Evaluation of Moisture Susceptibility of Warm Mix Asphalt with MMLS3

J. Lee [1], Y. Kim[2], D. Cho[3], S. Yang[4], J. Lim[5], S. Kwon[6]

[1]Senior Researcher,Korea Institute of Construction Technology, Republic of Korea , yijaejun@kict.re.kr
[2]Senior Researcher,Korea Institute of Construction Technology, Republic of Korea , yongjook@kict.re.kr
[3]Senior Researcher,Korea Institute of Construction Technology, Republic of Korea , dongwoocho@kict.re.kr
[4]Researcher, Korea Institute of Construction Technology, Republic of Korea, siyang@kict.re.kr
[5]Researcher,Korea Institute of Construction Technology, Republic of Korea , jklim@kict.re.kr
[6]Senior Research Fellow,Korea Institute of Construction Technology, Republic of Korea , sakwon@kict.re.kr

ABSTRACT

Various environmental problems by global warming have caused a great interest of warm-mix asphalt(WMA) technology in the world. WMA technology provides various environmental benefits; for example, the production and compaction temperatures are dropped using WMA technology; thus gas emissions and odors from asphalt plants are also reduced. Based on these various benefits and technological awareness of WMA, Korea Institute of Construction Technology (KICT) has developed a new WMA technology. The new technology applies wax-type WMA additives that were developed by Kumho Petrochemical Co.

This paper deals with simulating moisture related-distresses among various laboratory tests using these WMA additives. KICT constructed pilot test sections to compare field performance between a hot mix asphalt (HMA) mixture as a control mix, and WMA mixture. The WMA sections using two different additives were produced and compacted approximately 30°C lower than temperatures applied at the control section. With these samples, a laboratory test using MMLS3 was conducted to investigate the moisture related-distresses of each section sample, which measures rutting profiles, surface texture and mixture weight loss. In the limited test results, the WMA samples showed slightly less weight loss than the HMA sample did after the simulation by MMLS3.

Keywords: warm-mix asphalt, accelerated pavement testing. wet condition.

RÉSUMÉ

Divers problèmes environnementaux par le réchauffement climatique ont entraîné un grand intérêt de l'asphalte chaud-mix (WMA) la technologie dans le monde. la technologie WMA offre divers avantages pour l'environnement, par exemple, les températures de production et de compactage sont supprimés en utilisant la technologie WMA; ainsi les émissions de gaz et les odeurs de plantes d'asphalte sont également réduits. Sur la base de ces différentes prestations et de sensibilisation technologique de WMA, Institut coréen de la Construction de la technologie (KICT) a développé une nouvelle technologie WMA. La nouvelle

technologie s'applique cire de type WMA additifs qui ont été mis au point par Kumho Petrochemical Co.
Cet article traite de la simulation liés à l'humidité, dégradations parmi les divers tests de laboratoire utilisation de ces additifs WMA. KICT construit sections pilote d'essai pour comparer les performances sur le terrain entre un enrobé à chaud (HMA) mélange comme un mélange de contrôle, et le mélange de WMA. Les sections WMA en utilisant deux différents additifs ont été produites et compacté environ 30 ° C des températures inférieures à appliquer à la section de contrôle. Grâce à ces échantillons, un test de laboratoire à l'aide MMLS3 a été menée pour étudier l'humidité liée-détresses de chaque échantillon de l'article, qui mesure l'orniérage profils, la texture de surface et la perte de poids mélange. Dans les résultats de test limitée, les échantillons ont montré une perte de poids WMA légèrement moins que l'échantillon ne HMA après la simulation par MMLS3.

