**OKLAHOMA DEPARTMENT OF TRANSPORTATION**
**SPECIAL PROVISIONS**
**FOR**
**MILLED HOT RECYCLING OF BITUMINOUS MATERIAL (PARTIAL DEPTH)**
**2"+ SURFACE RECYCLING**
**PROJECT NUMBER, JP NO. 00000(04), COUNTY**

These Special Provisions revise, amend, and where in conflict, supersede applicable sections of the 2009 Standard Specifications for Highway Construction, English and Metric.

## 410.01 DESCRIPTION

This work consist of heating, pulverizing and milling the in situ bituminous materials to the depth and width shown on the plans. An emulsified asphalt binder agent is then incorporated into the pulverized material. Then the material is spread and compacted in accordance with the plans and specifications, and as directed by the Engineer.

## 410.02 MATERIALS



### A. Asphalt Emulsion

Provide an asphalt emulsion that meets the requirement of Table 410:2. Ensure the final emulsion properties meet the mix design parameters in Table 410:1.

### B. Mix Design

Submit the mix design to the Engineer for approval prior to the start of the project. Perform additional mix designs based on road variability, as directed by the Engineer. Ensure the mix design procedure, including sample preparation, testing protocol, and job mix formula meet the criteria of Table 410:1. See Appendix A for mix design procedure.

Prepare 150mm specimens in a Superpave Gyratory compactor. Ensure the mixture meets the following criteria for the selected design asphalt emulsion content.

Table 410:1

| Property | Criteria | Purpose |
|---|---|---|
| Compaction effort<br>Superpave Gyratory Compactor | 30 gyrations, 1.25 angle, 600 kPa stress | Density Indicator |
| Density<br>AASHTO T 166 or equivalent | Report | Compaction Indicator |
| Tensile Strength *<br>AASHTO T 283, 77°F | 75 psi minimum | Stability Indicator |

| Table 410:1 | | |
|---|---|---|
| Property | Criteria | Purpose |
| Retained Strength based on cured stability ** | 80% min | Moisture Damage |
| Asphalt Pavement Analyzer AASHTO TP 63, 140°F, Wet, 8000 cycles | See Section 3.7 of Appendix A<br>8mm Maximum | Rut Resistance |
| Indirect Tensile Test AASHTO T-322 | See Section 3.8 of Appendix A | Thermal Cracking |
| * Cured strength tested on compacted specimens after 140°F curing to constant weight | | |
| ** Vacuum saturation of 55 to 75 percent, water bath 77°F 24 hours | | |

**C. Asphalt Emulsion**

If necessary, use additives to meet the requirements in Table 410:1. In the case that an additive is used, describe the type and allowable usage percentage in the submitted design recommendation.



| Table 410:2 | | | |
|---|---|---|---|
| Test | | Minimum | Maximum |
| Residue from distillation, % [1] | AASHTO T-59 | 60.0 | 65.0 |
| Viscosity, SF @ 25ºC, seconds | AASHTO T-59 | 15 | 100 |
| Oil distillate by distillation, % | AASHTO T-59 | | 2.0 |
| Sieve Test, % | AASHTO T-59 | | 0.1 |
| Storage Stability, 24 hrs, % | | | 1.0 |
| Penetration @ 4ºC, 100g, 5s, dmm [2] | AASHTO T-49 | 150 | |
| Penetration @ 4ºC, 100g, 5s, dmm [2] | AASHTO T-49 | -25% | 0.25% |

[1] Modified AASHTO T-59 procedure – distillation temperature of 350°F with a 20 minute hold. The AASHTO T-59 vacuum distillation procedure may be substituted once the maximum oil distillate is satisfied.

[2] The penetration value will be ± 25% of that value reported in the project design for QC/QA testing. (e.g. If the penetration is reported to be 200 dmm, the acceptable range would be 150 to 250 when testing QC/QA samples.)

## 410.03 EQUIPMENT

Provide equipment for milled hot recycling which meet the requirements of subsection 411.04 of the Standard Specifications, and the following:

### A. Processing Equipment

Provide equipment for heating, pulverizing, milling, injecting, mixing, placing and finishing that meets the following requirements:

#### (1) Pre-Heating Mechanism

Supply multiple heating devices, under a 24' long adjustable width closed or shielded hood, capable of heating asphalt concrete pavement to a temperature that allows milling to the desired depth without producing undesirable pollutants prior to the heater milling operation.

