11-6-2013

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Shu Wei Goh
Michigan Technological University

Mohd Rosli Mohd Hasan
Michigan Technological University, mmohdhas@mtu.edu

Zhanping You
Michigan Technological University, zyou@mtu.edu

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Procedia - Social and Behavioral Sciences 96 (2013) 2782 – 2790

Procedia
Social and Behavioral Sciences

13th COTA International Conference of Transportation Professionals (CICTP 2013)

Performances Evaluation of Cecabase® RT in Warm Mix Asphalt Technology

Shu Wei Goh, Mohd Rosli Mohd Hasan, Zhanping You*

Department of Civil and Environmental Engineering, Michigan Technological University, Houghton, Michigan 49931, USA.

Abstract

The purpose of this study was to evaluate the performance of warm mix asphalt (WMA) mixtures containing different percentages of Cecabase® RT using dynamic modulus (|E*|), tensile strength ratio (TSR), four point beam fatigue, flow number and asphalt pavement analyzer (APA) rutting tests. In this study, 0.2%, 0.35% and 0.5% Cecabase® RT were incorporated in the 5E3 Superpave mixtures prepared at three different temperatures, 100°C, 115°C and 130°C. A Hot Mix Asphalt (HMA) mixture was used as the control mixture. All the mixture samples were prepared using PG 58-34 binder and compacted at 86 gyrations under different temperatures. The rheological and aging property of control HMA and WMA made with 0.2%, 0.35% and 0.5% Cecabase® RT were tested by Dynamic Shear Rheometer (DSR). From the results, it was found that WMA has significantly lower aging factor compare to control HMA results in higher rutting at the early stage of pavement serviceability. It was also noticed that an increment of Cecabase® RT added and the production temperatures used in preparing WMA specimens do not significantly affect the |E*|, fatigue life, TSR and tensile strength of mixtures. Subsequently, the rutting resistance of the WMA reduced when more Cecabase® RT was added and lower mixing/ compacting temperatures were used.

Keywords: Warm Mix Asphalt; Dynamic Modulus; Tensile Strength; Fatigue; Rutting, Rheology

1. Background

Formerly, asphalt mixtures were produced at high temperatures (between 150°C to 180°C) and thus often referred to as Hot Mix Asphalt (HMA). A technology named Warm Mix Asphalt (WMA) was developed in

* Corresponding author. Tel.: +1-906-487-1059; fax: +1-906-487-1620.
E-mail address: zyou@mtu.edu

doi:10.1016/j.sbspro.2013.08.311

Europe that allows HMA to be produced at a lower temperature. Besides, environmental awareness has been increasing rapidly over the past years and extensive measures like air pollution reduction targets set by the European Union with the Kyoto Protocol have encouraged efforts to reduce pollution (McKeon 2006). The HMA industry is constantly exploring technological improvements that enhance the material's performance, increase construction efficiency, conserve resources, and advance environmental stewardship. Over years of research efforts, a few WMA technologies were introduced including the foaming method using Aspha-min® and Advera® WMA; organic additives such as Sasobit®, Licomont BS 100 and Asphaltan B®; and chemical packages such as Evotherm® and Cecabase RT®. At a minimal heat application and significantly lower temperature, WMA technology allows the mixing, transporting and paving process by lowering the viscosity of asphalt binder and/or improving the workability of mixture. Several benefits were found by lowering the mixing and compaction temperatures, such as less emission, cost of energy saving, longer construction season, less odor and construction during non-peak periods (Chowdhury and Button 2008). It is reported that energy savings by 30%, with a corresponding reduction in CO_2 emissions of 30%, are realized when WMA is used compared to conventional HMA. These energy savings and emissions reductions could be greater if burner tuning was adjusted to allow the burners used in the WMA process to run at lower settings. In addition, a lower temperature used during the production also accounted for the reduction in electrical usage to mix the material, as well as to transport the material through the plant (D'Angelo, Harm et al. 2008). In the United States, WMA mixture is produced, placed and compacted at 10 to 40^{o}C lower temperatures than the conventional HMA mixture (Vaitkus, Čygas et al. 2009). However, it also could be described as the asphalt mixture produced at a 20 to 40^{o}C lower temperature than the HMA but at a higher temperature than the water boiling temperature (D'Angelo, Harm et al. 2008). Sometimes, the terminology of "Low Temperature Asphalt" is also used for the description of WMA (Vaitkus, Čygas et al. 2009).