1. INTRODUCTION

With warning of global warming, asphalt industries have concerned about reduction of greenhouse gas emission. Warm Mix Asphalt (WMA) is a terminology standing for energy saving technologies which can drop mixing and compaction temperatures when asphalt pavements are produced. Most warm mix asphalt technologies work by lowering the viscosity of the asphalt binder which allows to better coat aggregate surfaces and reduces the target temperatures to reach adequate workability of the mixture.
A direct benefit of this decrease in temperature is reduction in the fuel costs at asphalt plants. Although there are many possible advantages in WMA, however, the potential negative impacts on the mixture performance must be fully evaluated. Because the mixing process for WMA occurs at a low temperature, the aggregate applied may not be completely dried before mixing, thus causing a weaker bond between the aggregate and asphalt binder. Additionally, some additives used during WMA production release foamed moisture to the mixture in order to lower the viscosity of the asphalt binder [3].
After WMA technologies were introduced to U.S.A in 2000, the National Center for Asphalt Technology(NCAT) has conducted research characterizing asphalt mixes using several warm-mix technologies. Subsequently, a warm-mix asphalt technical working group(TWG) was formed by FHWA and NAPA in 2005.One of the most intriguing aspects of WMA is its potential to improve compaction. To give paving crews the opportunity to compare warm mix to hot mix,[7] Voskuilen et al (2004) described the findings of a laboratory investigation into half-warm foamed bitumen treatment.[8]
Recently, Hurley et al. [2] evaluated moisture damage susceptibility of the asphalt mixtures using AASHTO T 283, and AASHTO T 324 Hamburg testing. In the testing evaluation, TSR testing was conducted on both the sample compacted hot and the reheated sample. Hamburg testing was conducted on samples compacted hot and after reheating. This Hamburg test is typically used to predict moisture damage of HMA but has been found to be sensitive to other factors, including binder stiffness, short-term aging, compaction temperature, and anti-stripping treatments. All these factors have been identified as potential problems seriously considered in the

evaluation of WMA. Therefore, the results from the Hamburg wheel-tracking device could provide a method to identify a WMA mixture that performs well. The objective of this research is to evaluate the moisture susceptibility of warm mixes using warm mix asphalt additives. For this research, these additives were chosen for a field trial test conducted during the project period. Evaluation of moisture susceptibility was accomplished by testing specimens in laboratory controlled accelerated loading condition.

2. MIX DESIGN AND SAMPLE PREPARATION

For this study, two wax-based WMA additives (WMA-L and WMA-S) are selected to produce WMA mixtures in the plant. Based on the manufacturer's recommendation, WMA-L additive is directly added into a pugmill mixer at the rate of 2.0% by weight of asphalt and WMA-S additive is added into the pugmill mixer at the rate of 1.5% by weight of asphalt.

To produce the WMA mixtures for paving interstate highway, as shown in Figure 1, the dense gradation of nominal maximum aggregate size (NMAS) of 13.0mm is selected to be mixed with a PG 64-28 asphalt. Following ASTM D 6927, optimum asphalt content is specified as 5.6% [1]. The two WMA mixtures were produced at 130℃ and a control HMA mixture was produced at 160℃. For this study, loose mixtures were immediately collected from the asphalt plant when the asphalt mixtures were produced and delivered to the highway laboratory of the KICT.

The loose WMA mixtures were reheated at 130℃ and compacted at 115℃. The loose HMA mixture was reheated at 160℃ and compacted at 135℃. All specimens for MMLS 3 test were compacted by gyratory compactor up to the target air void of 6.0%.

