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16. Abstract

TxDOT maintenance personnel have noted problems with a commonly used, stockpiled maintenance mix known as Item 334, Hot-Mix Cold-Laid Asphalt Concrete Paving Mixture (HMCL). It is generally used by maintenance personnel as a blade-on/level-up material and not as a pothole repair material (except when necessary). Performance problems include stripping in the stockpile, a tendency towards instability in hot weather, and a lack of winter workability. The objective of this research project was to identify a series of simple but meaningful laboratory tests and acceptance criteria for HMCL patching materials which will ensure reasonable stockpile life and field performance. The complete results of this research project are presented in research report 1717-1. This report provides a summary of those results and recommendations for implementation.

A literature review was conducted to identify published information on patching materials with a particular emphasis on test procedures developed for maintenance mixtures. A survey was performed of maintenance personnel in all TxDOT district offices to identify problems. Several different HMCL mixtures were designed and evaluated in the laboratory. These mixtures were designed using two types of aggregates (crushed gravel and crushed limestone) and three types of binders (AES-300S, MC-800, and MC-800 with diesel) for a total of six different mixtures. Laboratory tests indicated that mixtures designed at 92 percent density had stabilities and strengths as high or higher than those designed at 95 percent density. Field mixtures were evaluated in the laboratory as a function of stockpile age. The rolling sieve cohesion test was found to be a simple test that adequately measures the cohesiveness of the HMCL materials.

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GUIDELINES FOR IMPROVING THE PERFORMANCE OF TxDOT ITEM 334, HOT-MIX, COLD-LAID ASPHALT CONCRETE PAVING MIXTURES

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IMPLEMENTATION RECOMMENDATIONS

The following list includes implementation recommendations resulting from this research project.

1. Select one to two districts to implement the recommendations below for a trial evaluation period for a minimum of one year.

2. Reduce design density to 92.0 percent for HMCL which is to be used in winter months to improve workablity.

3. Evaluate workability of the lab-designed and field-produced mixture using the workability test described in Appendix A.

4. Evaluate the cohesion of the lab-designed and field-produced mixture using the cohesion test described in Appendix B.

5. Using test method Tex-530-C, evaluate the visual stripping of the fine aggregate separately from the coarse aggregate as described on page 7.

6. Consider a specification requirement stating that the material shall be capable of being stocked for at least six months without stripping and shall be workable at all times (see page 8). It may be rejected at any time during the six month period if, in the opinion of the Engineer, the patching material has stripped (more than 10 percent uncoated particles) or otherwise become unfit for use.

SUMMARY OF RESEARCH PROJECT 0-1717

Pothole and surface repair of asphalt pavement remains one of the most commonly performed maintenance operations for the Texas Department of Transportation (TxDOT). TxDOT maintenance forces use several different types of patching materials. Most of the problems with these maintenance mixtures occur with Item 334, Hot-Mix, Cold-Laid Asphalt Concrete Paving Mixture hereafter referred to as HMCL, which was the subject of TxDOT research project 0-1717. HMCL is generally used by maintenance personnel as a blade-on/level-up material and not as a pothole repair material (except when necessary).

While many of the districts report good performance of this material, others note that performance is inconsistent. Primary complaints noted include:

- stripping;
- tendency to push and rut in hot weather; and
- unworkable in winter and too rich in summer.

The objective of this research project was to identify a series of simple but meaningful laboratory tests and acceptance criteria for HMCL patching materials which will ensure reasonable stockpile life and field performance. For a full report on the research results of this project, refer to Research Report 1717-1. (1)

LITERATURE AND DISTRICT SURVEY

At the outset of this research project, researchers conducted a literature review to identify published information on patching materials with a particular emphasis on test procedures which have been developed for maintenance mixtures. The literature review revealed that the more expensive, better-quality pothole materials last significantly longer than conventional maintenance mixes. Since the major cost of pothole repair appears to be labor, equipment and traffic control, significant savings can be obtained by using more effective materials and methods.

Some agencies no longer use cold-applied materials but are using hot-mix for most all pavement repairs. Their research shows that hot-mix patches last 7 to 10 times longer than their conventional cold-mix repairs. To perform these hot-mix repairs, maintenance vehicles are equipped with hot bins to keep the mixture hot during repair operations. Most of the research identified in the literature addressed pothole repair and materials which are quite different than TxDOT's HMCL and the applications in which HMCL is used. Test procedures which were identified in the literature and which were further evaluated in this study address the workability and cohesion properties of a mix.

