An Assessment of Testing and Conditiong Protocol to Evaluate Asphalt Mixtures

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ABSTRACT

Asphalt mixtures frequently contain a wide variety of components that may interact. When put into service, they can be damaged due to several factors such as traffic, loading, and environmental impact. Thus, it is necessary to predict or simulate the asphalt mixtures' damage and performance in service utilizing laboratory conditioning protocols and tests. This paper investigates the property measurements themselves and how a mixture test can simultaneously assess oxidation and moisture damage. In this study, three asphalt mixtures are used with different mixture tests such as Indirect Tensile Tension (IDT), Cantabro Mass Loss (CML), and Hamburg Loaded Wheel Tracking (HLWT). Unaged (control) and two laboratory conditions were utilized to simulate the performance of the mixture in service. The result showed that the laboratory conditioning of the combined effects of oxidation and moisture simulates better the asphalt damages in service than laboratory single environment effect conditioning. The CML test is recommended for the evaluation and capture of these combined damage effects.

Keywords-warm mix asphalt; laboratory conditions; Sasobit; Rediset LQ1200

I. INTRODUCTION

Laboratory conditioning is often administered in two ways: oxidative degradation by Long-Term Oven Aging (LTOA) and moisture damage through hot water conditioning or freeze-thaw. Authors in [1] acknowledged that little research had been done regarding the aging of asphalt mixes. LTOA procedures spanning from 2 to 8 days at 85 °C have been recommended [1-3]. Consequently, the existing aging regimen (AASHTO R30) was devised with 5 days of LTOA at 85 °C, which is a routinely applied approach to generate oxidative stress on asphalt samples [4-6]. AASHTO T283 [7] and ASTM D4867 [8] are the most commonly used moisture conditioning technologies nowadays. T283 involves vacuum saturating compressed samples, undergoing a 16-hour FT cycle before being transferred to a 60 °C water bath for 24 ± 1 hours, whereas D4867 involves vacuum saturating compressed samples immersed in a 60 °C water bath for 24 ± 1 hours and can optionally undergo a 15-hour FT cycle. Even though these exact techniques are not universally utilized [5, 9], they are very commonly used to assess moisture susceptibility [4, 10]. The kind of damage caused to compressed asphalt mixture samples is the most interesting part of this research. Usually, oxidative and moisture conditioning are studied independently and are evaluated by different mixture tests such as IDT, APA, HLWT, and CML [11-17]. Many researchers do not consider the impact of one environment's effects on the other, specifically how prolonged oxidation influences WMA resistance to moisture degradation in comparison to HMA. Several studies investigated moisture damage resistance with the help of AASHTO T283 and/or HLWT test as a role of oxidative aging durations, generally produced by LTOA [5, 6, 10, 11, 18].

Authors in [5] used LTOA to produce oxidative stress for 4 and 8 days at 85 °C and a revamped version of AASHTO T283 moisture conditioning without integrating the indicated 16-hour curing period and 24-hour storage period. They conducted IDT tests on both dry and moist samples prior to LTOA as well as after 4 and 8 days of LTOA to explore variations between the moisture resistance of WMA and HMA with increased oxidative damage. As discovered in [5], the preliminary TSR of WMA was equal to or superior to that of HMA and grew higher with rising LTOA periods for WMA than for HMA. In terms of tensile strength values, HMA originally had greater dry and moist tensile strength readings. After 4 days of LTOA, the authors noted that WMA dry tensile strength neared HMA's, which denotes a convergence of values, but after 8 days, HMA and WMA demonstrated considerable disparities. The authors gathered wet tensile strength data and revealed that

WMA increased at a higher rate than HMA across the aging cycle analyzed by the researchers. Extended LTOA is projected to enable WMA's wet tensile strength to surpass that of HMA.