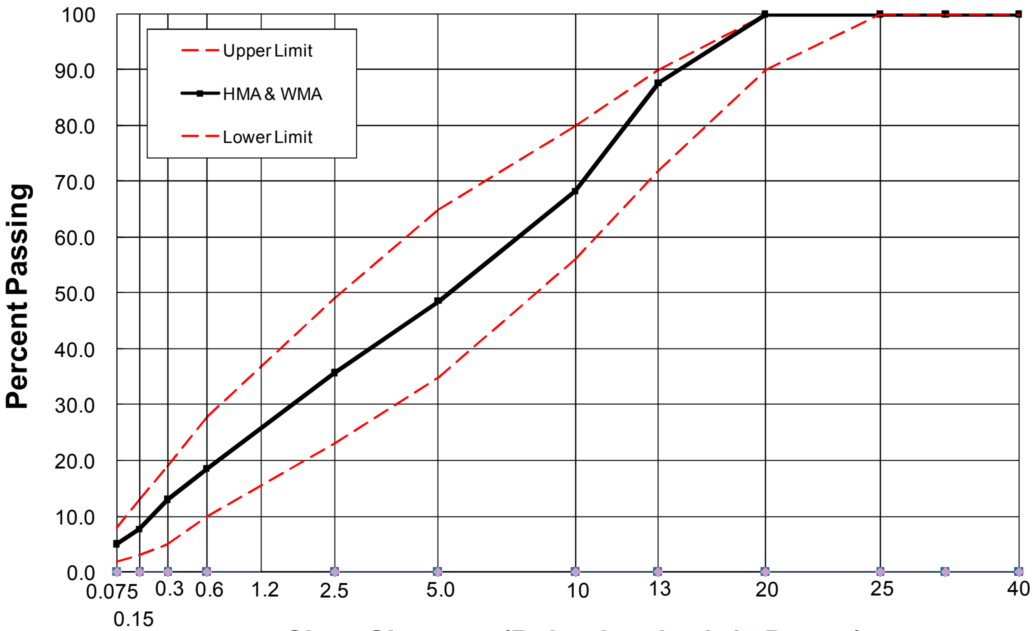


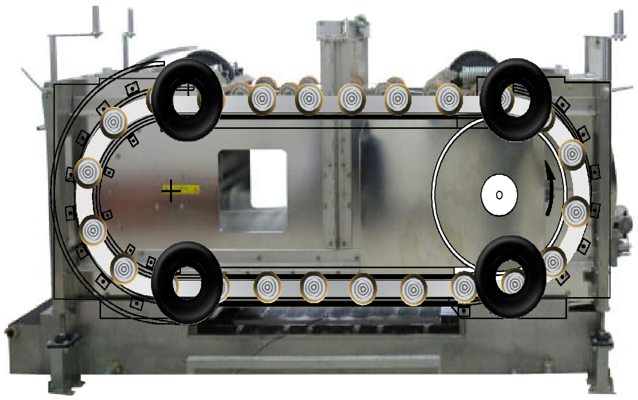
Figure 1 Aggregate gradation

3. LABORATORY SETUP AND TESTING EQUIPMENT

3.1 Third-Scale Model Mobile Load Simulator (MMLS3)

The MMLS3 is a tool for determining moisture susceptibility, rutting and fatigue in the laboratory and field under different traffic and environmental conditions.

As shown in Figure 2, It is an accelerated loading device consisting of four 300-mm diameter pneumatic tires linked by a chain bogey system and driven by a variable speed motor. In laboratory tests, the MMLS3 applies a unidirectional load to specimens clamped into the test bed. The axle load is held constant by a suspension system that allows for loads between 2.1 kN and 2.7 kN. [4].



(a) MMLS 3

(b) Specimen set up for moisture test

Figure 2 Schematic of MMLS 3

As can be seen in Figure 3, individual specimens are clamped properly in the test bed. Test specimens are 150 mm in diameter, with two parallel edges removed. Removing the edges of the aligned specimens allows the wheel load to transfer through the specimens rather than through the test bed clamps. Prior to wheel loading, an initial surface profile is measured from each specimen as a reference point to measure subsequent rutting. Several profile measurements were taken over the course of an MMLS3 test In addition, more profiles were measured in a time sequence to investigate deformation of the specimens up to 80,000 of maximum loading cycle.