The project team surveyed maintenance personnel in all of the TxDOT district offices to determine:

(1) types of patching materials used in district;
(2) material formulations (binders and aggregates used);
(3) materials which perform well and in what applications;
(4) materials which perform poorly and in what applications; and
(5) material sources.

LABORATORY EVALUATION OF DENSITY REQUIREMENTS FOR MIX DESIGN

Several different HMCL mixtures were designed and evaluated in the laboratory. These mixtures were designed using two types of aggregates (crushed gravel and crushed limestone) and three types of binders (AES-300S, MC-800, and MC-800 with diesel) for a total of six different mixtures. The objective of this portion of the laboratory effort was (1) to evaluate the properties of mixtures fabricated at different densities (in addition to 95 percent density as currently required), and (2) to evaluate the suitability of laboratory tests to differentiate between mixtures with different degrees of workability and cohesion. Hveem and Marshall stability, Marshall flow, unconfined compressive strength, SHRP (Strategic Highway Research Program) workability, and SHRP cohesion tests were performed on all mixtures. Laboratory tests indicated that mixtures designed at 92 percent density had stabilities and strengths as high or higher than those designed at 95 percent density. However, 89 percent density mixtures exhibited properties which clearly showed that it is a density too low for HMCL.

The cohesion test was found to be a simple test which adequately measures the cohesiveness of the HMCL materials. This test generally showed that the cohesion decreased as density decreased (and asphalt binder decreased) as would be expected. Mixtures designed at 95 percent density generally had the best cohesion properties (89 to 95 percent retained) while the mixtures designed at 92 percent density saw a loss in cohesion with values ranging from 75 to 88 percent retained. A dramatic loss of cohesion was observed in the mixtures designed at 89 percent density with values generally ranging from 10 to 39 percent retained. SHRP recommends a minimum retention value of 60 percent as a successful value for this test.

The SHRP workability test was also found to be a simple test; however, no significant trends were observed for any of the mixtures. Values of workability for all of the mixtures were less than one and most of the values were less than 0.5. SHRP criteria state that values under three are acceptable. Since this test was developed for high-performance pothole patching materials, a different criteria should be applied for HMCL mixtures.

All mixtures were cured in a pan in at 60 °C (140 °F) oven to evaluate their curing characteristics. A significant amount of time (four or more days) is needed to adequately cure HMCL materials prior to further laboratory testing (at 60 °C [140 °F] in a forced-air oven). The rate of weight loss (weight loss versus time) was evaluated as an index of the susceptibility to hardening or loss of workability. The mixtures made with MC-800 seemed to cure faster than the mixtures made with either MC-800 and diesel or AES-300S. This may be an explanation for some field reports which indicate that MC-800 mixes tend to have poor winter workability.

EVALUATION OF TEST METHODS USING FIELD-PRODUCED HMCLs

The laboratory testing program described above was used for laboratory produced maintenance mixtures. In addition, another testing program was carried out for field produced maintenance mixtures. These mixes were evaluated as a function of age using various test methods with the primary objective being to identify appropriate relevant test procedures. Several test methods were used to evaluate materials sampled from stockpiles at various stockpile ages (from about zero to six months of age). Mixture properties were evaluated through the following tests:

- Hveem Stability;
- SHRP Cohesion;
- SHRP Workability;
- Blade Penetrometer (workability);
- Unconfined Compressive Strength;
- Marshall Stability; and
- Stripping Test (Tex-530-C).

Most of the field materials which were evaluated in the study showed poor winter workability but good in-service field performance during the six-month evaluation period. Note that the materials were placed in service as patches during warm weather months and when mix was fresh.

This portion of the project identified the SHRP Cohesion Test (rolling sieve test) as a very simple test which correlates well with stockpile age. Mixtures exhibited excellent cohesion (70 to 95 percent retained) and dropped to values below 40 percent after six months in the stockpile. The SHRP Workability Test is also a very simple test procedure which was developed for high performance pothole patching materials. Most of the HMCL mixtures evaluated in this project had much lower (better) workability ratings. The data did not indicate a significant correlation between workability rating and stockpile age; however, there was a slight trend of increasing workability rating with stockpile age. The standard criteria for this test state that mixtures with a workability rating below three are acceptable. This criterion should be lowered for TxDOT HMCL mixtures. All of the HMCL materials tested in this project had workability ratings below two.