#### (2) Heating Milling Unit

Provide a unit capable of heating, milling, and windrowing the first layer of the pavement that is being processed. Ensure the machine has automatic grade controls that allow the correct depth of material to be removed. Under some conditions more than one heating and milling machine can be used if needed. Three-fourth inch ( ¾") is the maximum allowable cut depth for each individual unit.



#### (3) Tunnel Heater

Provide a tunnel heater capable of continuing the heating process by straddling the windrow of heated milled material created by the first milling heater. Ensure the heater is able to continue to heat the underlying pavement while straddling the existing windrow of material. More than one tunnel heater may be needed.

#### (4) Milling-Mixing-Paving Unit/Units

Provide a milling-mixing-paving unit(s) possessing the following capabilities and characteristics:

- equipped with two or more telescopic milling heads capable of milling widths up to 15 feet and depths to 3 inches
- milling heads controlled by automatic grade controls
- capable of leaving a milled, textured surface on which to lay the recycled material
- milling head units equipped with a metering device able to deliver the amount of asphalt emulsion in the milling heads, as required by the mix design (ensure the metering device is capable of delivering the amount of asphalt emulsion to within ±0.2 percent of the required amount by weight of pulverized bituminous material (e.g. if the design requires 1.0 percent, the metering device will maintain the emulsion content to between 0.8 percent and 1.2 percent)
- asphalt emulsion pump of sufficient capacity to allow emulsion contents up to 3.0% by weight of pulverized bituminous material

- equipped with a paving screed capable of spreading and laying the recycled, processed material in one smooth, continuous pass
- an independent, self propelled paver having electronic grade and cross slope control for the screed that can be used in conjunction with the milling mixing heaters if performance can be demonstrated to the satisfaction of the Engineer
- sufficient size and power to spread and lay the mixture in one smooth continuous pass according to the plans
- capable of immediately follow ing the milling/mixing/heater operations

***(a) Emulsion Addition***

Control the addition of asphalt emulsion through metering devices capable of adjusting for the variation in the depth of the pulverized material going into the milling/mixing unit. Ensure the metering devices are capable of delivering the amount of emulsion to within +/- 0.2 percent of the required amount by weight of the pulverized bituminous material. Apply the emulsion to the milling drums full width during the final pass of the milling-mixing-paving unit.

**B. Rollers**



Provide rollers that are in good condition, capable of reversing without backlash, and operable at speeds slow enough to avoid displacement of the recycled mixture. Provide vibratory rollers equipped with working amplitude and/or frequency controls specifically designed for compaction of the material on which it is to be used. Ensure two double drum vibratory rollers, and one pneumatic tired roller are on the project at all times for compaction as directed by the engineer. Ensure the vibratory rollers have a gross operating weight of not less than 20,000 lbs. and a width of 78 inches. Ensure all rollers have properly working scrapers and water spraying systems. Provide sufficient rolling capacity to satisfy the density requirements of subection 410.04.B.

## 410.04 CONSTRUCTION

Rehabilitate existing asphalt concrete pavement to meet the typical sections shown on the plans, and the lines and grades established by the Engineer.

**A. Heating, Milling, and Placement**

Heat and hot mill the existing pavement to the required depth and width as indicated on the plans. Heat and mill the existing pavement a minimum of three times to reach the required depth of treatment. The maximum depth of milling for each individual pass is limited to three-fourth inches ( ¾”). Recycle shall be in a manner that does not disturb the underlying material in the existing roadway.

Produce the hot recycled material through a milling and mixing unit capable of processing the paving material and asphalt emulsion to a homogeneous mixture. Incorporate the asphalt emulsion into the hot recycled bituminous material at the initial rate determined by the mix design(s) and approved by the Engineer. Sampling and testing for the mix design and during mixture production may result in varying quantities of asphalt emulsion at various locations of the project to achieve desired design specifications. Perform asphalt emulsion changes at the direction of the Engineer.

Spread the material by using a screed attached to the milling and mixing unit, or a separate paver as described in subsection 410.03.A.4. Spread the recycled material in one continuous pass, without segregation, and to the lines and grades established by the Engineer. Ensure the material temperature is a minimum of 190°F immediately behind the paving screed.

**B. Compaction**

Perform compaction of the recycled mix by using rollers meeting the requirements of subsection 410.03.B. Change rolling or roller patterns when major displacement and/or cracking of the recycled material is occurring, or when density requirements are not being met. When possible, ensure pavement is fully compacted before allowing rollers to stand on the pavement. Upon completion of the rolling operations, do not allow rollers to park with drum contact perpendicular to the longitudinal joint.

