A DISCUSSION OF MMLS3 PERFORMANCE TESTING OF LABORATORY PREPARED HMA SLABS AND BRIQUETTES COMPARED WITH HAMBURG AND APA WHEEL TRACKING TESTS

André de Fortier Smit - Center for Transportation Research (CTR)
University of Texas at Austin, Suite 200, 3208 Red River, Austin, TX 78705-2650
Phone: (512) 506 5837, Fax: (512) 506 5839, asmite@mail.utexas.edu

Fred Hugo - Institute for Transport Technology (ITT)
University of Stellenbosch, Dept Civil Engineering, Private Bag X1, Stellenbosch, 7602, South Africa
Phone: +27 21 808 4363, Fax: +27 21 808 4361, fhugo@sun.ac.za

Yetkin Yildirim - Center for Transportation Research (CTR)
University of Texas at Austin, Suite 200, 3208 Red River, Austin, TX 78705-2650
Phone: (512) 232 1932, Fax: (512) 475 7914, yetkin@mail.utexas.edu

Arif Chowdhury - Texas Transportation Institute (TTI)
Texas A&M University, College Station, TX 77843-3135
Phone: (979) 458 3350, Fax: (979) 845 9356, a-chowdhury@ttimail.tamu.edu

ABSTRACT

A new procedure was developed to allow trafficking of laboratory prepared specimens (briquettes) or field cores using the third scale Model Mobile Load Simulator (MMLS3). This supplements the testing of laboratory compacted slabs. The procedure entails testing of eight or nine aligned 150 mm diameter specimens confined within specially prepared moulds to keep the specimens in place during testing. Testing may be done with the specimens beneath water, which can be heated to evaluate both permanent deformation and moisture damage to the specimens. Testing can also be conducted dry and heated to evaluate rutting only. These MMLS3 trafficking tests have a perceived advantage over Hamburg Wheel Tracking Device (HWTD) or Asphalt Pavement Analyzer (APA) tests in that specimens are tested with pneumatic tires inflated to a selected pressure, running in one direction over the specimens at significantly higher loading rates and applied forces. These conditions more closely simulate field trafficking. The paper discusses rutting results obtained from MMLS3 performance tests on aligned laboratory prepared specimens. Two case studies are presented that compare the results of these tests on different asphalt mixes with those from HWTD and APA tests in the laboratory. In one of the case studies a comparison of laboratory and field rutting is made.

Key Words: MMLS3, -trafficking, HWTD, APA wheel-tracking, rutting.
INTRODUCTION

A number of wheel tracking tests such as the Hamburg Wheel Tracking Device (HWTD) and the Asphalt Pavement Analyzer (APA) have been developed to evaluate the rutting performance of asphalt mixes in the laboratory. These tests are typically done at elevated temperatures on laboratory prepared specimens (briquettes) compacted to fixed voids levels. These wheel tracking tests provide a rapid evaluation of asphalt mixture properties, the results of which may be used in quality control assessments as part of product specifications. An example of the latter is the Texas Department of Transportation (TxDOT) initiative to include Hamburg wheel tracking specifications for quality control of some dense graded mixtures and stone matrix asphalt (SMA). Although the wheel tracking devices are primarily used to evaluate the rutting, moisture susceptibility and fatigue properties of asphalt, they are rarely used for performance investigations. A new MMLS3 testing procedure was developed to allow performance evaluations of asphalt mixtures in the laboratory.

Various agencies are investigating the relationship between the results of various wheel tracking rutting tests and actual field performance (1). Powell (2) investigated this relationship for a number of different wheel tracking devices (excluding the MMLS3) and concluded at the time that rutting obtained from wheel tracking tests in the laboratory was not a reliable “predictor” of total field rutting as monitored at the National Center for Asphalt Technology (NCAT) pavement test track. This conclusion is expected given the vast differences in loading as applied by wheel tracking devices such as the HWTD and APA in the laboratory and those by trucks in the field. The MMLS3 more closely simulates field trafficking, allowing a better evaluation of mixture performance.

