Specifications developed and used by the Florida Department of Transportation to ensure that a high level of quality is maintained during the design and construction process are discussed. The need for control of the uniformity of the mix is stressed with corresponding recommended specifications for the measurement of viscosity levels of the reprocessed binder material. Performance as well as economic and energy considerations are discussed. Recommendations are also given for using strength equivalencies equal to those of the conventional paving mixtures.

When recycling of asphalt-concrete pavements is considered as a design alternative, all too often the initial thought of those individuals involved in the construction process is that an inferior product must be accepted. In many cases, this has resulted in the use of specifications that do little, if anything, to ensure the level of quality of asphalt-concrete mixtures and the flexible pavement structure.

Hot-mixed recycled asphalt-concrete mixtures can be produced from a variety of materials obtained from many sources. The handling and processing techniques permitted by specifying agencies will ultimately dictate the level of quality in the final product. In many cases, hot-mixed asphalt pavements have been viewed as a means of making use of waste materials. This attitude is changing, but there still seems to be a general hesitancy to expect the same standards of quality required of conventional paving mixtures.

In the case of the Florida Department of Transportation (FDOT), some of these same fears existed in the initial stages of specification and procedural development. A great amount of latitude was given to the contractor to permit wide variations in asphalt content and gradations. In addition, little effort was made to actually specify the physical properties of the reprocessed asphalt cement in the final mixtures.

It was the attitude of FDOT that initial projects should be constructed and evaluated very carefully so that realistic specifications could be developed that would ensure performance levels equal to or exceeding those of conventional paving projects.

Other research efforts had confirmed the fact that proper specification controls would yield quality paving mixtures. Little and Epps (1) have reported insignificant differences between properties of recycled and conventional asphalt mixtures or pavements. There are also indications that recycled asphalt cements may not harden (increase in viscosity) as rapidly as the original asphalt (ASTM STP 14).

Parts of the data obtained from the hot-mix recycled pavements constructed in Florida have been published previously (2-4). In June 1980, guidelines (5) were published and distributed throughout the state to FDOT's materials, construction, and design personnel for use in selecting and evaluating pavements as potential candidates for recycling. Although minor modifications are required to meet the needs of individual projects, basically a standard set of specifications is used for all recycled pavements. These specifications include most of the same control restrictions of any conventional paving mix. Laboratory and field test results have confirmed that these control levels can be maintained. Furthermore, it has become evident that violations of the basic principles of good quality control and acceptance limits result in the same poor performance of pavements that would be expected in any other construction phase.

Preliminary Evaluations

Ensuring the quality of recycled asphalt pavements is very similar to ensuring the quality of any other conventional mixture. The primary problem exists in the fact that we have been using conventional procedures for so long that we have lost touch with the evolutionary development of all of the quality control measures employed in association with the component parts of the final mixture. Many engineers have been led to view the salvaged asphalt and aggregate combination as another commercial component that must be monitored and controlled in a fashion similar to that for any of the other materials composing the final asphalt-concrete paving mixture.

It is for this reason that I would like to devote a portion of this paper to some of the more important aspects of the control of the salvaged asphalt-concrete mixture.

As is the case with conventional asphalt paving, the quality control measures adopted for the final mixture are worth very little if there is no assurance that the component parts are produced under similar standards.

The procedures presented here for the development of a final mix design for a recycled-asphalt project are what I believe to be a preferred sequence of events. The steps taken may vary depending on (a) how the salvaged material is obtained (milled or processed through a crusher) and (b) the percentage of salvaged material proposed for incorporation into the final mixture.

Regardless of the above conditions, the major elements in the process are (a) materials characterization of salvaged asphalt-concrete mixture, (b) preliminary mix design, and (c) final mix design. The purpose of the preliminary and final mix designs is to establish the estimated design asphalt content and to determine the final job-mix design that conforms to the requirements of the standard specifications.

Characterization of Salvaged Asphalt-Concrete Mixture

A sufficient quantity of salvaged asphalt-concrete mix should be obtained in order to determine asphalt content and gradation and to perform preliminary mix design tests. In Florida, the Marshall design method is used to establish the standard mix design. Sampling of these materials should be based on consideration of the following:

1. If material is obtained from an existing stockpile or from a crushing process, the same frequencies and sampling locations should be used as would be required in conjunction with any commercially produced aggregate. Special care must be taken to identify quantities of materials that have widely varying viscosity levels. Normally, if average viscosity values can be established and the variance of these quantities does not exceed 10-15 percent of the mean, the variations can be easily handled in the field.