A blade penetrometer test was also used to evaluate mixture workability. This simple test is similar to the SHRP workability tests but uses a blade attachment instead of a bullet shaped attachment. These penetrometer values were considerably higher than those in the SHRP workability test. While the data indicated an increase in workability rating with stockpile age, some of the test values exceeded the capacity of the penetrometer.

Marshall stability tests were performed on all field materials and the stability values ranged between 800 and 1600 lb. Some of the mixtures showed an increase in stability with age and a slight drop in stability with additional aging. Unconfined compression tests also indicated an increase in compressive strength with stockpile age.

Test method Tex-530-C, Effect of Water on Bituminous Paving Mixtures was used to evaluate the susceptibility of the mixtures to stripping of the asphalt from the aggregate by water. Samples were tested in both cured and uncured conditions. These results were compared with field samples taken at six to eight months of stockpile aging. In general, the tests performed on the *cured* mixtures matched the field data better than the uncured mixtures.

Implementation of results from this research are presented in the remainder of this summary report.

GUIDELINES FOR IMPROVING THE PERFORMANCE OF HMCL:

IMPLEMENTATION RECOMMENDATIONS

Maintenance personnel use hot-mix, cold-laid (HMCL) asphalt concrete pavement extensively as a versatile material for blade-on/level-up pavement repairs. Its composition can vary from district to district in the type of aggregates used, gradation, and type of binder. The composition of HMCL which is specified by a district is often based on the past experience and performance history, as well its intended use. Different mixture characteristics are desired based on intended use or past problems.

It is necessary for HMCL to be workable. Workability refers to the ease with which a mixture can be handled, shoveled, and raked. It is sometimes desirable that this mix have adequate winter workability which is often difficult to achieve. Achieving good mixture workability can often be at the expense of other desirable mixture properties. For example, workability can be gained by using a relatively soft binder or adding diesel to the binder; however, the mixture can then be susceptible to instability problems in warmer months. Certain aggregates such as sands and gravels can also improve mixture workability but can contribute to pushing and shoving under traffic and stripping in the stockpile.

The following are some general guidelines aimed at improving the desired characteristics of HMCL.

1. WORKABILITY

As mentioned above, workability refers to the ease with which the mix can be handled, shoveled and raked. It is generally desirable that a stockpiled mix remain workable for at least six months. Workability is not usually an issue in warm months, unless the stockpile is excessively aged or the binder in the mix has hardened prematurely. Since the binder is the portion of a bituminous mixture which is susceptible to changes in temperature, it is typically the source of winter workability problems. It is, therefore, logical to assume that if a stockpiled mix has a high binder content (which is susceptible to cold temperatures), it will be an immovable, cohesive mass in cold, winter months.

Less binder in the mix will provide for better workability in winter months. In fact, Limestone Rock Asphalt (LRA) pavement (Item 332) which is supplied by Vulcan Materials of Uvalde, Texas, has a history of good winter workability but also has a relatively low density which is typically about 88 percent. On the other hand, HMCL is presently designed at 95 percent density. Results from this research project showed that lowering the design density requirement to 92 percent (and thus lowering the asphalt content) does not adversely affect strength and stability properties of the mixture, and in some cases, it actually improved those properties. It is, however, a *drier* mix and is less cohesive. Cohesion tests performed on these mixes demonstrated adequate cohesiveness.

The following specification addition to Item 334.3 is recommended for implementation consideration. Recommended specification addition is noted in italics.

Item 334.3

(2) Density. The mixture shall be designed to produce an acceptable mixture at an optimum density of 95.0 percent *(or 92.0 percent if produced or designed for use from November 1 through March 1 and if so designated by the Engineer)*, when tested in accordance with Test Method Tex-207-F and Test Method Tex-227-F. The operating range for control of laboratory density during production shall be optimum density plus or minus 1.5 percent.

Laboratory density is a mixture design and process control parameter. If the laboratory density of mixture produced has a value outside the range specified above, the Contractor shall investigate the cause and take corrective action. If three (3) consecutive test results fall outside the specified range, production shall cease unless test results or other information indicate, to the satisfaction of the Engineer, that the next mixture to be produced will be within the specified range.