Authors in [11] evaluated the aged and unaged moisture sensitivity of five various WMA combinations made using Asphamin, Cecabase, Evotherm, Rediset, and Sasobit. AASHTO R30 and T283 were used to generate LTOA and moisture conditioning, respectively. The dry and wet tensile strengths and TSR values of the mixes following R30 aging showed that there was minimal variation between the majority of mixtures following LTOA, except the mixture with Asphamin [12]. Authors in [13] examined the moisture sensitivity of WMAs made with Sasobit, and Evotherm using the SC T 70 (24 hours in 60 °C water) benchmark of South Carolina. The researchers identified wet and dry tensile values of the samples pre- and post-LTOA by using AASHTO R30. Prior to LTOA, the researchers noted the greater values of wet tensile strengths in HMA and Sasobit in comparison to Evotherm. The study showed that LTOA increased the moisture damage resistance of Sasobit and Evotherm made mixes compared to HMA. Furthermore, the findings revealed that SC T 70 enhanced the flow resistance in all mixes. Authors in [15] evaluated the performance of asphalt mixtures with different additives including Titan 7205, Styrene-Butadiene-Styrene (SBS) and Crumb Rubber (CR). The unconditioned and AASHTO R30 conditioned asphalt mixtures were evaluated and tested utilizing Dynamic Shear Rheometer (DSR) testing, CML, Tensile Strength Ratio (TSR), and IDT. The study concluded that Titan 7205 would be an alternative additive to be used with HMA.

Authors in [6, 19, 20] utilized the combined effects of oxidation and moisture to evaluate asphalt mixtures. Moisture conditioning was conducted in accordance with AASHTO T283 prior to and post various periods of LTOA [6]. The Laboratory Mixed Laboratory Compacted (LMLC) samples of mixes patterns that had undergone long-term aging for 16 weeks at 60 °C were examined through dry and wet IDT testing. LMLC samples were conditioned and tested by the HLWT test and wet and dry IDT. Before performing LTOA, the researchers noted that WMA mixes were more moisture susceptible than HMA, after aging for 16 weeks at 60 °C or 5 days at 85 °C. Also, authors in [19] evaluated asphalt mixture damages utilizing several laboratory conditioning protocols, including single and/or combined environmental effects as well as mixture tests at intermediate temperature. CML and binder tests correlated with each other. However, neither CML nor binder tests did correlate with IDT strength. IDT testing is sensitive to oxidation damage and was unable to react to laboratory conditioning protocols that considered combined or various environmental effects, i.e. oxidation, moisture, and freeze-thaw. CML had a good ability to detect various environmental effects. In order to evaluate the properties of intermediate temperature mixtures in relation to non-load related environmental effects, Cantabro testing was recommended.

Hundreds of field-aged and laboratory-conditioned specimens in a warm, non-freezing environment with several laboratory conditioning protocols, including single and/or combined environmental effects as well as different mixture and binder tests were evaluated in [20]. Asphalt mixture damages in service were investigated and the filed temperature and moisture levels in asphalt mixes were tracked over time and used in the evaluation. The combined effects utilized in this study include 5 days of 85 ^oC oxidation, 14 days of immersing in 64 ^oC water, and 1 freeze-thaw cycle. This laboratory conditioning procedure can simulate at least 4 years of field aging while conventional single-mechanism protocols cannot. IDT results of field cores showed that S_t values increase over time until a specific period (around 4 years) and then decrease as the influence of moisture starts to damage the asphalt mixture. Also, the HLWT value showed that the rut depth of field cores decreases until a specific long period (around 4 years), and then it begins to increase as the influence of moisture starts to damage the asphalt mixture. The CML results of field aging showed an increase in ML values over time representing that the asphalt mixture deteriorated over time in service. The study recommended that the asphalt industry needs to be more rigorous when evaluating mixes in laboratories and that combined environmental effect conditioning should be taken into account when implementing.