MMLS3 tests are typically performed on pavements in the field or test slabs prepared in the laboratory. A new MMLS3 procedure was developed to allow testing of cylindrical laboratory specimens compacted to specific densities or asphalt cores retrieved from the field. This allows a rapid assessment of the permanent deformation and moisture sensitivity of these specimens, expanding the capabilities of the MMLS3. As with the HWTD and APA devices, testing may be done at elevated temperatures both wet and dry. The MMLS3 wheel trafficking tests have a perceived advantage over HWTD or APA tests in that specimens are tested with a pneumatic tire inflated to 690 kPa (100 psi) running in one direction over the specimens at significantly higher loading rates and applied forces, conditions that more closely simulate field trafficking.

The paper outlines the HWTD, APA and the new MMLS testing procedures and configurations as well as criteria established to evaluate the properties of asphaltic materials tested using these devices. Results of performance testing using the new MMLS3 test procedure are presented and compared with those obtained from HWTD and APA tests on the same materials. This allows a direct comparison of the results of tests using the different devices on similar materials. A discussion of the devices follows, emphasizing the difference between using wheel tracking/trafficking devices for materials evaluation and ranking purposes as opposed to the performance prediction of asphalt mixtures in the field.

WHEEL TRACKING/TRAFFICKING TEST CONFIGURATIONS AND TEST CRITERIA

What follows is a description of the HWTD, APA and new MMLS3 test configurations and criteria used to evaluate asphalt material characteristics using these devices.

Hamburg Wheel Tracking Device (HWTD)

The HWTD was originally developed in Hamburg, Germany where it is used as a specification requirement to evaluate rutting and stripping of asphalt mixes (1, 3). The device was introduced to the USA in the 1990s and has been modified from its original design to test cylindrical specimens. Specimens are tested submerged in water heated to temperatures up to 50 °C (122 °F) by loading with a steel wheel having a diameter of 200 mm (7.9 in) and a width of 47 mm (1.9 in). Additional loading is applied to the wheel such that the total load applied to the test specimens is in the order of 0.7 kN (158 lbf). This results in very high contact pressures on test specimens. HWTD tests are conducted at a rate of 52 load applications per minute. This equates to a speed of about 0.25 m/s (0.8 ft/s). The loaded wheel oscillates back and forth over the tested specimens. One forward and backward motion comprises two loading cycles.

HWTD specimens are laboratory compacted to fixed voids levels, typically 7 percent and a height of 63 mm (2.5 in). Specimens are cut to allow two specimens to be aligned alongside each other such that the trimmed
edges are in contact. This ensures that the loaded wheel is always in contact with the asphalt concrete specimen as it rolls back and forth over its surface during testing. The widths of the cut specimen leading edges in contact are 60 mm (2.4 in), thus the ratio of the width of the leading edges to the width of the HWTD wheel is 60/47≈1.3. This ratio reflects on the degree of possible edge effects and specimen confinement.

In the TxDOT HWTD procedure (4), testing of specimens is continued until a total of 20,000 cycles are applied or until rutting of the tested specimens exceeds 13 mm (0.5 in). A specification requirement adopted is that rutting be less than 13 mm (0.5 in) after the application of 20,000 at 50 °C (122 °F). Rut depth is measured continuously during trafficking. Various parameters are used in the interpretation of HWTD test results i.e. rut depth, creep slope, stripping slope and stripping inflection point. The creep slope is defined as the inverse of the deformation rate within the linear range of the deformation curve after densification and prior to stripping (if stripping occurs). The stripping slope is the inverse of the deformation rate within the linear region of the deformation curve after stripping occurs. The creep slope relates primarily to rutting from plastic flow (shear failure) and the stripping slope indicates accumulation of rutting due to moisture damage (5). The stripping inflection point is the number of wheel passes corresponding to the intersection of creep slope and stripping slope.

Aschenbrener (3) reports an excellent correlation between the HWTD and pavements with known field performance. He mentions that the HWTD is sensitive to asphalt cement stiffness, the quality of aggregate, length of short-term aging, asphalt cement source, liquid and hydrated lime anti-stripping agent and compaction temperature. Izzo and Tahmoressi (5) investigated the repeatability of the device and concluded that it yielded repeatable results for mixtures produced with different aggregates and with test specimens fabricated by different compaction devices. The advantages and disadvantages of the HWTD are discussed in more detail later in the paper.