In addition to the lower design density recommendation above, a low temperature workability test is recommended. This test is a two-part test performed on the mixture after it is cured to a constant weight at 60 °C (140 °F). The first part of the test is a subjective rating of workability. It consists of cooling the cured mixture to 4 °C (40 °F). The mixture shall be rejected if it cannot be readily broken up with a spatula having a blade length of approximately 400 mm (8 inches). The second part of this test consists of placing the cooled mixture into a box which measures 102 mm (4 inches) on all sides with a 10 mm-hole in one side. A soil penetrometer (with adapter) is pushed through the hole in the box and the maximum resistance is recorded as the workability measurement. A value under two is considered acceptable. Appendix A describes these tests.

2. COHESION

Another important characteristic of HMCL which should be evaluated prior to acceptance is its cohesion. Cohesion is a measure of the mixture's ability to stick together. A mixture in which the asphalt age-hardens excessively as well as a mixture which is too dry (low in asphalt content) will have poor cohesion. This test may also be able to identify a mixture in which too much diesel has been added.

The test consists of placing cured, cooled HMCL into a Marshall mold and compacting with a Marshall hammer (5 blows to each side). The sample is then weighed and placed along the bottom edge of a 305 mm (12 inch) diameter sieve with 25 mm (1 inch) openings while both the sieve and sample are standing on end. A cover is placed on the sieve (still on end) and the sieve is rolled back and forth 20 times. Then the sieve (with sample still inside) is laid against the edge of a table allowing room for sample pieces to fall through the sieve openings. The retained material is then weighed and a minimum retention value of 60 percent is acceptable. This test procedure is presented in Appendix B.

3. STRIPPING

Test Method Tex-530-C is commonly used to evaluate the susceptibility of HMCL paving mixtures to stripping of the asphalt from the aggregate by water. This test is performed by placing a 200 g (7 oz.) sample of mix into boiling water maintaining the water at medium boil for 10 minutes. Excess asphalt is skimmed from the water surface with a paper towel. Water from the beaker is decanted and then the wet mix is emptied onto a paper towel. The degree of stripping is visually estimated and reported as percent of stripping (after 24 hours of drying).

In HMCL, field sand is sometimes used in the mix and is often the culprit when stripping occurs. However, when visually estimating percent stripping according to the procedure described above, the human eye may inadvertently give more importance to the larger particles or coarse aggregate. Therefore, it is recommended that the fine aggregate portion of the sample be visually evaluated separately from the coarse aggregate. The existing test procedure is shown below with proposed additions italicized in steps nine through twelve.

Step	Action
1	Bring the oil bath to between 163 and 177 °C (325 and 350 °F).
2	Obtain a 200 g (7 oz.) representative sample of the material to be tested.
3	Fill the 2000 mL (68 oz.) beaker to approximately half capacity with distilled water and heat to boiling.
4	Add 200 g (7 oz.) of mix to the boiling water and rotate the beaker to evenly distribute the mix over the bottom of the beaker.
5	Place the beaker in the oil bath. The water should return to boiling within 3 minutes.
6	Maintain the water at a medium boil for 10 minutes ± 30 seconds, then remove from the bath.
7	Skim any asphalt from the water surface with a paper towel.
8	Decant the water from the beaker and empty the wet mix onto a white paper towel.
9	*Allow mixture to dry for 24 ± 2 hours.*
10	*Separate sample on a 2.00 mm (No. 10) sieve into the coarse and fine fraction.*
11	*Visually estimate the degree of stripping present in the coarse fraction and also in the fine fraction. Examination under slight magnification may aid in determining the extent of stripping.*
12	*Report the test results as the estimated percent of stripping in the coarse aggregate and the estimated percent of stripping in the fine aggregate. Neither the fine nor coarse aggregate fraction should exhibit more than 10 percent stripping.*

The Pennsylvania DOT has a clause in their Section 485 specification for bituminous patching material which TxDOT may wish to consider in the Item 334 specification. This clause is stated as follows:

> *..............................The material shall be capable of being stocked for at least six months without stripping and shall be workable at all times.*
>
> *Stocked patching material may be rejected at any time during the six month period if, in the opinion of the District Materials Engineer, the patching material has stripped (more than 10 percent uncoated particles) or otherwise become unfit for use.*

