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JOINT HIGHWAY RESEARCH PROJECT

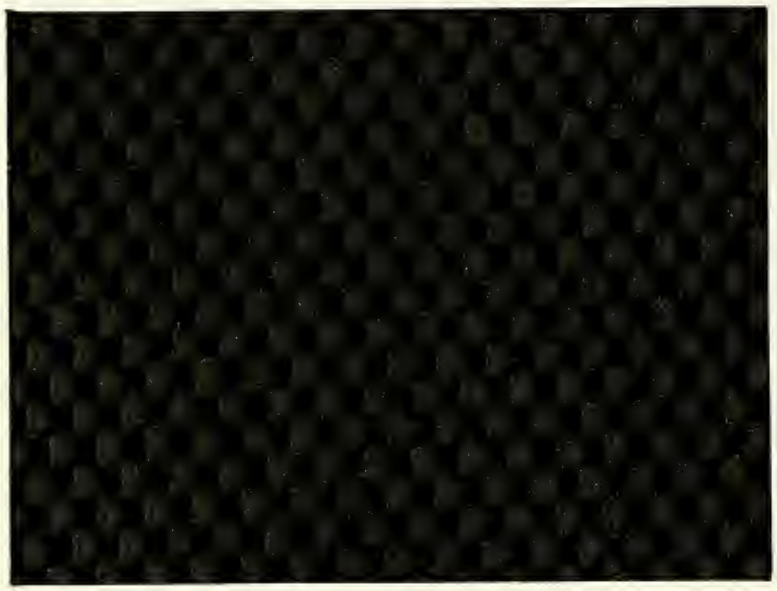
Executive Summary

FHWA/IN/JHRP-87/11 – 2

MATERIAL CHARACTERIZATION OF HOT-MIX RECYCLED BITUMINOUS PAVEMENTS

L.E. Wood
A.S. Noureldin

PURDUE UNIVERSITY



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16. Abstract

A detailed laboratory investigation was performed to characterize the performance of the hot mix recycled asphalt pavement in comparison with a virgin mix. A virgin mixture and three recycled mixtures were evaluated. Marshall size specimens were fabricated and evaluated using the pulse velocity, resilient modulus, indirect tensile strength, Hveem stability and Marshall stability tests. In addition the recycled binder itself was evaluated using a stage extraction technique and the thin film oven test results. Long term aging of recycled mixtures was also studied. Subjective conclusions were established for the performance of recycled mixtures under various conditions.

Virgin mixture stiffness and strength parameters were higher than those of recycled mixtures. However, long term aging properties of two of the recycled mixtures were better than the virgin mix, especially when regarding the failure tensile strain. The thin film oven test and the indirect tensile test were identified as additional criteria for the choice of type and amount of recycling agent to be used. The results of this study will provide the highway engineer with a better understanding of the effect of different factors on the tensile and resilient characteristics of hot recycled bituminous paving mixtures

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EXECUTIVE SUMMARY

Hot mix bituminous pavement recycling is a process in which reclaimed bituminous pavement materials, reclaimed aggregated materials, or both are combined with new bitumen, and/or rejuvenating agents, and/or virgin aggregate as necessary to produce hot-mix paving mixtures meeting all standard materials specifications and construction requirements for the type of mixture being produced.

The technique has become widely used in a practical manner. However, there are several fundamental questions still unanswered in the area of hot mix recycling that require immediate research. Among them are homogeneity, compatibility and rate of hardening of a recycled mix when compared to a virgin mix. In addition, assurance is needed that weathering actions, long term behavior, mechanical properties of compacted recycled mixtures and the effect of repeated loads on recycled pavements are not problems.

A detailed laboratory investigation was performed to characterize the performance of the hot mix recycled asphalt pavement in comparison with a virgin mix. A virgin mixture and three recycled mixtures were evaluated. Marshall size specimens were fabricated and evaluated using the pulse velocity, resilient modulus, indirect tensile strength, Hveem stability and Marshall stability tests. In addition the recycled binder itself was evaluated using a stage extraction technique and the thin film oven test results. Long term aging of recycled mixtures was also studied. Subjective conclusions were established for the performance of recycled mixtures under various conditions.

Virgin mixture stiffness and strength parameters were higher than those of recycled mixtures. However, long term aging properties of two of the recycled mixtures were better than the virgin mix, especially when

regarding the failure tensile strain. The thin film oven test and the indirect tensile test were identified as additional criteria for the choice of type and amount of recycling agent to be used. The results of this study will provide the highway engineer with a better understanding of the effect of different factors on the tensile and resilient characteristics of hot recycled bituminous paving mixtures.

Study Purpose

The objectives of this study are not to prove the feasibility of recycling. Recycling is a proven fact and many successful processes exist. Material characterization is an important step in all recycling methodologies that are used to identify the properties and the amount of rejuvenation and virgin material required to achieve a mixture that will have the properties and performance equivalent to a new pavement structure built with virgin material.

The research objectives of this study are:

1. Establishment of the effectiveness of mixing on the dispersion and distribution of the recycling agent to produce a homogeneous mixture.

2. Determination of the effect of weathering by means of artificial laboratory aging on the rejuvenated asphalt materials.

3. Evaluation of mechanical properties of the recycled mixes by means of pulse velocity, resilient modulus and indirect tensile strength tests. Hveem and Marshall stability tests are also to be included as part of this evaluation.

