Construction and Building Materials 144 (2017) 399–405

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Evaluation of moisture susceptibility of asphalt mixture using liquid anti-stripping agents

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HIGHLIGHTS

- Asphalt mixtures containing anti-stripping additives were evaluated.
- Several tests were conducted to qualify mixtures' moisture susceptibility.
- Hamburg wheel tracking test data were analyzed by several methodologies.
- The result shows that the developed agents enhance moisture resistance and rutting resistance.
- Field testing indicates the feasibility of applying the anti-stripping agent.

ARTICLE INFO

Article history:
Received 5 December 2016
Received in revised form 7 March 2017
Accepted 28 March 2017

Keywords:
Anti-stripping agent
Asphalt mixture
Boiling water test
Moisture susceptibility
Hamburg wheel tracking test
Field application

ABSTRACT

In this study, aliphatic amine type-developed liquid anti-stripping agents, were evaluated for application in asphalt mixture. Boiling water test was conducted as a screening test, followed by indirect tensile test. The tensile strength ratio and image analysis method were used to evaluate the moisture susceptibility of the asphalt mixtures. In continuation of Hamburg wheel tracking test to evaluate the rutting resistance of the asphalt mixture, actual field application was performed. The results showed that the developed agents improved the stripping and rutting resistance of the asphalt mixture compared to those of the one containing other anti-stripping additives.

1. Introduction

The moisture damage causes loss of adhesion, and adversely affect to the strength of the asphalt mixture dramatically. It can also cause the premature pavement failures such as rutting and raveling on the pavement surface [1,2]. Moisture sensitivity testing has been applied by many agencies in the asphalt mixture design stage and the result of this testing can be used to eliminate certain asphalt and aggregate combinations or to investigate the needs of an anti-stripping additive. The potential to incur moisture damage can be controlled or reduced by material selection, mixture designs, increasing a high asphalt film thickness, additives, proper pavement design, compaction, and drainage [3]. Solaimanian [4] suggest that the most common technique to mitigate moisture damage is the use of additives or modifiers with the asphalt binder or the aggregate, and AASHTO T-283 is a widely-recognized laboratory test method for the evaluation of moisture susceptibility. Al-Qadi [5] summarized that developing laboratory moisture damage evaluation tests is challenging and it is hard to simulate field performance because of the high variability of the factors affecting moisture damage and the process of developing new test procedures still continues. Amelian and Abtahi [6] applied an image analysis technique, visual rating in boiling water test and concluded that the boiling water test was converted from subjective rating to a more objective evaluation by applying image analysis techniques and there was a good relationship with tensile strength ratio (TSR) values. The Hamburg wheel tracking test (HWTT) has been widely used as a standard laboratory test to evaluate mixture moisture susceptibility and rutting resistance. Yin [7] introduced a novel method to analyze HWTT results and three new parameters were proposed to quantify mixture moisture susceptibility before and after stripping occurred and rutting resistance. The new test parameters demonstrate significant advantages in characterizing mixture resistance to stripping and rutting in the HWTT. Walubita

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http://dx.doi.org/10.1016/j.conbuildmat.2017.03.214
0950-0618/

Table 1
Aggregate gradation.

Sieve size (mm)	20	13	10	5	2.5	0.6	0.3	0.15	0.075
Percent passing (%)	100.0	85.2	74.4	56.8	41.5	25.2	15.3	10.2	7.0

[8] suggested that the newly derived HWTT data analysis parameters, with considering the rutting path-history, yields promising results for predicting the early-life rutting performance of the Hot Mix Asphalt. Recently, many types of anti-stripping additives such as bio-additives, nano-composite, and glass fibers have been developed and examined by different methods. Subsequently, they showed positive effects on improving moisture damage and rutting resistance of asphalt mixture [9–11].

The purposes of this study are to comprehensively evaluate the moisture susceptibility of asphalt mixtures modified with several anti-stripping additives based on laboratory tests, HWTT, and field application. Laboratory works included conducting screening test (boiling water test), and indirect tensile strength (ITS) test based on ASTM D3625-96 and KS F 2398, respectively on specimens prepared with different type of anti-stripping additives. Also, image analysis method was employed to estimate mixture stripping resistance and compared it with ITS test results. HWTT protocol of the Tex-242-F specification was implemented and the data were subsequently analyzed by current and new methodologies to evaluate moisture susceptibility and rutting resistance of the asphalt mixtures. Finally, actual field testing was performed to fortify the laboratory tests and HWTT.