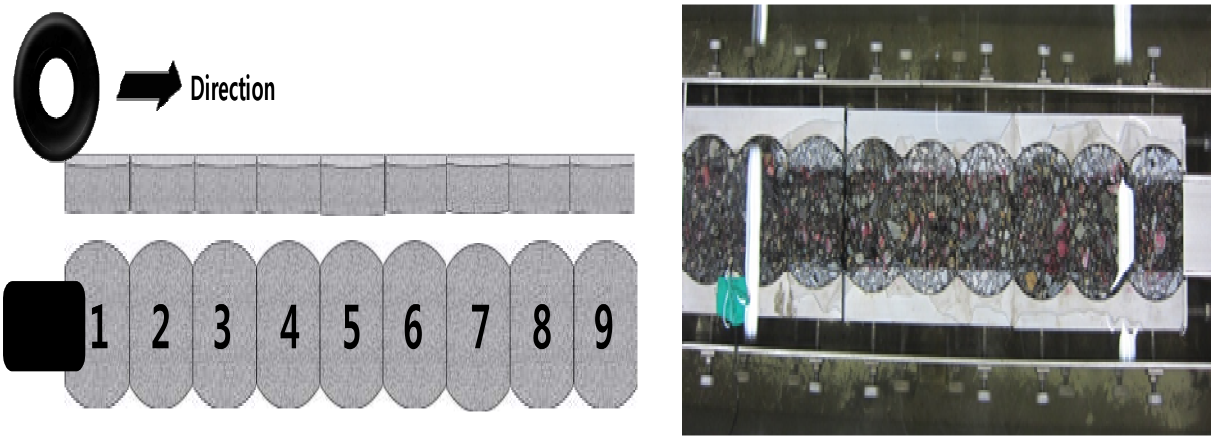


Figure 3 Specimen preparation of running MMLS3 test

3.2 Running MMLS3 under Wet Condition

The MMLS3 test was conducted in wet condition in order to evaluate the moisture susceptibility of the WMA mixtures. During the test, as shown in Figure 4, the specimens were submerged in heated water. A wet heating system utilizes to keep a constant temperature of water and specimens. The wet heating system consists of a heater and a pumping device to circulate the heated water through the test bed. A thermocouple clamped between two test specimens controls the water heater and maintains the desired testing temperature so that the target testing temperature can be automatically adjusted and maintained.

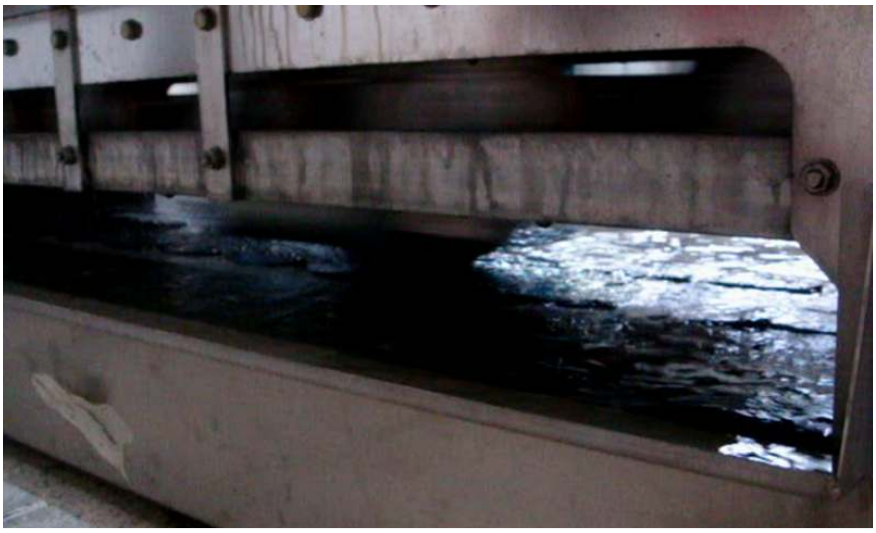


Figure 4 MMLS3 test under wet condition

3.3 Measurement of Rutting Profiles

To measure rut depth of the specimen, P 900 electronic profilometer was used. Because the specimens have a low profile, their profiles can be measured without lifting the machine off the specimens. The measurements are automatically stored into digital format which can easily be processed.[5]

4. Results

4.1 Measurement of Rut Depth

The permanent deformation of the three different mixture types (HMA mixture and two WMA mixtures) under wet condition was investigated as a function of number of wheel passes of MMLS 3. Three specimens for each mixture type were prepared and total nine specimens were employed to evaluate a performance of mixture under wet condition.