**C. Acceptance**

Pavement will be accepted on a lot-by-lot basis. Normally, a lot is be considered to be one day's production. However, the Engineer may terminate a lot at any point and designate a new one when a materials or workmanship adjustment has been made which results in the desired correction.



Ensure the density of each lot is a minimum of 92% of the Maximum Theoretical Specific Gravity (Gmm) at the Job Mix Formula (JMF) emulsion content. The Gmm is determined from daily production testing as required in subsection 410.04.H, "Quality Control". The roadway density for each lot will be the average of tests of three separate specimens taken randomly within the limits of the area represented by the lot. Cut test specimens for each lot from the pavement by sawing or coring a specimen a minimum size of 6 inches on the cut side or diameter, at locations and times established by the Engineer. The tests may be on the cut specimens or through use of nuclear density gauges at the discretion of the Engineer.

**D. Traffic**

After the recycled material has been compacted, do not permit traffic (including construction traffic) onto the completed recycled material until the material has cooled to 150°F or less. After opening to traffic, maintain the surface of the recycled pavement in a condition suitable for the safe movement of traffic.

**E. Irregularities**

Repair damage to the completed milled hot-in place recycled bituminous material prior to the placement of the hot mix asphalt concrete surface course, or other applicable surface treatment, and as directed by the Engineer.

**F. Curing**

Allow the recycled asphalt surface to cure for a minimum of 24 hours prior to placing the hot mix asphalt concrete surface course, or other applicable surface treatment. Apply the final surface course/treatment within 21 days after the hot recycling.

**G. Weather limitations**

Complete milled hot-in-place recycling operations when the atmospheric temperature measured in the shade, and away from artificial heat, is 50°F and rising. This temperature requirement can be adjusted or waved by the Engineer.

Do not perform such operations when the weather is foggy or rainy.

**H. Quality Control**

The Engineer is responsible for quality assurance of the materials, and the depth of milling of the hot-in-place recycling process. The Engineer may choose to test, or to delegate to the Contractor, the schedule of testing to be completed on the items listed below:

**(1) Asphalt Emulsion**

The sampling rate will be determined by the Engineer. Samples will be obtained from the shipping trailers prior to unloading into the Contractor's storage units.



**(2) Asphalt Emulsion Content**

The Engineer will check and record the emulsion content for each segment in which the percentage is changed. The emulsion used will be checked daily for yield per unit of measure in addition to the calibrated emulsion metering system for correct yield. For reporting purposes, the yield determination will be used. Emulsion content changes will be made based upon mix design recommendations for each road segment of varying construction. Do not adjust the JMF asphalt emulsion content without the consent of the Engineer.

**(3) Mixture Testing**

Samples will be obtained for testing mixture properties at a minimum of once daily, or as directed by the Engineer. Samples of mixture will be taken from the roadway behind the paving screed. Testing will be performed at a sufficient frequency to determine the properties of the in-place asphalt pavement combined with asphalt emulsion, and shall be used as the reference density for compaction determination (subsection 410.04.B). Sample preparation and testing protocol will follow those approved in the submitted design and job mix formula.

**(4) Depth of Pulverization (Milling)**

Maintain the nominal dimension on both outside vertical faces of the cut. Dimensions will be checked at least each ¼ mile. A minimum of three passes, at a maximum depth of cut of ¾" per pass, will be used to achieve the overall depth of reprocessing.

**410.05 MEASUREMENT**

Work as described for this item will be measured by the square yard of completed sections for the depth specified.

The asphalt emulsion will be measured by the ton.

**410.06 BASIS OF PAYMENT**

Accepted quantities of work performed and materials furnished will be paid for at the unit price bid for:

| **Pay Item:** | **Pay Unit:** |
|---|---|
| *(A) HOT-IN PLACE RECYCLED ASPHALT CONCRETE* | Square Yard [Square Meter] |
| *(B) HOT-IN PLACE ASPHALT EMULSION* | Ton [Metric Ton] |

Payment is considered full compensation for the removal and processing of the existing pavement, preparing, hauling, and placing all materials, all freight involved, all manipulations, including rolling, and for all labor, tools, equipment and incidentals necessary to complete the work.



The cost of cutting specimens and satisfactorily placing and finishing new materials in areas where specimens have been taken will be included in the price bid for recycled mixture in place.