4. LABORATORY CURING PROCEDURES

According to Test Method Tex-206-F (Method of Compacting Test Specimens of Bituminous Mixtures), HMCL mixtures shall be cured to a constant weight at a minimum temperature of 60 °C (140 °F) to remove moisture and/or hydrocarbon volatiles prior to sample molding. As part of this research study, several different types of HMCL mixtures were cured in a 60 °C (140 °F) forced air oven for more than six days. The mixtures were manufactured with two types of aggregates: (1) a crushed limestone and (2) a crushed gravel. Three types of binders were used: (1) MC-800 with diesel (designated as MC-800d in Figure 1), (2) MC-800, and (3) AES-300S. Figure 1 shows the curing rates of all six mixtures.

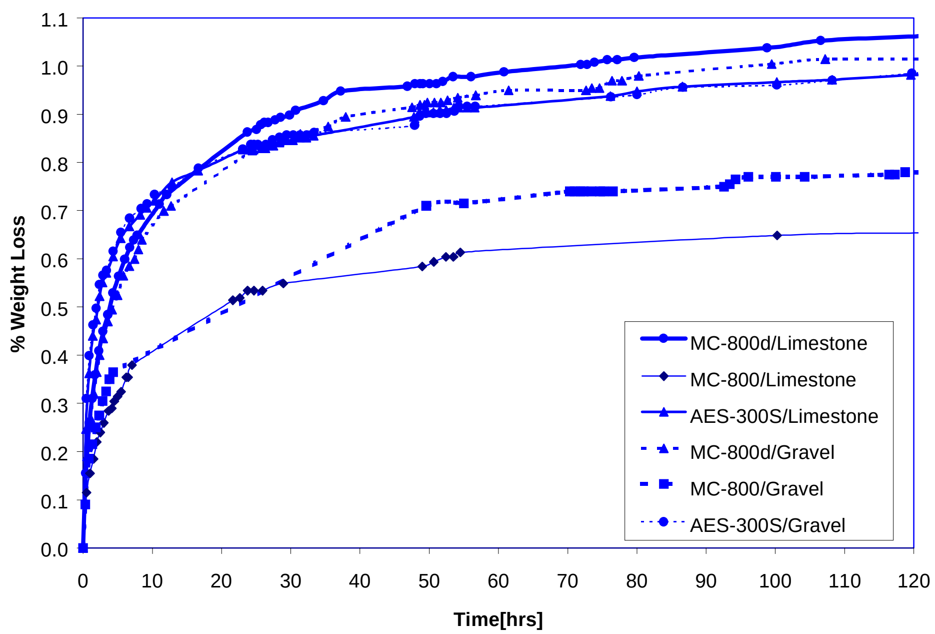

Figure 1. Curing Rate for Different HMCL Laboratory Mixtures.

As stated above, test method Tex-206-F requires curing prior to sample molding. The same curing procedure is also required prior to performing the workability and cohesion tests as described in Appendices A and B. Care should be taken to adequately cure mixtures and Figure 1 provides an indication of how long the curing process may take. All of the mixtures in this research project were cured for 48 hours.

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1. Estakhri, C.K., L.M. Jimenez, and J.W. Button, 1999. *Evaluation of Texas DOT Item 334, Hot-Mix, Cold-Laid Asphalt Concrete Paving Mixtures*, Research Report 1717-2, Texas Transportation Institute, Texas A&M University, College Station.

2. Wilson, T. P. and R.A. Romine, 1993. *Asphalt Pavement Repair Manuals of Practice*. SHRP-H-348, Strategic Highway Research Program, National Research Council, Washington, D.C.

Appendix A

Test for Workability of Hot-Mix, Cold-Laid Bituminous Paving Mixtures

WORKABILITY OF HOT-MIX, COLD-LAID BITUMINOUS PAVING MIXTURES

This procedure may be used to evaluate the cold-weather workability of hot mix-cold laid bituminous paving mixtures. It is not intended to quantify workability but to screen for any potential problems. Part I of this test is a subjective workability rating procedure and Part II is adapted from the SHRP-H-348, *Asphalt Pavement Repair Manuals of Practice.* (2) This test is to be performed on cured mixtures during mixture design and for mixture acceptance.