The chemical package additive is one of the WMA technologies which developed in the United States. These chemical packages usually include anti-striping agents and they are designed to enhance coating, adhesion, and workability of the asphalt mixture (Anderson, Baumgardner et al. 2008; Gonzalez Leon, Grampre et al. 2009). Some of the chemical packages also act as the emulsification agent (Daniel and Fowler 2006; Hurley, Prowell et al. 2006; Davidson 2008). Water in this emulsion flashes off as steam when mixing with aggregate and enhances the coating of aggregate by the asphalt. Additionally, these WMA additives do not change asphalt viscosity(Hurley and Prowell 2006; Prowell, Hurley et al. 2007). The chemical additive that contained surfactant acted as "lubricant" and work at the microscopic interface of aggregate and the asphalt (Anderson, Baumgardner et al. 2008). The "lubricant" reduced the internal friction when asphalt mixture is subjected to high shear rates (i.e. mixing process) and high shear stress (i.e. compacting). This "lubricant" typically effective at a certain temperature ranged from 85°C to 140°C.

The purpose of this study was to evaluate the performance of WMA mixtures containing different dosages of Cecabase® RT using dynamic modulus, tensile strength ratio, four point beam fatigue, flow number and asphalt pavement analyzer (APA) rutting tests. Cecabase® RT is a relatively new additive in the WMA technology and there have been only a few laboratory experiments conducted. Therefore, further detailed studies and tests are needed to evaluate the performance of Cecabase® RT as an additive in WMA in terms of rheological properties of asphalt binder and mixture performance.

Nomenclature

WMA	warm mix asphalt
E*	dynamic modulus
TSR	tensile strength ratio
APA	asphalt pavement analyzer
F_N	flow number

2. Materials and Methods

2.1. Cecabase®RT

Cecabase® RT is a patented chemical package developed by CECA, a division of Arkema Group (Ceca 2009; Gonzalez Leon, Grampre et al. 2009). It was made up by 50% of renewable raw materials that produce increased workability to the asphalt mixture a lower temperature (Ceca 2009). The Cecabase® RT is available in liquid form and can be inject directly into the asphalt. Fig. 1 shows the Cecabase® RT used in this study.

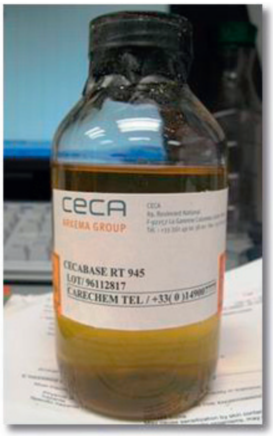

Fig. 1. Cecabase® RT

2.2. Sample preparation and evaluation

In this study, a PG 58-34 asphalt binder was used. The specimens were prepared based on the Superpave™ design of 5E3 (nominal maximum aggregate size of 12.5mm with designed traffic level less than 3 million ESALs). The control and WMA mixtures were batched and mixed using a bucket mixture in the lab. For control mixture, the samples were mixed and compacted at 163°C and 153°C, respectively. While for WMA mixture, Cecabase® RT was added at the rate of 0.2%, 0.35% and 0.50% based on binder weight, and prepared at 100°C, 115°C and 130°C. The mixture specimens were compacted using the 86 gyration numbers which were then evaluated using dynamic modulus, tensile strength ratio, four point beam fatigue, flow number and asphalt pavement analyzer (APA) rutting tests. Meanwhile, asphalt binder rheological behavior at different percentage of Cecabase® RT contents were also evaluated.

3. Result and Discussion

3.1. Asphalt rheological properties and aging factor

Section headings should be left just The rheological properties and aging factor were evaluated using Dynamic Shear Rheometer (DSR). Prior to test, the specimens formerly exposed to the short term aging process. This aging process is known as the asphalt binder condition after pavement construction and is simulated by heating in the oven for 12 hours. Four different temperatures were used for short-term aging in this case study and they were 163°C for control, and 100°C, 115°C and 130°C for WMA.