2. If the material is to be obtained from exist-
ing pavement by the cold-milling process, variations in layer thicknesses and type of asphalt-concrete mixtures, according to data from prior sampling and original construction plans, must be established. Care must be taken to identify changes in materials that result from having the recycling project encompass sections of existing pavement constructed under more than one original construction contract.

3. Pavement being removed by cold milling and reprocessing must also be separated by viscosity level. Variations in the degree or type of cracking may provide indications where additional samples should be taken for recovery and characterization of the existing asphalt cement.

The standard procedure established for use in Florida when an existing pavement is characterized requires a minimum of two samples per lane mile or five representative samples per project to be tested to determine asphalt content and aggregate gradation and to obtain recovered asphalt for testing.

The bitumen is extracted from the asphalt cement by using the trichloroethylene reflux procedure (AASHTO T-164, Method B) and recovered by the Abson Method (AASHTO T-170). Samples should be cut to approximately the same thickness as anticipated for the milling depth. Sufficient quantity of asphalt cement must be recovered, regardless of whether the mix is from an existing roadway or previously developed stockpile, to conduct the following tests:

1. Absolute viscosity at 140°F (60°C) (ASTM D2171);
2. Cannon constant stress rheometer: (a) viscosity and shear susceptibility at 77°F (25°C) and (b) viscosity, shear susceptibility, and shear modulus at 41°F (5°C);
3. Kinematic viscosity at 275°F (135°C) (ASTM D2170); and
4. Penetration at 77°F (ASTM D5).

On standard hot-mixed recycling projects bid in Florida where portions of the existing pavement are removed and permitted to be incorporated into the new mix, a summary of the characterization data is provided in the bid document. An example of such a summary is shown below (average values based on test results from top 3 in of roadway):

Extracted gradation:

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>Percent Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/4 in</td>
<td>100</td>
</tr>
<tr>
<td>1/2 in</td>
<td>98</td>
</tr>
<tr>
<td>3/8 in</td>
<td>95</td>
</tr>
<tr>
<td>No. 4</td>
<td>70</td>
</tr>
<tr>
<td>No. 10</td>
<td>48</td>
</tr>
<tr>
<td>No. 20</td>
<td>36</td>
</tr>
<tr>
<td>No. 30</td>
<td>16</td>
</tr>
<tr>
<td>No. 200</td>
<td>6.8</td>
</tr>
</tbody>
</table>

Asphalt content: 6.0 percent
Viscosity at 140°F, 102 907 poises
Penetration at 77°F, 17

This provides the prospective bidders with information that can be used when potential material combinations are developed for bid purposes.

Preliminary Design

This aspect of controlling the quality of recycled asphalt mixtures is often minimized, but it is believed to be a key in arriving at the proper combination of salvaged asphalt concrete, new aggregate, and asphalt rejuvenator. This same procedure is used in the design of conventional mixtures except that the percentage of asphalt cement is not affected by asphalt existing in one aggregate material component. The following general procedure should be used:

1. The mean value of the extracted gradations of the salvaged asphalt should be combined with new aggregate materials to obtain a final gradation that will comply with standard gradation requirements.
2. A Marshall mix design evaluation should then be performed in order to establish the design asphalt content. The Florida procedure requires the blending of aggregate from the extraction of salvaged mix with new aggregates. The hot mix is prepared by using a standard AC 20 material to prepare the Marshall test specimen. The Marshall properties obtained for the selected mix design should conform to FDOT standard specifications (5).

Examples of the preliminary design blend and Marshall properties are presented in Tables 1 and 2. The flow diagram shown in Figure 1 illustrates graphically the steps involved in arriving at the preliminary design. The information obtained in the preliminary process becomes the basis of developing bid estimates by the contractors and at the same time provides the materials engineer a beginning point in evaluating the final design.