II. MATERIAL AND METHODS

Table I shows the gradation of a mix design used in this study. HMA, termed as M0, is used as the control mix, while two WMA additives are used, Sasobit (M1) and Rediest LQ-1200 (M2). The doses of Sasobit and Rediest LQ-1200 additives are 1.5% and 0.5% by weight of the binder, respectively. During the mixing procedures, the oven was set to the approximate plant mixing temperatures of 160 ^oC for the HMA and 140 ^oC for the two WMAs. The samples were conducted with target air voids (V_a) of 7 ± 1% according to AASHTO T166. Samples with different sizes were produced as required for mixture testing. Different mixture tests were utilized including IDT, CML, and HLWT. Also, different laboratory conditions were used, including unaged, single, or combined effects of oxidation and moisture as described below.

A. Laboratory Conditioning

1) Oxidation Conditioning

Oven condition was conducted according to AASHTO R30. After the mixture samples were prepared, they were placed in an oven (Figure 1) at a temperature of 85 °C for 120 ± 0.5 hours. After the conditioning was completed, the oven was turned off and the samples were allowed to cool down to room temperature.

2) Combined Effects of Oxidation and Moisture Damage Conditioning

The specimens were initially vacuum saturated to approximately 80% of V_a according to AASHT T166. They were then temporarily stored in room-temperature water until they were transferred to a pre-heated water bath at 64 ^oC, as shown in Figure 2. The specimens were conditioned in the water bath for 14 days and were then allowed to cool to room temperature. Finally, the specimens were transferred to the oven for oxidation conditioning as described above.

TABLE I. PROPERTIES OF THE TESTED MIXTURES

Mixture ID	**M0**	**M1**	**M2**
PG	64-10	64-10	64-10
Bitumen (%)	5.6	5.6	5.6
WMA	None	Sasobit	Rediset LQ-1200
Dosage	None	1.5 % binder	0.5 % binder
P_{25mm} (%)	100	100	100
$P_{19.0mm}$ (%)	100	100	100
$P_{12.5mm}$ (%)	92.2	92.2	92.2
$P_{9.5mm}$ (%)	86.8	86.8	86.8
$P_{4.75mm}$ (%)	57.2	57.2	57.2
$P_{2.36mm}$ (%)	38.7	38.7	38.7
$P_{1.18mm}$ (%)	24	24	24
$P_{0.60mm}$ (%)	15.6	15.6	15.6
$P_{0.30mm}$ (%)	10	10	10
$P_{1.5mm}$ (%)	7	7	7
$P_{0.075mm}$ (%)	5.4	5.4	5.4
NMAS (mm)	12.5	12.5	12.5
G_b	1.0	1.0	1.0
G_{sb}	2.7	2.7	2.7
P_s	94.4	94.4	94.4
G_{se}	2.8	2.8	2.8

PG = Performance Graded, WMA = Warm Mix Asphalt, P_{xxx} = percentage passing a xxx mm sieve, NMAS = Nominal Maximum Aggregate Size, G_b = specific gravity of asphalt binder, G_{sb} = bulk specific gravity of aggregates, P_s= aggregate percentage, G_{se} = effective specific gravity of aggregates, D_P = dust percentage

Fig. 1. Oxidation conditioning.

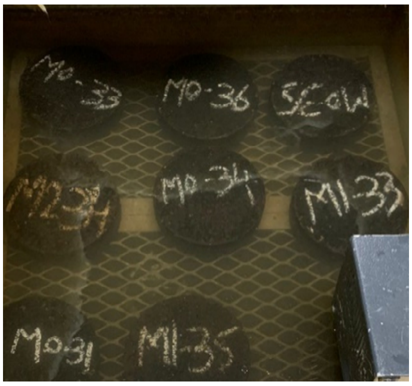

Fig. 2. Moisture conditioning.

B. Mixture Testing

1) Cantabro Mass Loss (CML) Testing

The specimen size used for CML is 150 mm in diameter and has a height of 115 mm. The samples were placed in a Los Angeles (LA) abrasion drum for 300 rotations at 25 °C without spheres ball (Figure 3). The specimen mass was recorded before and after testing. The percentage of mass loss was calculated by:

$$ML = \frac{m_1 - m_2}{m_1} \times 100 \quad (1)$$

where ML is the percentage of mass loss , m_1 is the specimen's mass before testing, and m_2 the specimen's mass after testing.

