(77°F) water bath used in the test of asphalt cement penetration, devices that are usually available in materials laboratories, were used in performing the test.

The results of both test methods are given in Table 5. A correlation between the two test methods was obtained in the following form:

\[ Y = 0.927X + 0.008 \]

\[ R = 0.976 \]

where \( Y \) = TSR at 51-mm/min (2-in/min) deformation rate and 25°C (77°F) test temperature and \( X \) = TSR at 1.6-mm/min (0.065-in/min) deformation rate and 12°C (54°F) test temperature.

The t-test indicated that there was no significant difference in the test methods at a 95 percent level of confidence. The methods were equivalent in their ability to predict stripping.

The test conditions selected in NCHRP Project 4-8(3)/1 were developed by using asphalt and aggregate sources representative of the United States; therefore, these test conditions may yield the best overall predictions. However, the modified test results are encouraging and appear to yield comparable predictions of TSR values for Virginia asphalts and aggregates.

Visual Examination of Split Specimens

After the indirect tensile tests were performed, the specimens were split apart and examined visually for stripping damage. Generally, the amount of stripping that was visible was indicative of the relative TSR, especially for the same mix with different properties (such as density) or with and without additives.

CONCLUSIONS

1. None of the mixes showed significant stripping damage after only preconditioning by vacuum saturation; therefore, either pavement damage would not occur in a short period of time or preconditioning by vacuum saturation does not predict the short-term performance of Virginia mixes. This conclusion is supported by observed stripping failures in Virginia.

2. Six of the eight mixes showed significant stripping damage after freeze-thaw preconditioning; therefore, pavements that incorporate these mixes would probably show evidence of stripping over a long period of time.

3. On the basis of results with the three asphalt cements used, asphalt cement does not significantly affect the tensile-strength ratio.

4. There was a significant difference between the performances of antistripping additives for one mix.

5. A modified test method that uses equipment now available in most materials laboratories in Virginia can be used in place of the test method that calls for a 1.6-mm/min (0.065-in/min) deformation rate and a 12°C (54°F) test temperature.

6. The relative magnitude of stripping can be detected by a visual examination of specimens.

ACKNOWLEDGMENT

I wish to express appreciation to the district materials engineers of the Virginia Department of Highways and Transportation for providing mix designs and aggregates. Special thanks also go to R. P. Lottman for his advice throughout the project.

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REFERENCES


Publication of this paper sponsored by Committee on Characteristics of Bituminous Materials.
Table 1. Description of asphalt concrete projects.

<table>
<thead>
<tr>
<th>County</th>
<th>District Project</th>
<th>Treatment</th>
<th>Temperature (°C)</th>
<th>Number of Specimens</th>
<th>Asphalt Type</th>
<th>Percentage</th>
<th>Aggregate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shelby</td>
<td>11</td>
<td>Fine</td>
<td>121</td>
<td>10</td>
<td>AC-10</td>
<td>5.0</td>
<td>Crushed iron ore, fine gradation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Coarse</td>
<td>121</td>
<td>10</td>
<td>AC-10</td>
<td>5.0</td>
<td>Crushed iron ore, coarse gradation</td>
</tr>
<tr>
<td>Hidalgo</td>
<td>21</td>
<td>Cured</td>
<td>124-129</td>
<td>12</td>
<td>AC-20</td>
<td>5.2</td>
<td>Limestone</td>
</tr>
<tr>
<td>Hays</td>
<td>14</td>
<td>Uncured</td>
<td>102</td>
<td>7</td>
<td>AC-10</td>
<td>5.5</td>
<td>Limestone</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fine</td>
<td>96-96</td>
<td>7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Coarse</td>
<td>102</td>
<td>7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Uncured</td>
<td>121</td>
<td>7</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: °C = (°F - 32)/1.8
*By weight of total mix.

Figure 1. Logarithmic relations between fatigue life and stress.

assessment mixtures produced by using a dryer-drum plant.

2. To compare the properties of asphalt mixtures produced by using a dryer-drum plant with the properties of asphalt mixtures produced in conventional plants, and

3. To evaluate the effects of curing treatment and mixing temperature on properties of asphalt mixtures produced by using a dryer-drum plant.