**Asphalt Pavement Analyzer (APA)**

The APA was originally developed in Georgia in the mid 1980s (1, 6). The APA is capable of evaluating the rutting, fatigue and moisture resistance of HMA mixtures. The fatigue test is performed on beam specimens supported on two ends. Rutting and moisture damage evaluations are typically performed on cylindrical specimens or briquettes compacted to a height of 75 mm (3 in). Testing may be done in both dry and wet conditions.

The APA applies a load of 0.44 kN (100 lbf) through a 25 mm (1 in) diameter rubber hose inflated to 690 kPa (100 psi) at a speed of about 0.2 m/s (0.66 ft/s). The loaded wheel oscillates back and forth over the hose. Rut depth is measured continuously during trafficking using linear variable displacement transducers (LVDTs) connected to the wheels. A rutting criterion used to assess rut resistance of asphalt mixtures tested using the APA is 4 mm after the application of 8,000 load cycles at 50 °C (122 °F). APA testing is done within a temperature chamber with possible temperatures ranges from 5 to 70 °C (40 to 160 °F).

Choubane et al (7) have indicated that the APA might be an effective tool to rank asphalt mixtures in terms of their respective rut performance. Kandhal et al (8) reported that the APA has the ability to predict the relative rutting potential of HMA mixtures and that it is sensitive to binder grade and aggregate gradation. Uzarowski and Emery (9) found good correlations between rutting resistance predicted by the APA and actual field performance of asphalt concrete pavements.

More recently Kandhal and Cooley (10) found that the APA test method with the best relationship to performance featured the use of (1) cylindrical specimens compacted to 4-percent air voids or beam specimens compacted to 5-percent air voids, (2) a test temperature corresponding to the high temperature of the standard binder performance grade for the project location, and (3) a standard APA linear hose. They report that laboratory rut depths measured with this method correlated well with field performance on an individual project basis, however, it was not generally possible to predict field rut depths from APA testing on any given project using relationships developed from other projects with different geographic locations and traffic. They also conclude, based on limited data, that the APA compares well with HWTD and simple performance tests as identified in NCHRP Project 9-19 (11) with respect to predicting the potential for rutting in the field.

**Model Mobile Load Simulator (MMLS3)**

The MMLS3 consists of four recirculating axles, each with a single 300 mm (11.8 in) diameter wheel that applies uni-directional loading. The tires may be inflated up to pressures of 800 kPa (116 psi). Axle loads varying between
2.1 kN (470 lbf) and 2.9 kN (650 lbf) are possible. The axle loads are automatically kept constant at a predetermined level by a patented suspension system. Nominal wheel speed is 2.5 m/s (8.2 ft/s), applying up to 7200 loads per hour. The speed of trafficking can be varied. For the MMLS3 tests described in the case studies that follow the wheel loads applied were kept constant at 2.7 kN (600 lbf) and tire pressures at 690 kPa (100 psi).

Figure 1 shows a photo of the new MMLS3 test configuration and Figure 2 is a schematic plan view of the aligned specimens within the test bed. From Figure 2 it can be seen that eight (or nine specimens in the latest test bed) are aligned butting along trimmed edges on either side. Aluminum moulds or clamps are used to confine the specimens during testing. These are shaped to ensure load transfer between the tested specimens. The mould configuration may be placed within a water bath for heated wet testing, ensuring that the tops of the specimens are submerged approximately 3 mm (0.1 in) beneath the water level during testing. The MMLS3 is aligned above the mould configuration such that trafficking occurs along the center of the aligned specimens. Also shown in Figure 2 are the dimensions of a trimmed specimen. These are compacted to a height of 100 mm (4 in) in the case of laboratory briquettes or cut to this height if field cores are tested. Specimen thicknesses may be varied between 35 mm (1.5 in) and 100 mm (4 in) in the latest test beds. The leading edges of the trimmed specimens are 100 mm (4 in) to allow an unobtrusive passageway for the 80 mm (3.2 in) wide MMLS3 inflated tire along the specimens. Thus the ratio of the width of the specimen leading edges to that of the tire width is 100/80=1.3, the same as that for the HWTD.