Part I - Subjective Workability Rating

Apparatus

- Balance with a minimum capacity of 2500 g (5.5 lb) accuracy of 1 g (0.1 lb) and sensitivity of 1 g (0.1 lb)
- Mixing pan, approximately 230 mm (9 inches) by 330 mm (13 inches) by 40 mm (1.5 inches) depth
- Refrigerator capable of cooling to 4 °C (40 °F)
- Thermometer, general use
- Spatula, blade length approximately 200 mm (8 inches)

Procedure

Step	Action
1	Obtain 2200 g (5 lb) sample of mixture.
2	Place mixture into a pan and cure to a constant weight at a minimum temperature of 60 °C (140 °F).
3	Cool mixture to a temperature of 4 °C (40 °F).
4	Test to see if mixture shall be capable of being broken up readily with the spatula.
5	Report results as *Pass* or *Fail.*

Part II - Workability Box Test

Apparatus

- Balance with a minimum capacity of 2500 g (5.5 lb) accuracy of 1 g (0.1 lb), and sensitivity of 1 g (0.1 lb)
- Workability Box (Figure A-1)
- Pocket Penetrometer (normally used for soil testing)
- Penetrometer Adapter (Figure A-1)
- Refrigerator capable of cooling to 4 °C (40 °F)
- Thermometer, general use

Procedure

Step	Action
1	Obtain three samples of HMCL of approximately 2500 g (5.5 lb) each. Cure samples at 60 °C (140 °F) until a constant weight is reached.
2	Cool mixture to 4 °C (40 °F).
3	Place cooled mixture into the workability box. Drop the mixture loosely into the box, making no effort to pack the material.
4	Push the penetrometer with adapter through the holes in both sides of the box. Record the maximum resistance as the workability measurement.
5	Record average workability results as acceptable (below two) or unacceptable (two or above).

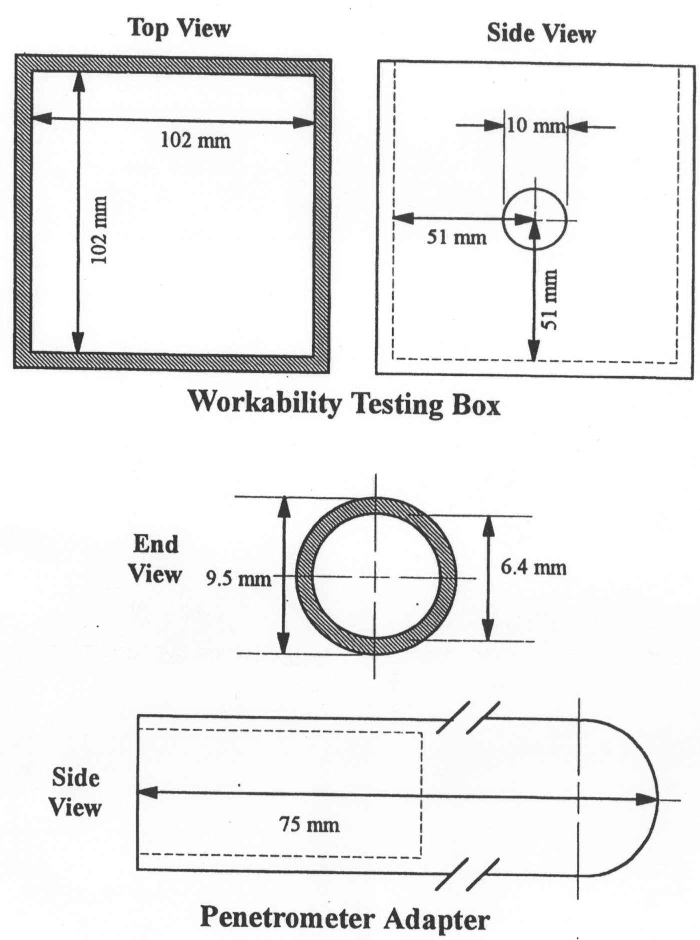

Figure A-1. Workability Testing Box and Penetrometer Adapter.
(After Wilson and Romine 1993)

1 inch = 25.4 mm

Wilson, T. P. and R.A. Romine, 1993. *Asphalt Pavement Repair Manuals of Practice*. SHRP-H-348, Strategic Highway Research Program, National Research Council, Washington, D.C.

