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EVALUATION OF BITUMINOUS PAVEMENTS FOR HIGH PRESSURE TRUCK TIRES

Executive Summary & Implementation Plan

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Prepared for Pennsylvania Department of Transportation in cooperation with
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Final Report



277 Technology Parkway • Auburn, AL 36830

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Prithvi S. Kandhal
Assistant Director
National Center for Asphalt Technology
Auburn University, Alabama

Stephen A. Cross
Assistant Professor
University of Kansas

E. Ray Brown
Director
National Center for Asphalt Technology
Auburn University, Alabama

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SUMMARY AND CONCLUSIONS

This research project was undertaken to evaluate 34 in-service heavy duty pavements across Pennsylvania to identify the material properties, mix design parameters, pavement construction properties, and pavement in-service properties which are responsible for the premature rutting (permanent deformation) of some HMA pavements. Of the 34 projects, ten were excellent, nine were good, 12 were fair, and three were poor based on a subjective rating system which was validated in this study.

Traffic, mix design, and construction data was collected for all projects. The total estimated traffic carried by the pavements (ranging in age from 2 to 19 years) ranged from less than one million ESALs to over 30 million ESALs.

Eleven 6-inch diameter cores were taken from each project to determine the VTM (voids in total mix), creep (permanent deformation), mix composition (asphalt content and gradation), fractured face count of coarse aggregate, particle shape and texture of fine aggregate, and recovered asphalt penetration and viscosity. The cores were also reheated and compacted using three compaction methods: gyratory testing machine (GTM), rotating base-slanted foot mechanical Marshall compactor, and static base mechanical Marshall compactor. Recompacted specimens were tested for VTM, Marshall stability and flow.

Transverse surface profiles of the pavement were obtained at two locations: worst site and a representative site within 500 ft of the worst site. Maximum surface rut depth and the rut depth in individual layers were determined from the surface profile and the thickness of the layers measured from transverse sets of cores. The maximum surface rut depth at the worst location on all projects ranged from 0.04 inch to 1.66 inch. In a majority of cases the underlying layers in conjunction with the wearing course contributed to the surface rut depth.

Mix Design. The number of blows/face used was 50 for 24 projects, 65 for three projects (Turnpike), and 75 for seven projects in designing the wearing mixes. Only seven projects of 34 projects had wearing mix design VTIVI equal to or greater than 4.0 percent. Of 26 binder mixes, 12 mixes had VTIVI equal to or greater than 4.0 percent. This indicates that both the wearing and binder mixes were designed closer to the minimum VTIVI value of the 3-5 percent range used by PennDOT.

Construction. Construction data indicates that the percentage of minus 200 material was generally higher in the “produced mix” compared to the “designed mix” for both wearing and binder mixes. In the case of the binder mixes, the percentage of material passing 1/2" and No. 8 sieve was also generally higher in the “produced mix” compared to the “designed mix” indicating that the “produced mix” was finer.

In-Service Properties. Excessive minus 200 in both wearing and binder mixes, and excessive material passing 1/2" and No. 8 sieves in binder mixes as reported during construction (testing of loose mixtures) was confirmed by the core test data. Average in-place VTMs in the wearing and binder courses were determined to be 3.2 and 3.0 percent which are significantly lower than the mix design VTMs. This indicates that the laboratory compactive effort was inadequate and/or

excessive fines created during construction filled the voids. Obviously, there are many projects which have VTMs lower than 3 percent. According to past experience HMA pavements approach the potential for rutting when the VTM is 3 percent or less.

Of the three compactors used to recompact the mix from the pavements, Marshall compactor with rotating base and slanted foot gave the highest density (least VTM) for both wearing and binder mixes. This compactor is recommended for use by PennDOT to obtain the near maximum potential compaction of mixes which is likely to be achieved in heavy duty pavements subjected to high pressure truck tires.

Average GSI (gyratory shear index) values of 1.35 and 1.26 for wearing and binder courses, respectively, are on the high side and indicate potential for rutting. Whereas a value of 1.00 is considered ideal to prevent rutting, values up to 1.20 may be acceptable.

Statistical Analysis

Some 60 independent variables covering the general design, construction and post construction data for each pavement were selected to determine their effect on rutting. The dependent variable selected for analysis was rut depth in inches divided by square root of total traffic in million ESALs. A threshold value of 0.2 for this dependent variable was determined in this study. Pavements are expected to develop undesirable amounts of rutting if this value is exceeded.

All data pertaining to the 60 independent variables and the dependent variable was analyzed using correlation analysis, linear regression analysis, and stepwise multiple variable analysis methods.

Since rutting is a complex phenomenon, no one independent variable alone could predict rutting with any degree of confidence. However, the following significant trends were observed and threshold values identified.