Temperature of 58°C and frequency of 10 rad/s were used for the DSR testing. Fig. 2 presents the testing results of DSR testing and the aging factor of control HMA and WMA. It is observed that the control HMA aged at temperature 163°C has higher aging factor compared to WMA. It is also observed that the aging factor for WMA doesn't affected by the aging temperature and also the amount of Cecabase® RT. Furthermore, it shows that all the binders meet the Superpave^{TM} specification requirement, where the minimum value is 1.00KPa.

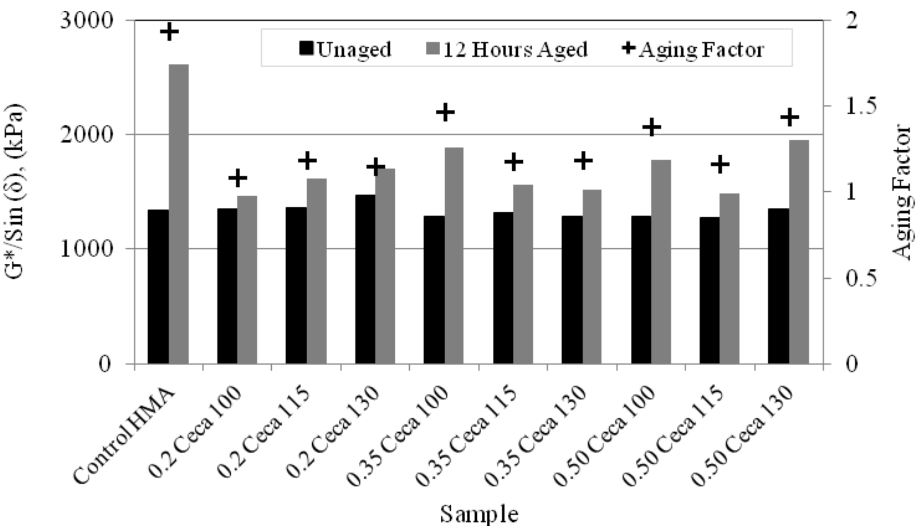

Fig. 2 Dynamic shear modulus test results and aging factor for control HMA and WMA made with Cecabase® RT

3.2. Dynamic modulus testing

The dynamic modulus testing was performed using UTM 100 from IPC according to AASHTO TP62-03. The temperatures used were -10°C, 4°C, 21.3°C and 39.2°C. The frequencies used in this test ranged from 0.1Hz to 25Hz. Ten different types of mixture were tested in this study: control HMA, and WMA made with Cecabase® RT at the rate of 0.20%, 0.30% and 0.50% based on asphalt binder weight. The recoverable axial micro-strain in this test was controlled within 75 and 125 micro strains so that the material is in a visco-elastic range (Mallick and Brown 2004; Witczak 2007).

Dynamic modulus of the control HMA and WMA made with Cecabase® RT was evaluated and compared using master curve technique. The master curve technique was used to shift all |E*| values at various frequencies and temperatures into one single curve. As mentioned previously, the concept of a sigmoidal master curve is to "shift" the relative |E*| from different temperatures to the time of loading using the sigmoidal fitting model, so that the various curves can be aligned to form a single master curve. In this study, a sigmoidal master curve was constructed using reference temperature of 4°C for the measured |E*| for control and WMA mixtures, and are shown in Fig. 3.

Fig. 3 shows that the production temperature and amount of Cecabase® RT used to produce WMA did not affect the |E*| of WMA; however, it is observed that all WMA mixtures made with Cecabase® RT are lower than control HMA. A higher |E*| means the mixture has better performance in terms of rutting resistant (Witczak 2007). The |E*| test results indicated that the WMA made with Cecabase® RT has higher rutting potential compare to HMA mixture.