*Mobilization* and *Traffic Control* will be bid as separate items, and not included in the price bid for *Hot-In-Place Recycled Asphalt Concrete* or *Hot-In-Place Asphalt Emulsion*.

## Appendix A

## Determining the Optimum Emulsion Content for Hot In-Place Recycling Mixtures (HIR)

### 1.0 SCOPE

1.1 This test method describes procedures for determining the optimum emulsion content for hot in-place recycling mixtures.

1.2 This test method describes the procedures and test methods for obtaining material from the existing roadway, preparation and testing.

### 2.0 APPARATUS

2.1 Diamond core bit and drill to obtain samples from the roadway.

2.2 Other equipment listed in AASHTO Test Methods T11, T27, T166, T209, T283, T312, T322 and TP63.

### 3.0 PROCEDURE

#### 3.1 Sampling and Processing

3.1.1 Obtain 6-inch cores from the areas to be recycled. If cores show significant differences in various areas, such as different type or thickness of layers between cores, then separate mix designs shall be performed for each of these pavement segments. It is recommended to take, at a minimum, one core for each lane mile and where visual differences in the pavement are noticed. At least 50 cores are needed for each mix design. Cores shall be cut in the laboratory to the depth specified for the HIR project. Cores shall be crushed in the laboratory. The mix design shall be performed on these crushed millings. Gradation of the millings after crushing shall be determined by AASHTO T11 and T27 (dried at no greater than 100°F). Core holes in the existing pavement shall be filled with cold lay material or equivalent and then compacted to the satisfaction of the engineer.

#### 3.2 Mixing

3.2.1 Specimen size: the amount that will produce a 4.5 to 4.7 inch tall specimen; use AASHTO T209 to determine the size for Rice specific gravity.

3.2.2 Number of specimens: 4 per emulsion content for a total of 6 for long-term stability and 6 for moisture testing for 3 emulsion contents. Two specimens are required for Rice specific gravity; test at the highest emulsion content in the design and back calculate for the lower emulsion contents.

3.2.3 Recommended emulsion contents: 0.5%, 1.0%, 1.5%, 2.0%, 2.5%. Choose three emulsion contents that bracket the estimated recommended emulsion content. The emulsion shall be 140-175ºF for the mixing process.

3.2.4 Place the split out crushed RAP in a 230ºF oven for 2-4 hours prior to mixing.

3.2.5 If any additives are to be used in the mixture, introduce the additives in a similar manner that they will be added during field production.

3.2.6 Mixing of test specimens shall be performed with a mechanical bucket mixer. Mix the heated crushed RAP with emulsion. One specimen shall be mixed at a time. Mixing time with emulsion should not exceed 60 seconds.

#### 3.3 Compaction

3.3.1 The molds for compaction should be placed in the 230ºF oven for a minimum of one hour before compaction.

3.3.2 Specimens shall be compacted immediately after mixing. Place paper disks on the top and bottom of the specimen before compaction.

3.3.3 Specimens shall be compacted with a Superpave gyratory compactor (SGC) in a 150 mm mold at 1.25° angle, 600 kPa ram pressure, and 30 gyrations.

**3.4 Curing after compaction**

3.4.1 Extrude specimens from molds immediately after compaction. Carefully remove paper disks.

3.4.2 Place specimens in 140°F forced draft oven with ventilation on sides and top. Place each specimen in a small container to account for material loss from the specimens.

3.4.3 Specimens for Rice specific gravity should be dried to constant weight (less than 0.05% weight loss in 2 hours). Care should be taken not to over-dry the specimens.

3.4.4 Cure compacted specimens to constant weight but no more than 48 hours and no less than 16 hours. Constant weight is defined here as 0.05% change in weight in 2 hours. After curing, cool specimens at ambient temperature a minimum of 12 hours and a maximum of 24 hours.

**3.5 Measurements**

3.5.1 Determine bulk specific gravity (density) of each compacted (cured and cooled) specimen according to AASHTO T166 or equivalent; however, the mass of the specimen in water (measurement C) can be recorded after one minute submersion.

3.5.2 Determine specimen heights according to ASTM D3549 or equivalent. Alternatively, the height can be obtained from the SGC readout.

3.5.3 Determine Rice (maximum theoretical) specific gravity, AASHTO T209, except as noted in Section 3.3 of this procedure, and do not break any agglomerates which will not easily reduce with a flexible spatula. It is normally necessary to perform the supplemental dry-back procedure to adjust for uncoated particles.