Final Design

After a contractor has been awarded a project, the proposed aggregate combinations as well as the rejuvenating agent for use in the final mixture must be submitted. Current Florida specification requirements for rejuvenating agents are given below. The asphalt rejuvenator should be a soft asphalt cement or asphalt cement blended with a softening agent or flux oil conforming to the requirements shown below. It should contain an approved anti-
stripping agent \( \left( \frac{\text{F}}{\text{C}} = \left( \text{F} \times 0.55 \right) + 32 \right) \):

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absolute viscosity after thin-film oven test</td>
<td>3:1 ratio minimum</td>
</tr>
<tr>
<td>Smoke point</td>
<td>260°F minimum</td>
</tr>
<tr>
<td>Flash point</td>
<td>400°F minimum</td>
</tr>
<tr>
<td>Solubility</td>
<td>97.5 percent</td>
</tr>
</tbody>
</table>

Residue from the asphaltic emulsion rejuvenator should meet the requirements shown above. The asphaltic emulsion rejuvenator should contain an approved antistripping agent. It should meet the requirements shown below:

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Requirement (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storage stability, 24 h</td>
<td>1.0 maximum</td>
</tr>
<tr>
<td>Sieve test</td>
<td>0.1 maximum</td>
</tr>
<tr>
<td>Residue by evaporation</td>
<td>65.0 minimum</td>
</tr>
</tbody>
</table>

The specified properties of the rejuvenating agents are primarily to assure that the material will be suitable from the standpoint of construction, safety, operation, and handling without excessive alteration of the absolute viscosity \( V_{60} \). The selection of the rejuvenating agent is an important factor in controlling the quality of the mix since the standard specifications require that the bitumen recovered from laboratory specimens as well as the plant-produced mix meet the 140°F viscosity requirements of 4500 poises ± 1500 poises. During the laboratory evaluation of the final mix design, the following areas are evaluated:

1. Are the Marshall mix design requirements in compliance with standard specification requirements? The bitumen demand for the job-mix formula is confirmed, and this in turn permits calculation of the amount of rejuvenating agent required for the recycled mix.

2. The bitumen recovered from the test specimens at optimum asphalt content from the Marshall design procedures must meet the 140°F viscosity requirements of 4500 poises ± 1500 poises. In addition, data are collected to provide for "straddle" design formulations to allow for adjustments of the job-mix formula and/or formulation of the asphalt rejuvenator to achieve the desired end result recovered viscosity.

3. Field adjustments of aggregate gradations obtained after extraction of the bitumen are evaluated as required, if necessary, to maintain specification compliance.

CURRENT SPECIFICATION REQUIREMENTS

The current specifications contain a number of key elements that past experience has indicated play a major role in providing realistic bids as well as ensure a high-quality flexible pavement layer.

Bid Document

Current bid documents provide for no minimum amount of salvaged asphalt-concrete mix for incorporation in the final job-mix formula; however, an upper limit of 70 percent has been included. This provides the materials engineer with latitude to adjust gradations, asphalt contents, and viscosities of the recycled mix. There have been no special gradations developed for recycled mixtures; rather, current standard gradation and Marshall design requirements are specified for these as well as for conventional mixtures.

The asphalt paving mixtures are bid by the ton; the asphalt cement is included as a part of the ton price, regardless of the percentage of salvaged material used by the contractor in the approved job-mix formula. This has expanded the bid competition and has provided the possibility for modified batch plants to compete with drum mixers.

FDOT has, for a number of years, provided an escalation clause in its standard specifications for conventional asphalt paving mixtures. In the past year, an adjustment clause has been included as a part of the supplemental special provisions. The provision is as follows:

In addition to the pay adjustment for varying asphalt content in the bid mix formula as issued, pay adjustments for the quantity of recycling agent included in the payment for Recycled Asphaltic Concrete will be made based on the Asphalt Price Index as specified in Amendment 009 of the Specifications Package. Asphalt Rejuvenator will be based on the Asphalt Cement Index and the Asphalt Emulsion Rejuvenator will be based on the Emulsion Asphalt Index. As an exception, the total adjustment will be made on the final estimate. The adjustment will be made on the actual amount of recycling agent used as determined by field measurement, excluding the quantity required for the adjustment to the six percent asphalt content in the job mix formula.