MMLS3 testing protocols include strength and/or fatigue evaluation of trafficked specimens after the completion of an MMLS3 test as described. Tested specimens having diameters of 150 mm (6 in) are cored to obtain 100 mm (4 in) diameter specimens for strength or fatigue testing. The semi-circular bending test (SCB) is typically used for strength and fatigue testing (12). These tests are also done on untrafficked specimens of the same mix to determine the extent of moisture damage resulting from MMLS3 trafficking and the residual strengths or fatigue lives of the trafficked cores. Spectral analysis of surface waves (SASW) techniques are also applied to monitor stiffness loss of the HMA cores during MMLS3 trafficking (13).

Studies are underway to formalize criteria to assess the rutting and moisture susceptibility of mixes tested using the MMLS3 in the laboratory (14, 15). Interim criteria have been established based on MMLS3 testing in the field at Westrack (16, 17), the NCAT test track (18, 19) and various locations in Southern Africa (14, 15). These are related to rutting, SASW measurements of stiffness as well as the results of material strength and fatigue assessments. Preliminary indications are that these criteria as adopted in the field may be appropriate to assess the performance of mixes tested in the laboratory using the new MMLS3 procedure.

Epps et al (16) and Martin Epps et al (17) established a rutting criterion of 3 mm (0.12 in) to assess the rutting potential of selected Westrack mixes tested with the MMLS3 at the critical temperature conditions in the field. In the case of Westrack, 60 °C (140 °F) was established and used as the critical temperature. Subsequent studies have shown that extrapolation of the rutting results after the application of 100,000 or 200,000 MMLS3 axles may be used as a basis for estimating the extent of rutting under truck trafficking of one million equivalent axles loads (ESALs) or more (18). This allows an evaluation of the field performance of an asphalt mixture using the MMLS3. Factors that have to be taken into account are axle load and frequency, tire pressure, effective traffic volume due to lateral wander, as well as climatic conditions during trafficking. Criteria have also been established for adjudicating susceptibility to moisture damage i.e. a limit of a 80 percent ratio for semi-circular bending (SCB) tensile strength, 80 percent for the residual SASW stiffness and 50 percent for SCB fatigue ratio of asphalt, after the application of 100,000 wet MMLS3 axles at 50 °C (122 °F) (14, 15, 18, 19).

**CASE STUDIES**

The paper discusses two different case studies involving MMLS3 testing using the new procedure. In these case studies, HWTD and APA testing was done in conjunction with MMLS3 testing, which allows a comparison of the different devices. The first case study presents the results of MMLS3, HWTD and APA wheel trafficking/tracking tests to investigate the rutting performances of different mixtures and materials ranging in quality. The second case study compares the results of aligned MMLS3 and HWTD tests on composite asphalt and concrete specimens. In this case study the laboratory rutting results are also compared to rutting of comparable asphalt pavements constructed in the field.
Case Study 1: Laboratory evaluation of different mixes using different wheel tracking devices

In this case study researchers selected four different mixes ranging in quality from very poor to excellent to investigate the rutting potential of these mixes towards the evaluation of Superpave shear testing protocols (20). The HMA mixtures selected for the study were a granite stone mastic asphalt (SMA), a Texas Type C mix with limestone aggregate, a granite Superpave mix and a Texas Type D mix with rounded river gravel. The order in which the mixes are listed is the ranking order of known field performance i.e. excellent to very poor. Table 1 reports material information and the gradations of these mixes. Wheel trafficking/ tracking devices used in the study were the MMLS3, HWTD and APA. Two different MMLS3 tests were done in the laboratory i.e. tests on slabs and separate tests on gyratory compacted specimens using the new procedure as outlined.

For the MMLS3 tests on the slabs, the four different mixes were compacted within a mould with width and length dimensions of 914 mm (36 in) and 1830 mm (72 in) respectively. The final thicknesses of the compacted surface layers to be tested were in the order of 70 mm (2.75 in). Post compaction densities of the slabs for the different mixes varied i.e. 96 percent for the river gravel Type D, 94 percent for the Granite SMA and Superpave mixes and 92 percent for the Limestone Type C mix. Specimens for the aligned MMLS3 tests as well as those for the HWTD tests were gyratory compacted to densities of 93 percent. Specimens for the APA tests were gyratory compacted to densities of 96 percent. APA specimens were tested dry whereas the MMLS3 and HWTD specimens (briquettes) were tested wet.