Mix Composition and Design. Rutting potential increased as (a) minus 200 content increased, (b) fractured face count of coarse aggregate decreased, (c) percentage of natural sand in the fine aggregate increased, (d) percentage of asphalt content increased, (e) Marshall mix design stability decreased, (f) mix design stability/flow ratio decreased, and (g) mix design bearing capacity of mix decreased. Threshold values to control the rutting are as follows:

	Wearing Mix	Binder Mix
Percent natural sand in the fine aggregate	Less than 20%	Less than 20%
Marshall mix design stability, lbs.	Above 2800	Above 2800
Design stability/flow ratio	Above 250	Above 275
Design bearing capacity	Above 275	Above 275

Threshold values of Marshall mix design stability, design stability/flow ratio, and design bearing capacity are considered high. These values (obtained from the job-mix formula) cannot be used because the “as placed” mixes were generally significantly different from the “as designed” mixes. Optimum pavement performance was generally observed when the percentage of material passing No. 8 sieve was 45-50 for wearing mixes, and 25-30 for binder mixes. The indicated maximum percentage of natural sand in the fine aggregate is 20. It is reasonably close to the present specification requirement of 25 percent which is considered adequate.

In-Service Properties. Rutting potential increased as (a) in-place VTM decreased, (b) gyratory shear index (GSI) increased, (c) recompacted VMA decreased, (d) recompacted VTM decreased, (e) recompacted stability decreased, (f) recompacted stability/flow ratio decreased, and (g) recompacted bearing capacity decreased. Threshold values to control the rutting are as follows:

	Wearing Mix	Binder Mix
Average in-place VTM	Above 3.0%	Above 2.0%
GSI	Below 1.2	Below 1.2
Recompacted VMA	Above 15%	Above 12%
Static base recompacted stability, lbs.	Above 3400	Above 3600
Static base recompacted stability/flow	Above 280	Above 260
Static base recompacted bearing capacity	Above 300	Above 280

Again, the threshold values of stability, stability/flow and bearing capacity cannot be used because these were obtained on aged, recompacted mixtures.

RECOMMENDATIONS FOR IMPLEMENTATION

Data from this research project indicates that the current PennDOT heavy duty specifications have minimized the rutting potential of HMA pavements in Pennsylvania. However, the following recommendations are made to improve and optimize the resistance of PennDOT HMA mixes to rutting induced by high pressure truck tires and increasing traffic volumes.

Materials

1. Coarse aggregate retained on No. 4 sieve. Continue to use at least 85 percent of particles with two or more fractured faces for wearing and binder courses.
2. Fine aggregate. Continue to use at least 75 percent manufactured sand in the fine aggregate for both wearing and binder courses. Encourage use of 100 percent manufactured sand if possible.
3. Size. Although limited data is available from this project to justify increasing the maximum size of aggregate for wearing and binder courses, it is prudent to do so based on nationwide experience. Use 1 1/2" maximum aggregate size (at least 5 percent retained on 1") for binder courses. Encourage increased use of ID-3 wearing course (3/4" maximum aggregate size).

Mix Design

1. Mechanical Marshall compactor with rotating base and slanted foot (75 blows/face) gave the highest density (least air void content), for both wearing and binder courses, compared to the gyratory testing machine (GTM) and conventional static base Marshall compactor (75 blows/face). Rotating base/slanted foot Marshall compactor should be used, at least in the central laboratory, to obtain near maximum potential compaction of mixes which will likely to be achieved after 2-3 years' traffic. This will minimize the potential over-asphalting of mixes designed for heavy duty pavements and high pressure truck tires.
2. Design mixes with at least 4.0 percent air voids when using rotating base/slanted foot Marshall compactor.

3. Current specifications for VMA, stability and flow appear adequate.

Mix Production Quality Control

1. Binder course mixes “as placed” were generally finer than mixes “as designed.” On average, the percentages passing 1/2", No. 8 and No. 200 exceeded the job-mix formula values by 4.3, 2.5 and 1.0 percent, respectively. Wearing course mixes “as placed” have 1.1 percent (average) higher minus 200 than the job-mix formula. Better mix gradation control is necessary. If the quality control charts or historical RPS data indicate that the values are consistently on the high or low side of the JMF, the mix design should be revised to incorporate production gradation. If all RPS lots on a project get 100 percent payment, it does not mean necessarily that the mix is satisfactory from a rutting standpoint because the mix could consistently be finer than designed and still meet the specification requirements.
2. Air void content in laboratory compacted samples of “produced mix” is more important than that of the “designed mix”. If the produced mix contains excessive minus 200 material, its air void content will be lower than the designed mix and, therefore, potential for rutting will increase. It appears from the preliminary review of the test data that the percentage of air void content obtained from the daily compacted Marshall specimens should be made a pay item in the RPS specifications in lieu of minus 200 material. A control of air void content will indirectly control the amount of minus 200 material in the mix. Some states use this approach because air void content of the daily compacted Marshall specimens is the most important parameter affecting rutting. Air void content should not be allowed to fall below 3.0 percent.
3. There is some indication of increased rutting potential if the freshly laid wearing course is subjected to high temperatures and channelized traffic for extended periods of time. Project construction traffic control should be planned in advance to minimize this effect. Whenever possible, the wearing course should not be placed until all binder courses have been completed.