Figure 5 shows the profile of specimen as a function of wheel trafficking loading. As shown in Figure 5, the profiles measured on specimen were subsequently deformed with increasing number of wheel passes. Accordingly, the rut depth was measured as a function of wheel passes and plotted as shown in Figure 6. To evaluate the performance of mixtures three specimens are prepared for three different asphalt mixture type; the average rut depths from three specimens of each mixture type are shown in Figure 3. The average rut depths up to 80,000 cycles in the wet condition are shown in Figure 6. In this study, Figure 6 shows that the general HMA mixture had slightly lower rut depths .

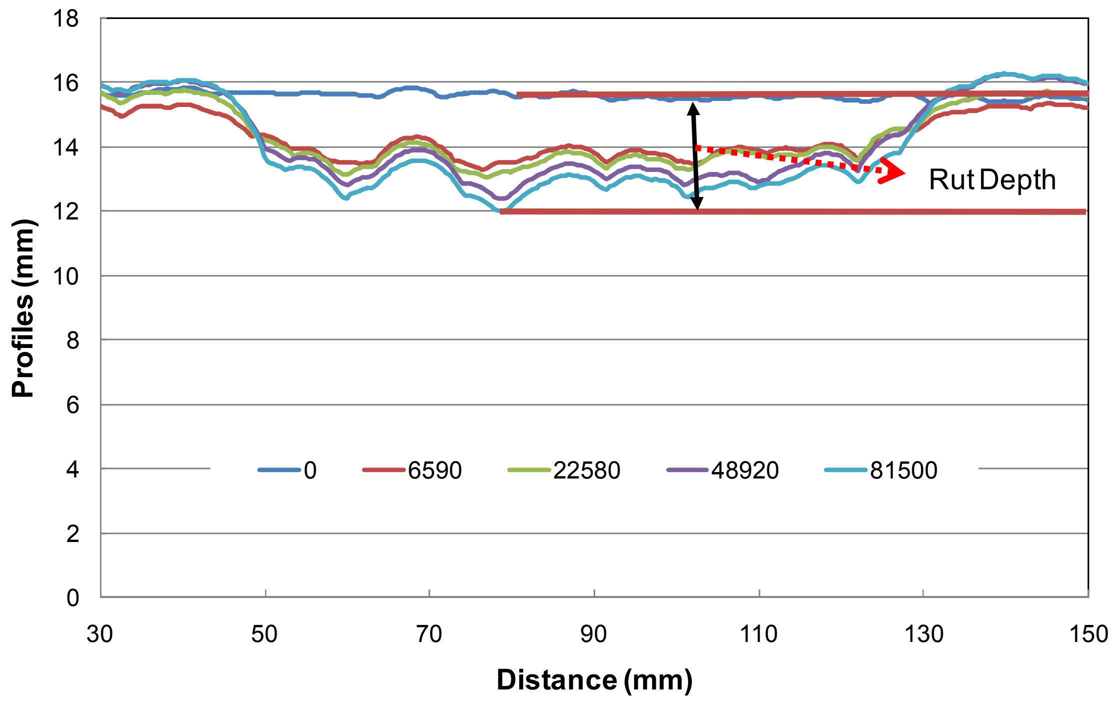


Figure 5 Rutting profiles of specimen under wetting condition

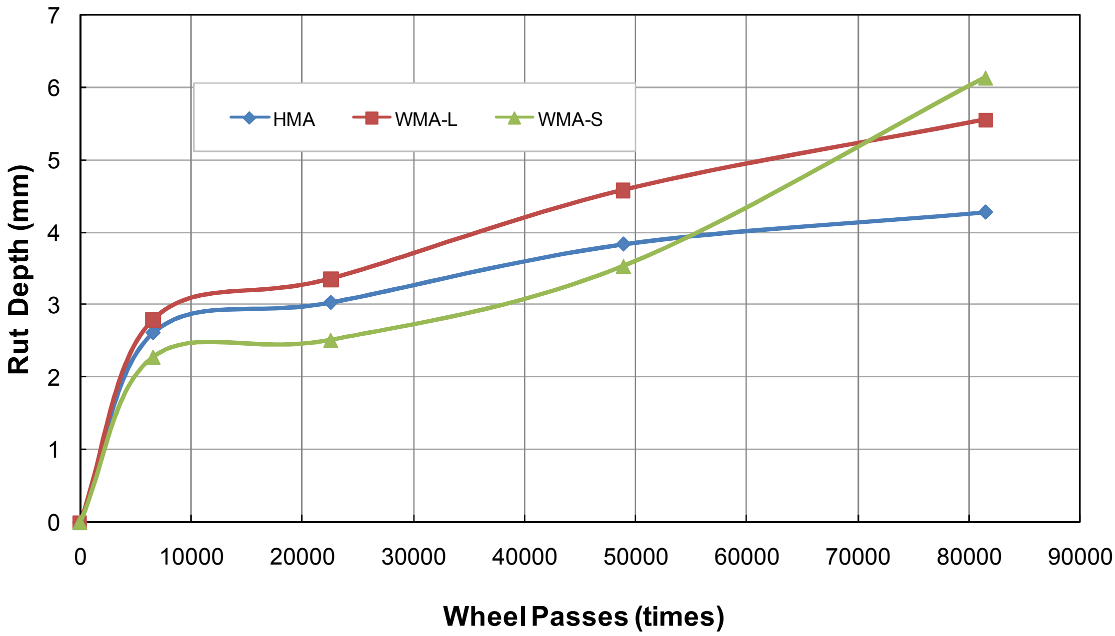


Figure 6 Measured rut depth as function of number of wheel passes

4.2 Mixture Weight Loss

Figure 7 shows the surface texture of a specimen before and after MMLS 3 test under wet condition. Figure 7 illustrates that the surface binder was washed due to aggregate loss of specimen. Based on visual observation, the aggregate loss was occurred during MMLS 3 test and can be stripping, one of moisture-related distresses. To evaluate the loss of mixture weight, sample weights were measured before and after the MMLS 3 test. , Equation (1) is used to calculate the loss weight

$$\text{Mixture Weight Loss} = \frac{W_B - W_A}{W_B} \qquad \text{Equation (1)}$$

where W_B and W_A are weights of the mixture weight before and after test, respectively.

The average mixture weight loss from three specimens was calculated over 80,000 number of wheel passes. Figure 8 shows different mixture weight according to mixture types. Contrary to rut depth results as shown in Figure 6, HMA shows the slightly higher weight loss among three mixture types.