Test Results

Figure 3 shows the average cumulative rutting of the mixes measured for the MMLS3 tests on the slabs and the aligned specimens. MMLS3 tests on the slabs were done dry at a temperature of 50 °C (122 °F) while those on the aligned specimens were done wet, also at 50 °C (122 °F). A total of 100,000 MMLS3 axles were applied for each test although the testing of the River gravel Type D mix was terminated prematurely due to excessive rutting of this mix. The figure indicates that the rutting of the different mixes from the MMLS3 tests on the slabs and aligned specimens was similar with the exception of the MMLS3 test on the Type C mix. The performance of these Type C specimens was considerably better when tested aligned compared to the slab tests. The Type D mix, being of poorer quality, performed the worst of the mixes, regardless of test configuration.

Figure 4 shows the APA and HWTD rutting test results. In the HWTD and APA, the loaded wheel oscillates back and forth over the specimens being tested, defining a single load cycle (typically this would count as two HWTD load cycles). The Type D mix failed prematurely in the HWTD test and this result is not shown. This mix did also not perform very well under APA (nor MMLS3) trafficking as indicated. The SMA mixture performed the best under each of the wheel tracking devices emphasizing the stability of this mix, particularly when confined. The Type C mix failed under HWTD loading but performed reasonably under APA and MMLS3 testing.

The very poor performance of the Type C mix in the HWTD with reasonable performance under APA and MMLS3 loading is an apparent anomaly and was investigated further with SCB fatigue testing of the aligned MMLS3 trafficked specimens. The tested specimens were cored to obtain 100 mm (4 in) diameter samples for fatigue testing. The same was done for the untrafficked cores. The strength or fatigue ratio (trafficked : untrafficked) is considered representative of the resistance of the mix to wet trafficking. It also served to indicate the effect of trafficking under dry high temperature conditions. These tests indicated that the Type C specimens had indeed undergone significant fatigue life loss with wet trafficking, as had the Superpave specimens. The residual fatigue lives of the aligned MMLS3 trafficked Type C and Superpave specimens were between 10 to 20 percent of corresponding untrafficked specimens. In contrast the SMA and Type D trafficked mixes had increased in strength indicating that these were resistant to moisture damage. The problem with the Type D mix, however, was a lack of rutting resistance.

Case Study 2: Laboratory evaluation of asphalt mixes for CRCP overlays

In this case study, MMLS3 tests were done on composite asphalt and concrete specimens tacked together. The objective of the tests was to evaluate the suitability of different mix and aggregate types for use as overlay materials on continuously reinforced concrete pavements (CRCP). Mixes used as overlays on these structures would be subjected to high compressive and shear stresses. Suitable mixes are required to resist these stresses.
Three surface mixtures: Texas Type C, 12.5 mm Superpave, and coarse matrix high binder (CMHB) mixtures, were designed using three aggregate types: gravel, quartzite, and sandstone. Nine different surface mixture designs were prepared using each aggregate for all mixture types. A PG 76-22 binder was used for all the mixes and each contained 1 percent lime to enhance their stiffness properties. The binder contents of the different mixes are shown in Table 2 as are the aggregate gradations.

Asphalt specimens for the MMLS3 tests were plant prepared but laboratory compacted. These specimens, having diameters of 150 mm (6 in) and thicknesses of 50 mm (2 in), were prepared by gyratory compaction to a density of 93 percent (%Gmm) i.e. 7 percent voids in the mix (VIM). The asphalt concrete specimens had to be sawn for the MMLS test configuration in which specimens are placed side-by-side (see Figure 2). The sawn specimens were tacked to concrete disks having a height of 50 mm (2 in) also sawn as indicated. The concrete disks were obtained by sawing 150 mm (6 in) diameter PCC concrete cores. The tack coat used to bond the asphalt and concrete specimens was an SS-1 slow setting emulsion. An application rate of 0.81 l/m² (0.04 gal/yd²) was applied.

MMLS3 tests were done using the new procedure, wet at a temperature of 50 °C (122 °F). Separate MMLS3 tests were done on each of the nine mix and aggregate combinations. A total of 120,000 wet MMLS3 axles were applied in each test. Figure 5 shows the average cumulative MMLS3 rutting curves for each of the mixes tested.