4. Investigation of long term performance of recycled mixtures. Various loading rates and temperatures are to be used for this investigation. A companion mix composed of virgin materials will be evaluated for

purposes of comparison.

Study Approach

The effectiveness of recycling agents and the extent to which a rejuvenator diffuse into the old asphalt binder was investigated using a stage extraction technique. The rate of hardening of the rejuvenated binders was studied and compared with a virgin binder by conducting the thin film oven test using different times other than the standard one (5 hours).

Hardening changes in a virgin binder (AC-20) were investigated and compared with other rejuvenated binders.

Strength and stiffness characteristics of recycled mixtures were to be evaluated and compared with conventional virgin mixtures by means of the pulse velocity, resilient modulus and the indirect tensile strength tests in addition to the Marshall and Hveem stability tests.

Long term behavior of recycled mixtures was to be investigated and compared with a virgin mixture. The time dependent viscoelastic behavior was simulated by loading rate and temperature dependent behaviors while the age hardening behavior was simulated by storage and specimens for two week at 140^{o}F.

Conclusions

The main goal of this extensive laboratory study was the characterization of hot mix recycled bituminous material. Three rejuvenating agents; AC-2.5, AE-150 and Mobilsol-30, have been used to produce recycled mixtures. In addition, AC-20 was employed to produce a virgin mixture which was used for comparison purposes. The main conclusions can be summarized as follows:

1. Stage extraction of hard asphalt film present in the recycled asphalt pavement (RAP) indicated a non uniform consistency distribution. Outer fractions were severely hardened while the inner fractions (at asphalt-aggregate interface) retained its initial consistency at the time of construction.
2. Recycling agents are most effective on the outer microlayers of the old pavement material.
3. Rejuvenated binders having the same consistency as a virgin binder may have hardening rates and temperature susceptibility different from the virgin binder.
4. The thin film oven test was identified as a potential added procedure in identifying recycling agents having a tendency to cause compatibility problems for the recycled pavement.
5. AE-150 caused the recycled binder to be more temperature susceptible and have higher hardening rate. In addition, a brittle skin tended to form on all thin film oven test residues and was easily separated from the rest of the sample when AE-150 was used as a rejuvenator.
6. AC-2.5 and Mobilsol-30 usages as rejuvenators resulted in binders with slower hardening rate than AC-20.
7. The stiffness, resilient modulus and strength properties for virgin mixture were in general, better than those of recycled mixtures. However, this outcome may be limited to the material used in this study.
8. Recycled mixture(s), with AE-150 as a rejuvenator, displayed stiffness and strength values that were remarkably lower than virgin and other recycled mixtures.

9. Hveem stability values for both virgin and recycled mixtures were above the Asphalt Institute minimum specified limit for mixtures used under heavy traffic category by about 20%. However, the test failed in discriminating between the mixtures (virgin or recycled).

10. Pulse velocity test parameters were neither sensitive to binder content nor to binder type present in mixtures.

11. Resilient modulus test results were very sensitive to both binder content and type. The test can be used for the design of asphalt mixture (virgin or recycled) and the evaluation of recycling agent used.

12. The indirect tensile test appears to be the best for characterization of hot mix recycled asphalt pavements. It was sensitive to binder content and type. In addition, it gives four response variables, each of which can be used for evaluation of recycled mixtures. The test parameters are strongly correlated with the resilient modulus and can be used to predict its value with minimum error. The test is very simple and inexpensive and can be used in addition to conventional tests (Hveem or Marshall) for quality assurance of recycled mixtures.

13. Marshall stability and flow values for all mixtures (virgin and recycled) were within Asphalt Institute specification limits for heavy traffic category bituminous mixes.

14. Differences in the long term time dependent viscoelastic behavior of virgin and recycled mixtures were not proven with certainty. The virgin mixture was superior to recycled mixtures when the time dependent behavior was simulated by changes in loading rates. However, the virgin and recycled mixtures gave almost identical

behavior when the time dependent behavior was simulated by changing testing temperature.

15. Long term aging characteristics of recycled mixtures were superior to virgin mixture except for those recycled mixtures with AE-150 as a rejuvenator. The virgin mixture appeared to age more rapidly than the other two recycled mixtures.

Recommendations

The authors would like to make the following recommendations for further research.

1. The use of the indirect tensile test as an additional specified criterion for evaluation of hot mix recycled asphalt pavement should be further studied. The test sensitivity to binder content and binder characteristics would help to control both amount and type of recycling agent to be used. In addition, the strong correlation between the test parameters and the resilient modulus may be used to predict the modulus values required for theoretical method of pavement thickness design.

2. The use of HP-GPC (high pressure-gel permeation chromotography analysis for the determination of the amount and the appropriate type of recycling agents required for rejuvenating the salvaged binder present in the old pavement should be developed. Studies should be conducted to determine possible relationship between HP-GPC data and pavement long term aging performance.

3. Fatigue properties of hot recycled asphalt mixes which govern the service life of pavement material should be studied. The relationship between fatigue properties of various recycled mixtures and parameters

such as viscosity, type of recycling agent and the resulting binder characteristics should be established.

4. Mobilsol-30 and AC-2.5 can be used as recycling agents for either in place hot mix recycling or central plant. However, the AE-150 is not recommended for hot mix recycling since it has been proven that it may cause compatibility problems.

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