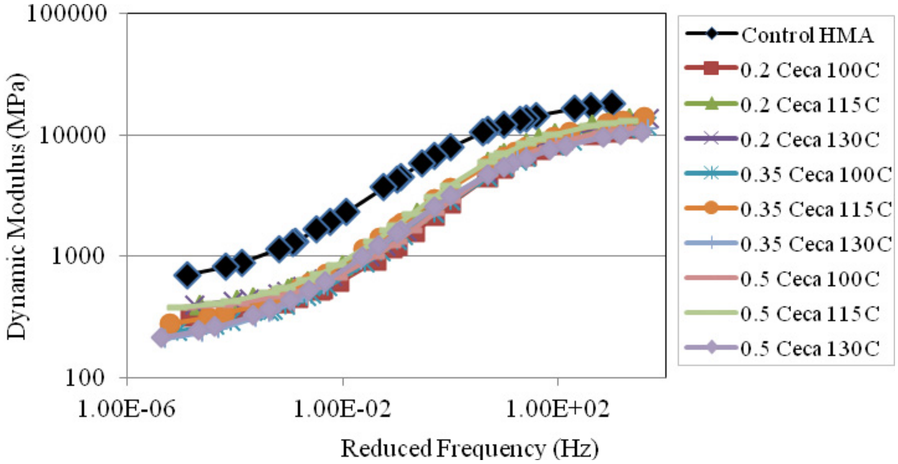

Fig. 3. Master curve of dynamic modulus of control HMA and WMA made with Cecabase® RT

3.3. Moisture susceptibility test

The moisture susceptibility of the control HMA and WMA made with Cecabase® RT was tested with tensile strength ratio based on AASHTO T283 (AASHTO:T283-03 2003). In addition, the tensile strength of the samples was evaluated as well. The tensile strength of asphalt mixture can be well related to fatigue cracking in asphalt pavement (Chapuis and Gatien 1995), and a higher tensile strength indicated that asphalt pavement can better resist cracking (tolerate higher strains before it fails). In this study, the control HMA and WMA samples were prepared at the size of 100mm in diameter and 63.5mm in height. The temperature and loading rate used in this study were 25ºC and 0.085mm/s.

Fig. 4 shows the Tensile Strength Ratio (TSR) testing results for Control and WMA mixtures made with Cecabase® RT. The result shows that most of the TSR for WMA passed the minimum TSR value required by the AASHTO T283 specification (TSR = 0.80). However, it was found that the tensile strength of WMA is lower than control HMA in general. It is also observed that the amount of Cecabase® RT added and the temperature used to produce WMA does not significant affect the TSR and tensile strength. This indicated that the WMA produced with Cecabase® RT at lower temperature has higher fatigue potential; however, the TSR value shows that WMA has similar moisture susceptibility compared to control HMA.