Laboratory-prepared specimens of mixtures obtained during construction of five projects in Texas were tested by using the static and repeated-load indirect tensile tests. A summary of the project information is given in Table 1. Test procedures and specimen preparation are described elsewhere (1, 2).

The properties analyzed were tensile strength, static Poisson’s ratio, and resilient modulus of elasticity. Fatigue life was defined as the number of load applications required to completely fracture the specimen.

ANALYSIS AND EVALUATION

Fatigue Properties

Only two stress levels were used. The results of previous studies have shown a linear relation between the logarithm of applied stress and the logarithm of fatigue life for asphalt mixtures. This relation for the repeated-load indirect tensile test (3) can be expressed as

\[ N_f = K_2 \left( \frac{1}{\sigma_0} \right)^{n_2} \]  

where

\[ N_f = \text{fatigue life (cycles)}, \]

\[ \Delta \sigma = \text{stress difference} = \sigma_f - \sigma_0 (\text{kPa}), \]

\[ \sigma_f = \text{applied tensile stress (kPa)}, \]

and \( K_2 \) and \( n_2 \) are material constants.

Values of \( n_2 \) were fairly constant, ranging from 1.24 to 2.65. These values were low compared with previously reported values for field cores of mixtures produced by conventional plants and for laboratory specimens at optimum asphalt content. Since \( 1/\sigma \) or \( 1/\Delta \sigma \) is always less than 1.0 for the normal range of stresses exerted on pavements, lower values of \( n_2 \) would generally indicate higher values of fatigue life.

Values of \( K_2 \) ranged from \( 1.86 \times 10^8 \) to \( 2.52 \times 10^8 \). These values are small compared with previously reported values for mixtures produced by conventional plants and for laboratory specimens at optimum asphalt content, which should indicate shorter fatigue lives.

The logarithmic relations shown in Figure 1 generally indicate that the dryer-drum mixtures had lower fatigue lives for the range of stress shown. However, as the \( N_f \) values indicate, the reverse would probably occur at very high levels of stress.

The coefficients of variation of fatigue life ranged from 2 to 82 percent; these values are generally lower than those reported by Navarro and Kennedy (4). This
Values of tensile strength, modulus of elasticity, and Poisson's ratio obtained for dryer-drum mixtures were approximately the same as values previously obtained for conventional mixtures (see Table 2). Thus, the coefficients of variation for each project were small, ranging from 4 to 25 percent. As the data given in Table 2 show, the resilient moduli obtained for dryer-drum specimens were consistent within each project; there­fore, the engineers of variation for each project were small, ranging from 4 to 25 percent. As the data given in Table 2 show, the resilient moduli obtained for dryer-drum mixtures tested in this study were slightly smaller than those of conventional mixtures but were within the range of previously reported values.

Effect of Curing Treatment and Moisture Condition

In general, there were no differences in the elastic and fatigue properties of the cured and uncured specimens. The effect of water content, however, could not be evaluated since no appreciable difference in water content was observed between the cured and uncured specimens of any given mixture. In fact, the water contents were approximately equal to those that might be expected in conventional plants.

Effect of Mix Temperature

As Figure 2 shows, an increase in mixing and compaction temperature caused a small decrease in tensile strength. The increments in the mixing and compaction temperature in this study, however, were small, and the mixtures also involved different asphalt contents. Thus, it was concluded that modulus of elasticity and static Poisson's ratio were not affected by changes in mix temperature.

As can be seen in Figure 1, the values of $n_2$ and $K'_2$ and, consequently, fatigue life were approximately equal for the group of specimens produced with 5.5 percent asphalt content at 96 °C (205 °F) and those produced with 5.3 percent asphalt content at 107 °C (225 °F). Nevertheless, there were differences in the fatigue life for the mixtures that contained 4.7 and 4.9 percent asphalt and were mixed at 102 °C (215 °F) and 121 °C (250 °F), respectively.

No consistent change in the value of the resilient modulus was observed with a change in mixing temperature (Figure 2). The resilient Poisson's ratio decreased with an increase in mixing temperature, and the change was significant at the lower asphalt content.

**SUMMARY AND CONCLUSIONS**

This paper summarizes the findings of a study to evaluate the fatigue and elastic properties of asphalt mixtures produced by using a dryer-drum plant. All specimens were mixed in the field and compacted in the laboratory. The resulting conclusions are summarized below.