The price adjustment applies only to the price of the bituminous material, free on board the manufacturer's asphalt terminal, and does not reflect variations in the cost of transportation from the terminal to the job site. Implementation of the adjustment on projects that use recycled asphalt concrete has had the effect of stabilizing the bids and has removed the apprehension surrounding the use.
of asphalt rejuvenator when there is competition with conventional asphalt-concrete mixtures. The 6 percent asphalt content level referred to in the adjustment clause is varied based on past history of optimum design levels of FDOT’s standard design mixtures.

Construction Control Specifications

After construction has begun, the quality control and acceptance testing required are very similar to those for conventional paving mixtures. Gradation analyses of aggregate component stockpiles are monitored daily along with extractions of the salvaged asphalt-concrete stockpiles. These tests are performed by the contractor’s quality-control technician as a part of the plant control program. The department’s technician performs extraction tests at a minimum rate of one sample per 1000 tons, or a maximum of one per day, for acceptance purposes. Any variations exceeding the tolerance limits of the established job-mix formula should be corrected immediately.

A major addition to the standard specifications concerned the control of the consistency of the asphalt cement in the final recycled asphalt-concrete mixture. Samples of recycled mix are taken at a minimum frequency of one per 2000 tons, and the asphalt cement is recovered by ASTM D1856. The viscosity of the recovered asphalt is measured at 140°F and must be 4500 ± 1500 poises. This level was established as a result of previous age-hardening studies performed by FDOT (2).

It had been established that recovered samples of asphalt cement taken from conventional paving mixtures produced with AC 20 were in the same viscosity range at the time of placement on the roadway. It is believed that this is one of the single most important quality-control measures, since it ensures the uniformity of the mix consistency during placement and compaction. Should a mix fail to meet this specification requirement, the contractor must adjust the mix immediately.

The corrective action may be accomplished in a number of ways, depending on the degree of nonconformance. The contractor can refer to the straddle design developed during the final design phase to decide whether the percentage of salvaged material should be adjusted or the grade of rejuvenating agent being used should be changed.

The established mix temperature at the time of discharge at the asphalt plant must be in the range of 240-300°F. Our experience has shown that this operating range can be uniformly maintained, and as long as the viscosity level is controlled within specification limits, the mix can be handled in the field in the same manner as any other conventional paving mixture.

There have been no revisions made to FDOT’s standard placement and compaction specifications that relate specifically to asphalt-concrete mixtures. We have made every effort to comply with the same standards of quality expected in conventional mixtures. If this is accomplished, it follows that the placement and compaction specifications should be no different than would be used with any similar paving mixture.

DISCUSSION OF PERFORMANCE

Performance data to date are limited since hot-mixed recycled asphalt-concrete mixtures have only been used in Florida for five years. However, the performance has been excellent. These pavements, in all cases, have equaled or exceeded the performance of similar roadway sections constructed by conventional processes.

There are strong indications from data collected that the in-service hardening rate of the recycled asphalts is somewhat less than that of comparable standard asphalt cements. At the present time, firm conclusions cannot be made, but the trends will be monitored until an analysis can be made to confirm the trends that have developed.

In areas where the pavement is in an advanced stage of cracking and the asphalt-concrete layer is removed entirely for reprocessing, the performance has far exceeded the conventional leveling and resurfacing approach. To date, this has been the most effective rehabilitation used by the state, and a major reason has been the elimination of the reflective cracking potential.

ECONOMIC AND ENERGY CONSIDERATIONS

The economic savings and energy reductions have been previously documented and reported by FDOT (2-5,8). Recently completed projects have confirmed the fact that generally there is a 15-30 percent reduction in the cost of the recycled project as compared with conventional paving methods. Depending on the location within the state and location of commercial aggregate sources as related to the recycling project, energy savings have ranged from 25 to 45 percent when compared with the conventional alternative.

SUMMARY

The specifications used by FDOT for control of recycled asphalt-concrete mixtures are still in the development stage, but our experience to date has shown that a high-quality pavement can be constructed incorporating salvaged asphalt materials. The following appear to be key points related to this type of construction process:

1. The same general gradation requirements and design properties should be used when recycled asphalt-concrete mixtures are specified.

2. Design strength equivalencies used in the pavement design process should be the same as those that would be assigned to the same standard mix produced by conventional processes.