Before After

Figure 7 Specimen view before and after MMLS 3 test

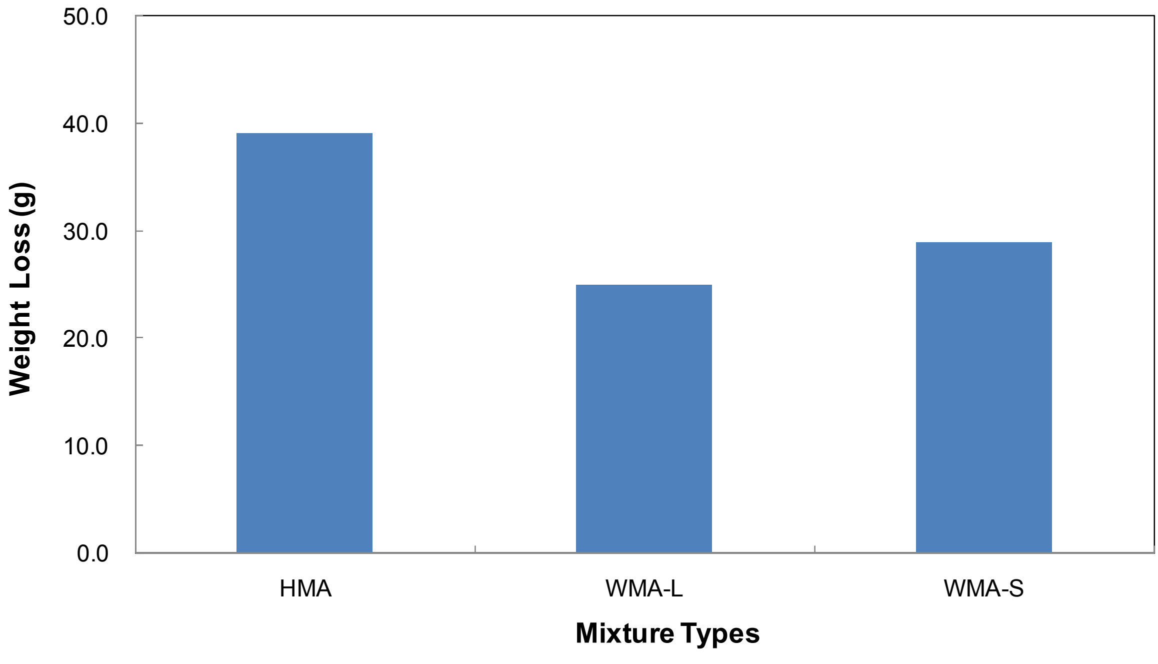


Figure 8 Weight of specimen

5. CONCLUSION

Based on the limited test results obtained from this study, the following conclusions are drawn:

1. General hot mix asphalt shows slightly higher rut-resistance than two warm-mix asphalts under wet condition.

2. However, in case of mixture weight loss, general hot mix asphalt resulted in more weight loss after 80,000 MMLS 3 wheel passes under wet condition.

6. FUTURE RESEARCH

This research has been partially developed in a moisture damage study on warm-mix asphalt pavement using small accelerated pavement tester. Therefore, to have more complete results, the moisture sensitivity of more WMA types and specimens under simulated field traffic loading will be continuously evaluated as a function of rut depth, weight loss, and surface texture on specimen.

ACKNOWLEDGMENTS

This work is supported by the Korea Institute of Construction Technology Project.

REFERENCES

1. ASTM. (2006) Standard test method for Marshall stability and flow of bituminous mixtures, American Society for Testing and Materials," ASTM D 6927, West Conshohocken, PA.
2. Hurley, G.C., Prowell, B. D., Kvansnak, A. N. (2010). Wisconsin Field Trial of Warm Mix Asphalt Technologies: Consturction Summary NCAT Report No. 10-04, National Center for Asphalt Technology.
3. Kandhal, P. S, 1992. Moisture Susceptibility of HMA Mixes: Identification of Problem and Recommended Solutions. NCAT Report No. 92-1, Nationalenter for Asphalt Technology.
4. MLS Test Systems, (2002-a). "MMLS3 Traffic Simulator Operator's Manual". MLS Test Systems.
5. MLS Test Systems, (2002-b). "Profilometer P900 Operator Manual. MLS Test Systems.
6. Mogawer, W. S., Susterman, A. J., Bahia, H. U., (2011) Evaluation Effect of Warm-Mix Asphalt Technologies on Moisture Characteristics of Asphalt Binders and Mixtures, TRB Annual Meeting DVD, Transportation Research Board.
7. National Asphalt Pavement Association (NAPA) (2008) Warm-Mix Asphalt: Contracts' Experiences, 2008 National Asphalt Pavement Association Information Series 134.
8. Voskuilen, J.L.M., Mangnus, M.Van de Ven, M.F.C., Van Wieringen, J.B.M., Bolk, H.J.N.A (2004) Experiences with Half-warm foamed Bitumen Treatment Process in the Netherlands, Proceedings of the 8th Conference on Asphalt Pavements for Southern Africa (CAPSA'04)