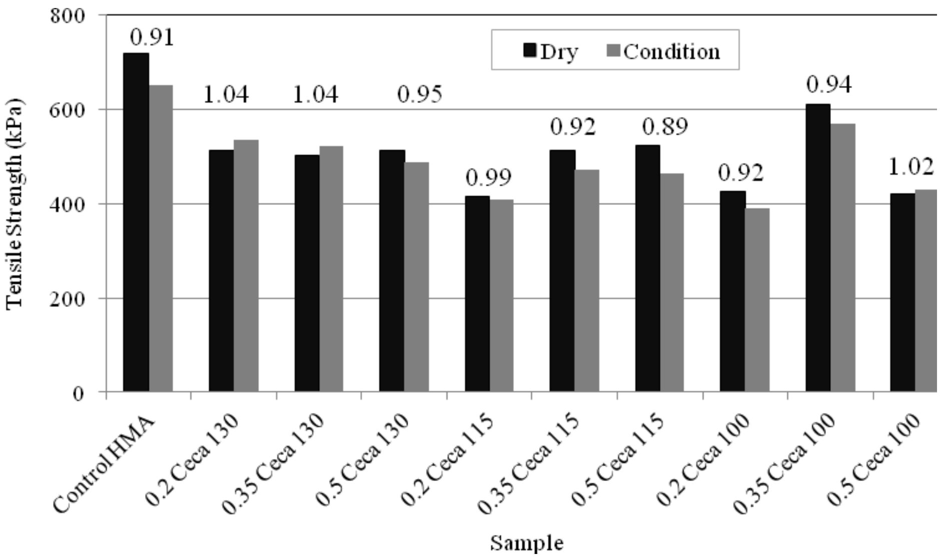

Fig. 4. TSR results of control HMA and WMA made with Cecabase® RT

3.4. Four point beam fatigue test

The results from the four-point beam fatigue tests are presented in Fig. 5. The purpose of this test is to determine the fatigue life of the asphalt mixture subjected to the repeated bending until failure where the fatigue failure was defined as 50% reduction of initial stiffness (AASHTO:T321-07 2007). A frequency of 10 Hz and 400 micro-strain (constant strain) were used for all the samples tested in this study. The testing result shows that most of the fatigue life for WMA made with Cecabase® RT is significantly higher than the control HMA. It is also noticed that there the fatigue life of WMA does not affect by the amount of Cecabase® RT added and temperature used to produced WMA in this case.

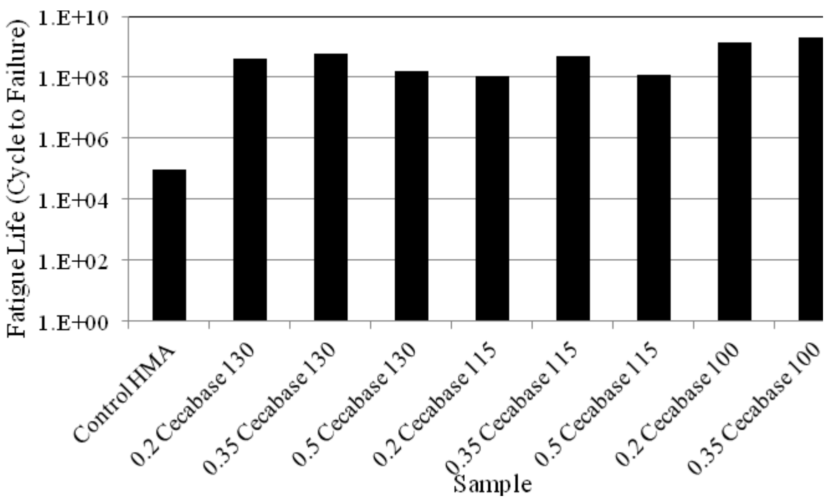

Fig. 5. Four Point Beam Fatigue Testing Results for Control HMA and WMA made with Cecabase® RT

3.5. Flow number testing

The flow number test is often referred to as dynamic creep or repeated loading test where the permanent deformation of the specimen is recorded as a function of load cycles. In this study, an effective temperature (rutting temperature) of 45°C was used in this test (Carpenter and Vavrik 2001; Witczak, Kaloush et al. 2002).

From Fig. 6, the testing results show that the F_N for WMA made with Ceabase® RT are lower than the control HMA. These results are in line with the findings from |E*| which WMA has a higher rutting potential. As mentioned previously, the reason behind was due to lesser aging of WMA during the production. The testing results also indicated that the F_N slightly decreases when more Cecabase® RT is added.