1. The engineering properties of the dryer-drum mixtures evaluated in this study—including tensile strength, static and resilient Poisson's ratio, and static and resilient modulus of elasticity—were generally equal to those of previously evaluated in-service and laboratory-prepared mixtures. The one exception was fatigue life, which appeared to be less for the dryer-drum mixtures.

**Table 2. Comparison of tensile strength and elastic properties.**

<table>
<thead>
<tr>
<th>Type</th>
<th>Tensile Strength (MPa)</th>
<th>Static Modulus of Elasticity (MPa)</th>
<th>Static Poisson's Ratio</th>
<th>Resilient Modulus of Elasticity (MPa)</th>
<th>Resilient Poisson's Source Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dryer-drum specimens</td>
<td>421-1021</td>
<td>558-1827</td>
<td>0.14-0.42</td>
<td>1283-3489</td>
<td>0.05-0.38</td>
</tr>
<tr>
<td>In-service cores</td>
<td>421-1089</td>
<td>317-1158</td>
<td>0.03-0.35</td>
<td>1524-4241</td>
<td>0.06-0.58</td>
</tr>
<tr>
<td>Laboratory specimens</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Limestone</td>
<td>1000</td>
<td>800</td>
<td>0.06</td>
<td>3362</td>
<td>0.21</td>
</tr>
<tr>
<td>Gravel</td>
<td>1000</td>
<td>1256</td>
<td>0.20</td>
<td>2696</td>
<td>0.06</td>
</tr>
</tbody>
</table>

Notes: 1 kPa = 0.145 lb/in²; 1 MPa = 145 lb/in²; $F = (°F - 32)/1.8$. Testing temperature = 24 °C.

*Average of values obtained for cycles corresponding to 30, 50, and 70 percent of fatigue life.

At optimum asphalt content.
Evaluation of Oregon's First Project in Hot-Mix Asphalt Recycling

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Gordon Beecroft and James E. Wilson, Oregon Department of Transportation, Salem

Pavement recycling has been suggested as a workable alternative to more conventional methods of pavement rehabilitation and a means of offsetting some of the problems that result from spiraling energy costs and shortages of raw materials. The Woodburn asphalt recycling paving project, Oregon's first experience with using a hot-mix process in large-scale recycling of asphalt concrete, is discussed. The project is described, overlay and mix designs are indicated, the construction program and the specific equipment used are reviewed, the program of materials sampling and testing and data collection is described, and test results are summarized. Special emphasis is given to an investigation of possible changes in material properties during the construction process. A summary is presented of the factors that most affect the production of emissions. Costs and fuel consumption are examined, and possible savings over a similar, conventional paving project are highlighted. Specific recommendations are presented for the benefit of other agencies that are considering similar projects, and future research needs are outlined.

The need to reduce fuel consumption and conserve natural resources has been an item of ever-increasing importance during recent years. In 1976, the highway division of the Oregon Department of Transportation (DOT) was faced with the problem of disposing of nearly 45,000 Mg (50,000 tons) of asphalt concrete pavement placed for temporary purposes in the rehabilitation of I-5 between Salem and Woodburn. Officials of the division recognized the possibility of using this asphalt concrete as raw material for recycling and, with the assistance of federal funding through Region 15 of the Federal Highway Administration (FHWA), a demonstration project that became known as the Woodburn asphalt pavement recycling project was initiated.

To fulfill the objectives of the national demonstration project program for asphalt pavement recycling, a comprehensive work plan was developed that specified the responsibilities of the highway division through the project's duration. Included in the plan was a program for sampling, testing, and evaluation before and during construction. In addition, provision was made for post-construction testing and evaluation to continue for years to come.

This paper discusses the results of the investigations performed by the highway division of the Oregon DOT in fulfilling its responsibilities through the first year of project evaluation. Specifically, the objectives of this paper are to

1. Present a description of the project, including its location, overlay thickness design, asphalt concrete mix design, and final mix specifications;
2. Indicate the final construction procedure and equipment used;
3. Describe the program of materials sampling and testing and collection of data on weather, pollutant

REFERENCES


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