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Evaluation of the effects of anti-stripping agents on the performance of asphalt mixtures

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HIGHLIGHTS

- Asphalt mixtures containing anti-stripping additives exhibited improvement of adhesive property.
- Hydrated lime showed maximum coating in comparison with Iterlene In/400-S.
- Iterlene In/400-S and hydrated lime increase the indirect tensile strengths in dry and wet specimens.
- Applying anti-stripping agents promoted TSR values of asphalt mixes against moisture susceptibility.
- Iterlene In/400-S showed better results of TSR compared with hydrated lime.

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ABSTRACT

Stripping is one of the most commonly occurring distresses in bituminous pavements. This occurs as a result of destruction of the bond between aggregate particles and bitumen. Impacts of traffic loading, aggregate type, bitumen characteristics and properties of the additives in mixes can modify resistance of mixes against moisture damage.

This study is aimed at determining the effects of two different anti-stripping additives, namely hydrated lime and a liquid anti-stripping agent (Iterlene In/400-S) on hot mix asphalt (HMA). Moisture susceptibilities of samples were determined by analyzing digital images taken from coated aggregate particles after performing boiling water test (ASTMD 3625). In addition, Modified Lottman test (AASHTO T283) was performed on mixes containing 0.2%, 0.3% and 0.4% of liquid anti-stripping agent and mixes containing 1%, 1.5% and 2% of hydrated lime.

The results indicated that the addition of hydrated lime and liquid anti-stripping agent increased moisture resistance of asphalt mixes to some extent (i.e. 13% and 16% of TSR ratio, respectively). Moreover, it was concluded that mix samples prepared using the liquid anti-stripping additive imparted more correlation and greater resistance to water damage, compared with control mixes and those containing hydrated lime.

1. Introduction

Many roads are paved applying hot mix asphalt (HMA) that imparts flexibility, comfort and ease of application. However, poor construction practices and defects of maintenance and repair works, frequently lead to complete HMA pavement failures [1]. Most of pavements in humid and wet climates encounter failures such as rutting, cracking and stripping [1] which occur as a result of traffic loading, thermal variation and water damages [2–6]. Water penetrates through pavement surfaces, causing failure between aggregate particles and bitumen which will finally result in stripping and raveling in pavements [7,8]. Stripping is one of the major failure modes defined as the bond destruction between bitumen and aggregate particles [9–11]. By punctual detection and fixing the defects, total destruction of pavements can be prevented [12].

Various studies confirmed that bitumen binder characteristics, aggregate type and mineralogy, aggregate surface texture and environmental conditions contribute to pavement deterioration appreciably [13].

In good climate regions, where aggregate quality is also good, the main reason of stripping is traffic loading. In severe climatic conditions, however; water, poor quality aggregates and inadequate control lead to stripping [14]. Due to scarcity of high quality aggregate sources, low quality aggregates may be used, which may

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result in early stripping of pavements [15]. In order to control and decrease damaging effects of water, many researchers suggested to apply anti-stripping additives to increase the bond between bitumen and aggregates, leading to improved wetting resistance and decreased bitumen surface tension [16–19]. Because of low cost and easy application, liquid anti-stripping agents, such as amines and di-amines have been commonly used [17]. The main disadvantage of these additives is their weakness against failures such as rutting [14]. Studies showed that amino additives increase Marshall Stability and stripping resistance of asphalt mixes and also increase service life of road pavements to some 25% [20].

Considerable literatures emphasize the application of hydrated lime to HMA mixes in order to improve their moisture resistance and imparting other additional benefits, including increased stiffness and resistance against rutting [21–23]. Increased bonding between bitumen and aggregate particles will end in reduced salt damage and enhanced stripping properties [23]. Researchers have concluded that the most effective amount of hydrated lime for controlling the moisture damage is 1–2% by dry weight of aggregates [24].

Testing methods that identify moisture susceptibility of asphalt mixes can be classified into qualitative and qualitative testing methods. Boiling water test and Static Immersion test (AASHTO T182) for example, are qualitative tests, indirect tensile strength (ITS) and Stiffness Modulus determination testing methods that determine mechanical strength of mixes are considered as quantitative testing methods [25]. The main disadvantage of qualitative tests is the role of visual inspection of people performing the tests. In order to overcome these problems, image analysis methods have been developed which result in objective and rather accurate data with little visual judgments [26].