Fig. 3. CML equipment.

2) Testing Indirect Tensile (IDT) Testing

IDT test was conducted on specimens' with 150 mm diameter and 95 mm height. The test processor is according to AASHTO T283, where specimens were loaded at 50 mm/min until they failed at 25 °C (Figure 4). Equation (2) was used to determine tensile strength (S_t):

$$S_t = \frac{200 \times P_{max}}{\pi \times t \times D} \quad (2)$$

where P_{max} is maximum load (N), t is the specimen's thickness (mm), and D is the specimen's diameter (mm).

Fig. 4. IDT equipment.

3) Hamburg Loaded Wheel Tracking (HLWT) Testing

HLWT was conducted according to AASHTO T324 standards (Figure 5). The specimens' size used for HLWT was 150 mm diameter by 63 mm height. HLWT was performed at 20,000 passes (or failure at 12.5 mm rut depth). Rut depth (RD_{HLWT}) measurements were taken at 5000, 10000, 15000, and 20000 passes. The key finding of the current study was RD_{HLWT} at 20,000 passes or fails. The samples were immersed in water at 50 °C for 30 ± 1 minutes before and during testing.

Fig. 5. HLWT equipment.

III. TEST RESULTS AND DISCUSSION

Table II summarizes the testing results for mixture tests. The values for a given test method of CML or IDT represent an average of 3 samples (Table II). In HLWT tests, 2 specimens were used (referred to as a set) to represent 1 test value, while an average of 3 sets were used to represent the test value in Table II. HLWT was performed at 20,000 passes or failure at 12.5 mm rut depth, where the pass number at which failure was reached is reported. Rut depth of HLWT (RD_{HLWT}) measurements were made at 5000, 10000, 15000, and 20000 passes.

TABLE II. MIXTURE TESTS RESULTS.

Conditioning	Mix	CML ML (%)	IDT S_t (kPa)	HLWT 5K	HLWT 10K	HLWT 15K	HLWT 20K	HLWT P12.5
LC0	M0	6.1	1415	2.55	6.50	10.62	---[1]	16462
	M1	7.6	1602	2.26	4.12	6.42	---[1]	19492
	M2	6.4	1757	3.85	4.11	8.63	---[1]	14928
LC1	M0	7.3	1711	1.29	2.38	3.39	4.61	---[2]
	M1	11.1	1835	1.44	4.68	5.60	7.25	---[2]
	M2	8.1	2115	1.45	4.13	7.13	---[1]	18816
LC2	M0	11.6	1073	6.10	10.4	---[1]	---[1]	12693
	M1	13.1	995	2.57	3.23	7.19	---[1]	17435
	M2	10.4	1174	7.26	---[1]	---[1]	---[1]	9647

LC0 = unaged, LC1 = oxidation, LC2 = combination of oxidation and moisture, ---[1]test reached rut depth of 12.5 mm before 20K passes, ---[2] test reached 20k passes.

IV. CONDITIONING EFFECTS

Figure 6 illustrates the comparison between the unconditioned control (LC0), and the two-LC (oxidation and combined effects) conditioning. For instance, each point in Figure 6 represents 2 CML test specimens, 1 of which was examined before conditioning (LC0), and the other after conditioning (LC1). HLWT test results are represented by the ratio between the depth and the number of passes. The ratio is calculated by dividing the rut depth value by the number of passes. Figure 6 illustrates that if the values are above the equality line in the equality plots, this case indicates higher values measured after conditioning. Values below the equality line in the equality plots indicate lower values measured after conditioning, and values on the equality line in the equality plots indicate no property change as a result of conditioning.