Specimens for the HWTD tests were also plant prepared and gyratory compacted to a density of 93 percent (%Gmm) and thicknesses of 63 mm (2.5 in). These specimens were tested at a temperature of 50 °C (122 °F) by applying 100,000 HWTD cycles instead of the typical 20,000 cycles. Figure 6 shows the HWTD test cumulative rutting curves for each of the mixes tested.

Test Results

Apparent from Figures 5 and 6 is the poorer performance of the mixes with siliceous gravel aggregates. Both the MMLS3 and HWTD tests highlighted the poorer relative performance of mixes with these aggregates. The poorer performance of these mixes was not unexpected given that the gravel aggregates are more rounded and less angular than the quartzite and sandstone aggregates. Rounded aggregates do not develop shear resistance to the extent of more angular type aggregates. This is particularly the case with stone skeleton mixes such as CMHB that rely on stone interaction for stability. One would have expected a poorer relative performance from the Superpave gravel mix in the HWTD as was indicated by the MMLS3 testing. Based on criteria established for MMLS3 testing, the Type C and CMHB gravel mixes have unacceptable rutting performances. These mixes, however, performed sufficiently well in the HWTD test.

Nine sections comprising the mixture and aggregate combinations used for the study were constructed on IH-20 in Marshall, Texas during November, 2000 as part of the rehabilitation of a CRCP. The mixes were compacted to a lift thickness of 50 mm (2 in). Each section is roughly 150 m (500 ft) long and has received the same volume of traffic since construction. The performance of the sections has been monitored on a yearly basis since construction. Table 2 indicates the average rutting monitored on the different sections during November, 2003 i.e. 3 years after construction. Rut depth was measured using the dipstick device at 30.5 m (100 ft) intervals along each section. The rutting values shown in Table 2 are the rut depths measured in the left and right wheelpaths of the outside lanes for each section.

Rutting of the sections in the field ranged between 0.9 and 1.7 mm (0.04 and 0.07 in) after 3 years of trafficking. The sections in the field comprising gravel aggregates rutted more than those with sandstone and quartzite. The ranking order of section rutting as observed in the field corresponds well with that determined for the MMLS3 and HWTD tests in the laboratory. The devices and in particular the MMLS3 was able to distinguish the relative performance of the better and poorer mixes in terms of rutting as observed in the field.

DISCUSSION

The first case study illustrates the nature of the different test devices. Each of the devices was able to distinguish between the poorer performing Type D mix and the very stable SMA mix, but ranked the performance of the Type C and Superpave mixes differently. These mixes and in particular the Type C mix were susceptible to moisture
damage. The aggressive loading in the HWTD exposed this weakness directly. Based on criteria used for the different devices the HWTD and APA devices identified the Type C and Type D mixes as being inadequate. Based on the rutting criterion, the MMLS3 identified the Type D and Superpave mixes as being inadequate and based on the MMLS3 residual fatigue life criterion the Type C mix is also disqualified. Hence, based on the MMLS3 criteria only the SMA mixture has acceptable resistance to rutting and moisture damage. The Superpave mix only just passed the APA rutting criterion of 4 mm after 8,000 cycles but had acceptable HWTD performance. TxDOT research done to establish the best Superpave shear test protocol (20) concluded that the MMLS3 was the most sensitive of the devices evaluated in that it was the only device able to separate the four mixtures tested into four significant performance groups. The rutting test results confirm this.

An aspect that is not always appreciated is the difference between the output from rut testers (such as the HWTD and the APA) and the MMLS3. Rut testers do not apply trafficking in a manner comparable to conventional vehicular wheel loading on highway or airport pavements. The loading mechanisms only simulate the action of a wheel by going back and forth over a small specimen at very slow speeds. While some comparison is achieved between mixes as shown in the case studies, there is a distinct possibility that some factors which affect performance are negated. In contrast, the MMLS3 is an accelerated pavement testing device that applies realistic trafficking to the pavement. The load is scaled but tire pressures are at the same level as in full scale trucks. Accordingly, the results are transferable to conventional real life trafficking. The device can be used directly to explore performance of the upper 125 mm of asphalt pavements in the laboratory and in the field. The MMLS3 can characterize a material/mix and predict actual performance if factors such as load frequency, temperature, lateral wander of load applications and aging are taken into account (16, 17, 18). Of course these factors are more easily established under controlled field tests such as those at Westrack and NCAT. In contrast, rut testers have limited capability of comparing performance of materials/mixes. If there is a desire to evaluate pavement performance under slow trafficking in a manner similar to rut testers, it can also be done with the MMLS3, by adjusting the speed. However trafficking is still uni-directional.