Appendix B

Test for Cohesion of Hot-Mix, Cold-Laid Bituminous Paving Mixtures

COHESION OF HOT-MIX, COLD-LAID BITUMINOUS PAVING MIXTURES

This procedure may be used to evaluate the cold-weather cohesion characteristics of hot-mix, cold-laid bituminous paving mixtures.

Apparatus

- Balance with a minimum capacity of 2500 g (5.5 lb) accuracy of 1 g (0.1 lb) and sensitivity of 1 g (0.1 lb)
- Standard Marshall mold, 63.5 mm (2.5 in) high, with a diameter of 102 mm (4 in)
- Standard Marshall compaction hammer (4.5 kg [10 lb], 457 mm [18 inch] drop height)
- Sieve with cover, 305 mm (12 inch) diameter, 25.4 mm (1 inch) nominal opening size
- Refrigerator capable of cooling to 4 °C (40 °F)
- Thermometer, general use

Procedure

Step	Action
1	Obtain three samples of HMCL of approximately 1200 g (2.6 lb) each. Cure samples at 60 °C (140 °F) until a constant weight is reached.
2	Cool mixture to 4 °C (40 °F).
3	Place cooled mixture into a standard Marshall mold. Compact the sample using five blows of a standard Marshall hammer to each side.
4	Extrude the sample, and record the weight of the compacted sample.
5	Place the compacted sample along the bottom edge of sieve while both the sieve and the sample are standing on end as shown in Figure B-1.
6	Place the cover on the sieve while it is still on end. Roll the sieve with the sample inside back and forth 20 times, taking approximately one second for each of the 20 passes.
7	Lay the sieve (with the sample still inside) against the edge of a table, allowing room for sample pieces to fall through the sieve openings. Leave the sieve in this position for 10 seconds.
8	Flip the sieve and lid over so that the sample in the sieve falls into the lid. Weigh the material retained.
10	Determine the percentage retained by dividing the weight retained by the original weight. Average the results from three samples. A minimum retention value of 60 percent is an acceptable cohesion value under this test.

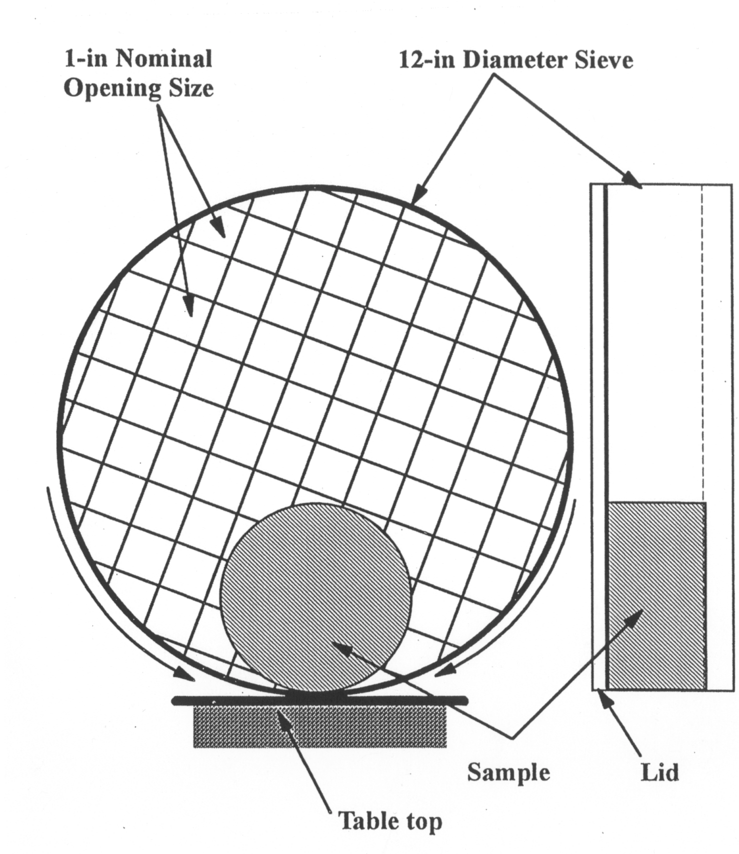

Figure B-1. Rolling Sieve Cohesion Test.
(After Wilson and Romine 1993)

Wilson, T. P. and R.A. Romine, 1993. *Asphalt Pavement Repair Manuals of Practice*. SHRP-H-348, Strategic Highway Research Program, National Research Council, Washington, D.C.