2. Materials

Asphalt binder and aggregate are the main components in asphalt mixture. The aggregates represented materials currently in production for hot mix asphalt with the particle size distribution, shown in Table 1. Asphalt binder PG58-22 grade was used as the base in order to easily find the effect of anti-stripping additive on the performance of asphalt mixture.

Asphalt mixtures containing developed liquid anti-stripping agents (K) were evaluated in this study. The agent K consists of silane additive, amine type surfactant, and stabilizer. Seven kinds of the agent K, numbered from 1 to 7, have different proportions of silane additive to amine type surfactant. Also, controlled mixture (C), without additive, and mixtures with limestone powder (L), and commercialized anti-stripping agent, which is currently used in Korea (W), were made for comparison purpose. In all cases, the mineral powder additive content was 2 percent by weight of aggregates, while the liquid additives were dosed at a rate of 0.5 percent by weight of asphalt binder.

3. Laboratory testing and analysis

This section covers the screening test for initial evaluation followed by the ITS test for moisture susceptibility evaluation and an image analysis.

3.1. Screening test (boiling water test)

This test procedure is a quick and simple method for evaluating the moisture sensitivity of an aggregate-asphalt mixture in order to select the expected anti-stripping agent, K. About 500 ml of distilled water is brought to boiling in a 1000–2000 ml glass beaker. Afterwards, the prepared aggregate-binder mix is placed into the boiling water. After 10 min ± 5 s, the mixture is allowed to cool while the stripped asphalt is skimmed away. The water is drained, and the wet mixture is placed on a paper towel and allowed to dry.

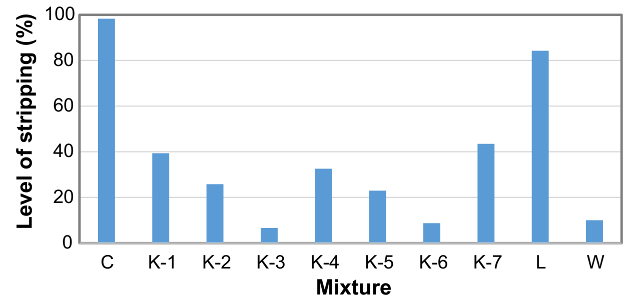

Fig. 1. Boiling water test results.

Visual rating is conducted to assess the level of stripping by the ratio of stripped aggregate particles to the amount of total [12].

In boiling water test, thirty samples were tested in boiling water in order to provide 3 replicates for each type of mixture. Fig. 1 shows the average results of screening test. The liquid agents are proved to provide positive effect to moisture resistance. Limestone powder, in this test, shows a drawback with high level of stripping. Among the developed anti-stripping agents K, mixes K-3 and K-6 were chosen to conduct the next stage of testing due to their low level of stripping percentage, 6.6% and 8.7%, respectively compared to the others.

3.2. Indirect tensile strength test

Indirect tensile strength (ITS) test was conducted to investigate the effect of anti-stripping additives on moisture susceptibility characteristic. The damage due to moisture is controlled by the specific limits of the tensile strength ratios (TSR). ITS test was performed according to the KS F 2398 [13] by compacted specimens of 100 mm in diameter and 63.5 mm in height at air voids 7 ± 0.5 percent. The specimens were separated into two subsets, unconditioned subset for dry ITS test and conditioned subset for wet ITS test. For conditioned specimens, they were saturated with water to between 55 and 80 percent then placed in a vacuum container filled with water. A vacuum of 13–67 kPa absolute pressure was applied for 5–10 min. Each specimen was wrapped in a plastic bag containing 10 mL of water and place it in a freezer at −18 °C for at least 16 h. The conditioned specimens were thawed in a bath of distilled water at 60 °C for 24 h. While the conditioned specimens were being conditioned, the unconditioned specimens stored at room temperature. All the specimens were cured in a 25 °C water bath for a minimum of 2 h prior to testing. There were 3 replicates for each type of mixture with the total of 15 specimens.

ITS test was conducted using ITS tester. During the test, compressive load was applied through two loading strips with a constant loading rate of 50 mm/min. The maximum indirect tensile force, at failure, was recorded and the corresponding ITS of the asphalt mixture was determined. The ITS, S_t, is calculated using Eq. (1):

$$S_t = \frac{2000P}{\pi D t} \quad (1)$$

where,

P = the maximum load (N),
t = the thickness of specimen (mm), and
D = the diameter of specimen (mm).