The positive comparison between the MMLS3 rutting as measured in the laboratory and that observed for the mixes trafficked in the field as outlined in the second case study reinforces the aforementioned statement. Differences in the magnitudes of laboratory and field rutting must of course be related to differences in trafficking conditions such as load, temperature, the presence of water, the influence of aging, the effects of lateral wander, the rate of loading and materials differences (varying density, binder type, binder content, etc). Ranking the relative performance of different mixes is beneficial although more attention should be given to and emphasis placed on the actual performance prediction of these mixes in the field. This aspect has been addressed successfully with the MMLS3 in the field (16, 17, 18) and in the laboratory (15). Space limitations do not allow for a thorough discussion of this aspect of MMLS3 testing, although the reader is referred to the references for a detailed account of field performance prediction using the MMLS3.

Another aspect to consider when evaluating the results of wheel tracking tests is their sensitivity to material properties and in particular material stiffness. TxDOT specifies HWTD criteria in terms of binder stiffness for dense graded mixes and stone matrix asphalt (SMA). Their experience with HWTD testing has indicated that the influence of the different mix related variables is related to the degree with which these tend to stiffen the mix. It has been found that the greater the stiffening effect - the better the HWTD performance of the mix. Binder grade is the dominant factor influencing the HWTD performance of asphalt concrete mixes. Stiffer materials are generally more resistant to rutting and less susceptible to moisture damage. Additives, particularly lime, increase the stiffness of asphalt mixes and those with lime additives generally perform well in the HWTD, often regardless of mix type or aggregate type. Asphalt mixes used in Texas are generally dense graded or have stone skeleton structures. These mixes provide added resistance to rutting to the extent that it is difficult to distinguish the relative HWTD rutting performance of different asphalt mixes types. The influence of aggregate type on HWTD rutting performance, however, is discernible, particularly when used with mixes having less stiff binders. The downside of basing mix designs on HWTD criteria, however, is that stiff mixes with low binder contents may be promoted to the detriment of fatigue performance.

Clearly each of the devices discussed in the paper have benefits depending on the nature of testing performed. Factors to consider in the application of these devices include costs, specimen preparation, the number of specimens that can be tested, time required for testing, the influence of edge effects, the mechanical complexity of the device and applicability of the test results to name a few. The case studies have demonstrated the importance of
understanding the performance of asphalt mixes under the different small scale trafficking devices. This knowledge provides a basis for the selection of an appropriate device for different applications. Applications can vary from ranking of performance of mixes to the quantitative determination of performance. Each of the devices has protocols depending on the respective application. A better understanding of the applications of the different small scale devices should result in more cost effective accelerated pavement testing in general.

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<table>
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<td>9.8</td>
<td>12</td>
<td>8</td>
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<td>3.7</td>
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### TABLE 2 Binder contents, gradations and field rutting performances of mixes used in Case Study 2

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<th>Sieve Size</th>
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<th>CMHB-C</th>
<th>Texas Type C</th>
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<td>Quartzite</td>
<td>Sandstone</td>
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<td>AC%</td>
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<td>5.6</td>
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</table>

Units in mm
A Discussion of MMLS3 Performance Testing of Laboratory Prepared HMA Slabs and Briquettes….

FIGURE 1 The new MMLS3 test configuration
FIGURE 2 Plan view of aligned specimen within moulds and specimen dimensions
FIGURE 3 Average cumulative slab and aligned MMLS Rutting from Case Study 1
FIGURE 4 Average cumulative APA and HWTD Rutting from Case Study 1
A Discussion of MMLS3 Performance Testing of Laboratory Prepared HMA Slabs and Briquettes.

FIGURE 5 Average cumulative MMLS Rutting from Case Study 2
FIGURE 6 Cumulative HWTD Rutting from Case Study 2