Authors in [19] showed that in an oxidation-dominated environment damage, both ML and S_t values would rise. Moisture and/or freeze-thaw dominated environment would result in an increase in ML but a decrease in S_t or no change at all. Combined environment (oxidation-moisture and/or freeze-thaw) damage might result in the two damage processes canceling each other for S_t or increasing the ML value as a result of the severity of the condition. Authors in [20] showed that the S_t values of field cores increase over time until a specific period (around 4 years) and then decrease as the influence of moisture damage [20]. The HLWT test showed that the rut depth of the field cores decreases until a specific period (around 4 years) and then it begins to increase as a result of moisture damage. The ML values of field aging increased over time representing that the asphalt mixture deteriorated over time in service.

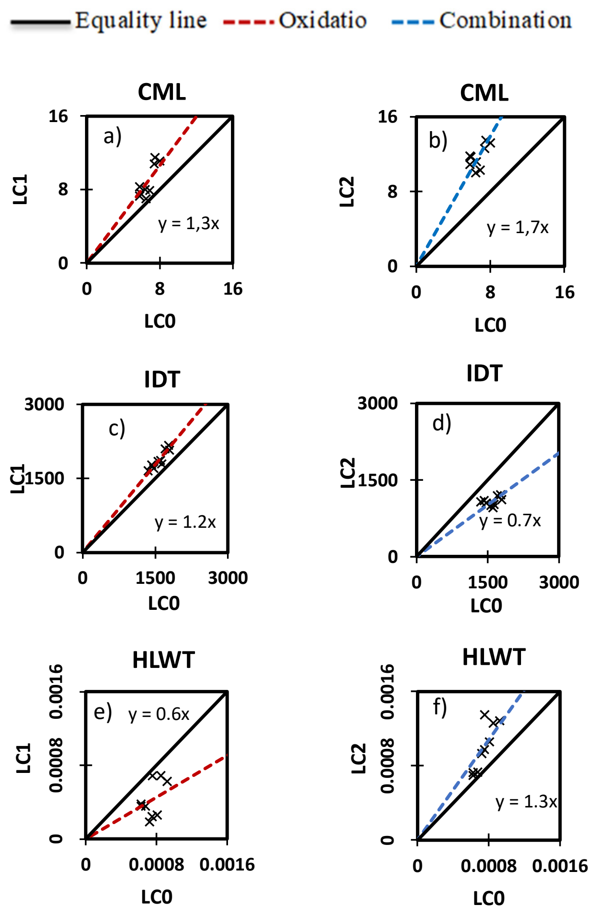

Fig. 6. Conditioning effects.

Figure 6(a)-(b) shows that the ML values are above the equality line. The slope in Figure 6(b) is higher than the one in Figure 6(a) as the severity of laboratory conditioning increases. The S_t values are shown in Figures 6(c) and (d). They are above the equality line for oxidation damage effects (Figure 6(c)). In contrast, the S_t values are below the equality line in the combined environment effects (Figure 6(d)) in accordance with the findings in [15, 16]. The HLWT results in Figure 6(e)-(f) showed rut depth value below the equality line for oxidation damage, but above the equality line for combined environment damages, in accordance with [16]. The laboratory testing results represented in Figure 6 confirm previous laboratory and field studies. The combined environment effects condition is more severe than single environment effects (i.e. oxidation or moisture). The effects of oxidation would damage the asphalt mixture in the early life cycle while moisture would influence the asphalt mixture in the long term.

V. CONCLUSIONS

This paper investigates the property measurements themselves and how a mixture test can simultaneously assess multiple types of damage, such as damage from oxidation and moisture. The laboratory results demonstrated in this study confirm other laboratory and field studies. The study concluded that laboratory conditioning of the combined effects of oxidation and moisture simulates better the asphalt damage in service than laboratory single environment effect conditioning. To predict or simulate the asphalt mixture damages and performance in service utilizing laboratory combined environment effects conditioning protocols, CML tests would be recommended to evaluate and capture these combined environment effects damage.

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