3. Recoveries of the asphalt cement from recycled asphalt-concrete mix should be made at regular intervals during the production process. This material should be obtained at the asphalt plant during normal production operations. Absolute viscosity measurements should be performed at 140°F (ASTM D2171) on the recovered-asphalt cements, and the viscosity level should be maintained at 4500 ± 1500 poises.

4. Placement and compaction requirements should not deviate from standard construction requirements used in conjunction with normal paving projects.

5. No lower limit should be placed on the percentage of salvaged material incorporated into the final design; however, an upper limit of 70 percent is suggested. This limitation permits more design latitude and uniformity of the mix during production.

REFERENCES


Method to Establish Pay Schedules for Rigid Pavement

RICHARD M. WEED

An equation is derived to compute the appropriate pay factor for any quality level of rigid pavement. The measure of quality used in this development is the estimated load-bearing capacity of the pavement although the results may be applied to specifications based on other quality measures. The appropriate pay adjustment is considered to be the present worth of any expense or savings expected to occur in the future as the result of a departure from the specified level of quality and may be positive or negative. Sensitivity tests demonstrate that the method is reliable provided the input variables are determined with reasonable accuracy. By using input values typical of a relatively urbanized area, this approach indicates that a minimum pay factor of about 60 percent is appropriate for the poorest-quality work and a maximum pay factor of about 115 percent is justified for work of truly superior quality. Additional factors are cited that, although unquantified, would tend to lower the minimum pay factor and raise the maximum pay factor. Finally, pay schedules are developed, the operating-characteristic curves of which closely approximate the theoretically derived relationship.

Statistical end-result specifications are now in widespread use and one of the reasons for their popularity among specification writers is that they provide a practical way to deal with work that is only slightly deficient. A construction item that falls short of the specified quality level does not warrant rejection but neither does it deserve 100 percent payment. Accordingly, statistical specifications usually employ some form of adjusted pay schedule to award payment in proportion to the level of quality actually achieved.

Throughout the nearly 20 years that specifications of this type have been evolving, several methods (1-3) have been proposed to establish the level of payment appropriate for different levels of quality. In those cases for which there is little or no information relating quality measures to performance, this is an especially difficult task and the methods have necessarily been quite arbitrary. However, there are a few cases for which the quality-performance relationship is well established and these, at least, provide the opportunity to develop a rational and logical procedure for determining appropriate pay factors.

One type of construction for which there are ample data relating performance to various quality characteristics is rigid (Portland cement concrete) pavement. The design guide (4) of the American Association of State Highway and Transportation Officials (AASHTO) has just been updated and now provides an equation that gives the expected number of equivalent 18-kip load applications that a rigid pavement can sustain as a function of several common quality characteristics. The details of the manner in which this equation can be used are presented in a separate paper by Weed in this Record. For the purposes of this paper, it is simply desired to establish that the technology required to design a pavement can also be used to assess the quality of a pavement, the as-built characteristics of which differ from the intended design values.

BASIS FOR PAY ADJUSTMENTS

Ordinarily, a pavement is designed to sustain a specified number of load applications before major repair (overlaying with bituminous concrete) is required. If, due to construction deficiencies, the pavement is not capable of withstanding the design loading, it will fail prematurely. The necessity of repairing this pavement at an earlier date results in an additional expense that, since it usually occurs long after any contractual obligations have expired, must be borne by the highway agency. It is the purpose of the adjusted pay schedule to withhold sufficient payment at the time of construction to cover the extra cost anticipated in the future as the result of deficient-quality work. Based on the procedure used to arrive at the original design parameters of the pavement, the as-built parameters can be used to estimate the fraction of design loadings the pavement will actually be able to sustain. For practical purposes, it is reasonable to assume that the yearly traffic volume is constant so that this fraction can be multiplied by the design life to obtain the expected life. Then, based on current construction costs and projected interest and inflation rates, it is possible to compute both future and present-worth values for credits and debits resulting from the rescheduling of the several generations of overlays that are required after the useful service life of the original pavement has been exhausted. The appropriate pay adjustment is the present worth of the sum of these credits and debits and, depending on the estimated life of the original pavement, this adjustment may be either positive or negative. As a result, the corresponding pay factors obtained by this method are not limited to a maximum of 100 percent.