Lottman Modified test (AASHTO T283) that can be considered as a quantitative testing method is one of the most commonly used tests for determination of moisture induced damages [19,25,27,28].

2. Scope and objectives

This research was focused on investigating the role of a liquid anti-stripping agent and hydrated lime filler in a continuously graded asphalt mix and subsequently their influence on moisture susceptibility of HMA. Three different percentages of Iterlene In/400-S and three different amounts of hydrated lime were added to asphalt mixes. Boiling water test (ASTM D3625) and Modified Lottman test (AASHTO T283) were performed to evaluate the effects of different amounts of anti-stripping additives on moisture susceptibility of mixes. The specific objectives of this research were to investigate the effects of hydrated lime and liquid ant-stripping agent on HMA using both mechanical tests and image analysis method.

3. Material and experimental testing

3.1. Bitumen

The base binder was an 85/100 penetration grade bitumen from Tabriz Refinery. Conventional bitumen tests, including softening point, penetration and ductility tests were performed on the base bitumen binder in order to determine its physical properties. The results are reported in Table 1.

3.2. Additive

Iterlene In/400-S is a dense liquid anti-stripping agent. Application dosage of this in mixes is between 0.2% and 0.4% by weight of bitumen, as recommended by the manufacturer [29]. In accordance with previous studies, it is suggested not adding the liquid anti-stripping agents directly to mixes at their mixing temperatures, but blend it with binder before mixing [30]. Physical and chemical properties of Iterlene In/400-S are reported in Table 2.

Table 1
Properties of the base bitumen.

Test	Standard method	Result	Specification limits
Penetration (25 °C; 0.1 mm)	ASTM D5	89	85–100
Softening point (°C)	ASTM D36	47	45–52
Ductility (25 °C)-cm	ASTM D113	102	Min.100
Flash point (°C)	ASTM D92	283	Min. 232

3.3. Aggregates

A sand stone aggregate, from Ojan Chai Quarry, near Bostan abad city in East Azerbaijan, Iran was used in the whole research. Gradation of aggregates was selected so that to conform with Type 3 wearing coarse gradation of Iran code of practice (Table 3). Tables 4 and 5 show the physical properties of both coarse and fine aggregates. In order to determine chemical compositions of the aggregates, ASTM C25 testing method was performed. The results are reported in Table 6.

4. Testing program

Two commonly used tests were applied to determine the moisture susceptibility of aggregates, namely, ASTM D3625 (boiling water) and AASHTO T283 (Modified Lottman) tests.

4.1. Boiling water test

Boiling water test (ASTM D 3625) is one of the simplest testing methods that is used to evaluate the adhesiveness characteristics of aggregate particles with bitumen (using a visual rating of the degree of stripping after test conditioning).

Coarse aggregate particles (6.5–9.5 mm) were coated with binder containing hydrated lime and the anti-stripping additive. An amount of 250 g of loosely coated aggregate particles were placed in water and were boiled for 10 min. After discarding water, the blends were placed on a white paper to estimate the amount of stripping visually. Images were also taken from different samples using a digital camera. The shots were then transformed into digital images, containing white and black pixels (Fig. 1). The stripped areas or uncovered parts of the aggregate particles are recognized by white pixels. The images were then cropped to define the exact stripped areas. Finally, in order to obtain the exact numbers of white pixels and evaluate the amount of stripped areas, MATLAB and AUTOCAD softwares were used. The results of this analysis are reported in Table 7.

4.2. AASHTO T283 (Modified Lottman test)

AASHTO T283 Modified Lottman test (ITS) is used to determine moisture sensitivity of compacted asphalt samples after subjecting them to saturation conditions [31]. In this research the optimum bitumen content of the mix was determined to be 5.6% by weight of the mix. ITS testing is consisted of loading a cylindrical sample with vertical compressive loads applied on its diametric plane. Failure usually occurs in the form of splitting along this loaded plane [32]. This test is performed on compacted specimens to reach an air void content in the mix ranging from 6% to 8%. Six specimens

Table 2
Properties of Iterlene In/400-S liquid anti-stripping additive.

Aspect	Liquid
Color	Amber
Density at 20 °C	0.90–0.96 g/cm^3
Viscosity at 20 °C	400 ± 50 cP
Flash point	>160 °C
PH	Base