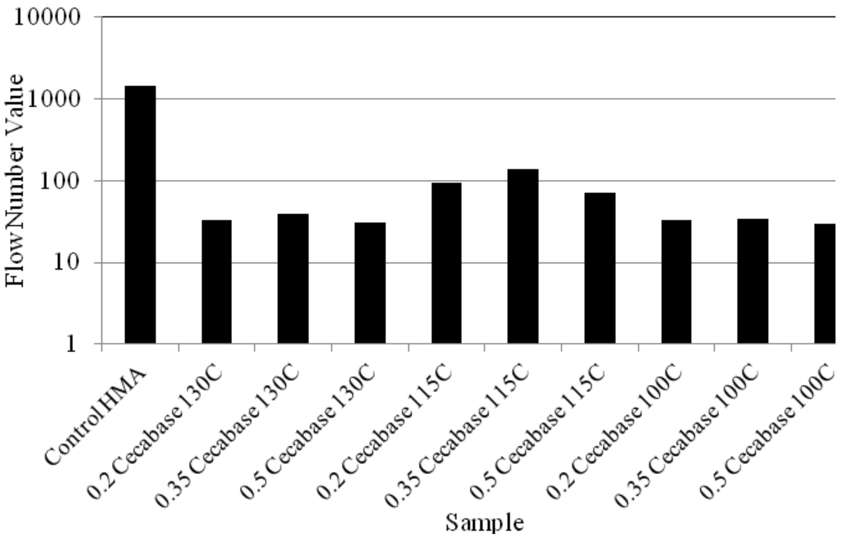

Fig. 6. Flow number of control HMA and WMA made with Cecabase® RT

3.6. Asphalt pavement analyzer rutting test

The rutting tests were conducted through the Asphalt Pavement Analyzer (APA) device based on AASHTO TP 63-03 at 58°C (136.4°F). The purpose of this test was to evaluate the rutting potential of WMA and compare the results with the control HMA. The results of the APA test are presented in Fig. 7. Based on the results conducted, it was found most of the WMA has higher rutting depth compare to the control mixture. The result also shows that WMA made with 0. 5% Cecabase® RT produced at 100°C has the highest rutting depth; and this finding is consistent with the result from F_N. It is also found that WMA made with 0.2% Cecabase® produced at 130°C has the lowest rutting depth. The finding is comparable to result of F_N testing where rutting potential for WMA is higher in general which mainly due to aging. Additionally, the rutting potential increase when more Cecabase® RT is added and a lower mix/ compact temperatures were used.

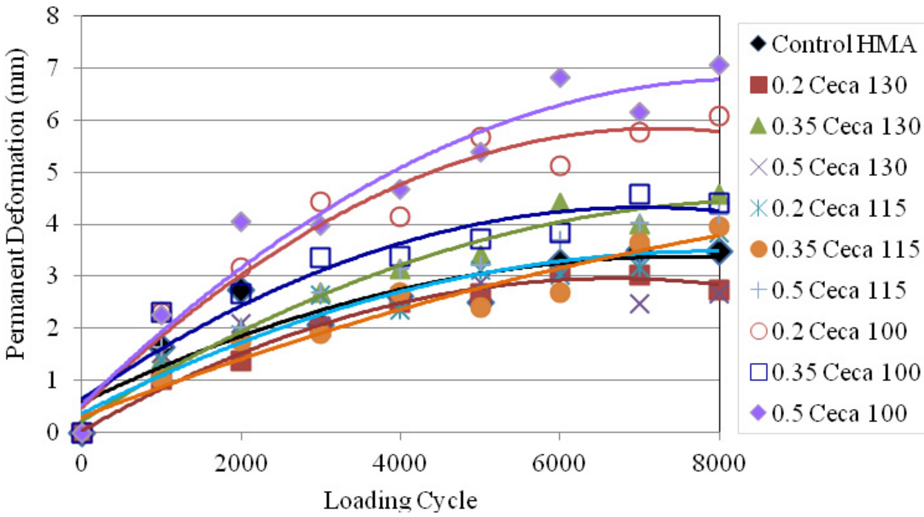

Fig. 7 APA Rutting Results for Control HMA and WMA made with Cecabase® RT

4. Conclusions

Based on the outcomes of this study several conclusions can be made. Through the DSR test result, WMA has significantly lower aging factor compare to control HMA, and this linked to the higher rutting depth at the early stage of pavement serviceability. Additionally, the result indicated that the production temperature and amount of Cecabase® RT used to produce WMA did not considerably contributed to the |E*|, fatigue life, tensile strength and TSR of WMA mixture. Finally based on the F_N and APA rutting tests result, WMA has a higher rutting potential compared to control HMA. Besides, the rutting potential of the WMA increases when more Cecabase® RT is added and lower mixing/ compacting temperatures were used.

Acknowledgements

The authors wish to express their gratitude to James Vivian, Moua Lee, David Porter, Damian Wallner and Travis Aho at Michigan Technological University for their help in running some preliminary tests. The research work was partially sponsored by the Federal Highway Administration through Michigan Department of Transportation (MDOT). The authors also appreciate the guidance and involvement of John Barak of MDOT as the Project Manager. The authors do not have any financial interest with any product and technologies used in this study.

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