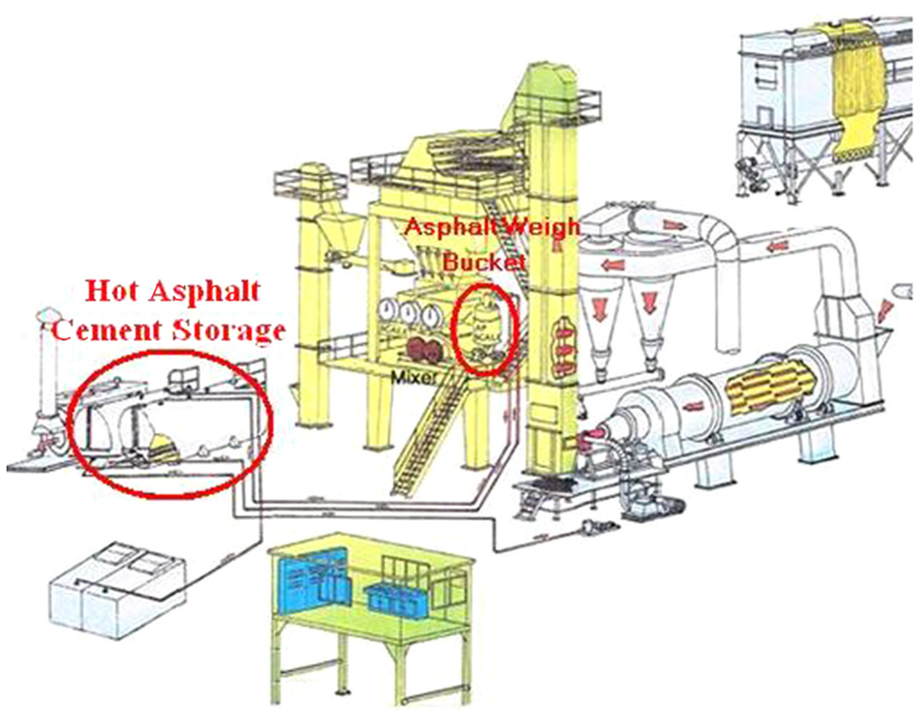

Fig. 1. Schematic of passible places for adding additives to the asphalt binder in asphalt plants.