3.5.4 Determine air voids at each emulsion content.

3.5.5 Determine Tensile strength by AASHTO T283 at 77°F after 2 hour temperature conditioning in a forced draft oven. This testing shall be performed at the same time that the moisture conditioned specimens are tested.

**3.6 Moisture Susceptibility**

3.6.1 Perform same conditioning and volumetric measurements on moisture-conditioned specimens as on other specimens. Vacuum saturate to 55 to 75 percent, soak in a 77°F water bath for 24 hours. Determine the Tensile strength of the saturated specimens by AASHTO T283. The average moisture conditioned specimen strength divided by the average dry specimen strength is referred to as percent retained strength.

**3.7 Asphalt Pavement Analyzer Testing for HIR Design Specimens**

3.7.1 Perform the Asphalt Pavement Analyzer (APA) testing according to AASHTO TP63 with the following exceptions:

3.7.1.1 Specimens shall be 150 mm in diameter and at least 50 mm in height and compacted to air voids +/- 1 percent of design air voids at the design emulsion content. Test specimens shall be cured at 140ºF no less than 16 hours and no more than 48 hours. Check specimen mass every 2 hours after 16-hour cure to check with compliance of no more than 0.05% change in mass in 2 hours.

3.7.1.2 After curing, two specimens are the minimum required to be run in the same mold in a water bath at a temperature of 140ºF, 100 lb/in$^2$ hose pressure, 100 lbs. wheel pressure.

3.7.1.3 The specimens must be placed in the water bath for a minimum of two hours at the test temperature prior to testing.

3.7.1.4 The mm of rut depth at 8000 cycles will be recorded as an average of the two specimens. The two separate test results will be reported, and the difference between the specimens shall not be greater than 2.5 mm if the average is < 8 mm.

**3.8 Thermal Cracking – Procedures for performing AASHTO T322 for HIR Design Specimens**

*NOTE: Procedure for critical cold temperature selection*

3.8.1 Specification temperature shall be chosen using FHWA LTPPBind software (Version 2.1) using the weather station closest to the project. The required temperature for the specification is the coldest temperature at the top of the HIR layer in the pavement structure. Use 98 percent reliability.

3.8.2 Perform the indirect tensile testing (IDT) according to AASHTO T322 with the following exceptions:

3.8.3 Specimens shall be 150 mm in diameter and at least 4.5 inches in height and compacted to air voids +/- 1 percent of design air voids at the design emulsion content. A trial specimen is recommended for this. Test specimens shall be cured at 140ºF no less than 48 hours and no more than 72 hours. Check specimen mass every 2 hours after 48-hour cure to check with compliance of no more than 0.05% change in mass in 2 hours. After curing, two specimens shall be cut from each compacted specimen to 2 inches in height. Perform bulk specific gravity after cutting.

3.8.4 Instead of three specimens, two specimens are the minimum required at each of three temperatures.

3.8.5 Select two temperatures at 10ºC intervals that bracket the required specification. For example, if the required specification temperature is –25ºC, then select testing temperatures of –20ºC and –30ºC. A temperature of –10ºC or –40ºC should then be selected to complete the third required temperature.

3.8.6 The tensile strength test shall be carried out on each specimen directly after the tensile creep test at the same temperature as the creep test.

3.8.7 The environmental chamber must be capable of temperatures down to –40ºC.

3.8.8 The critical cracking temperature is defined as the intersection of the calculated pavement thermal stress curve (derived from the creep data) and the tensile strength line (the line connecting the results of the average tensile strength at the two temperatures).

## 4.0 EMULSION CONTENT SELECTION

4.1 The properties of the specimens at design emulsion content shall meet the properties in Table 410:3.

| Table 410:3 | | |
|---|---|---|
| 150 mm specimens shall be prepared in a Superpave Gyratory compactor. The mixture shall meet the following criteria at the selected design asphalt emulsion content: | | |
| Property | Criteria | Purpose |
| Compaction effort, Superpave Gyratory Compactor | 30 gyrations, 1.25° angle, 600 kPa stress | Density Indicator |
| Density, AASHTO T166 or equivalent | Report | Compaction Indicator |
| Tensile Strength*, AASHTO T283, 77°F | 75 lb/in² min. | Stability Indicator |
| Retained strength based on cured stability ** | 80 % min. | Ability to withstand moisture damage |
| Asphalt Pavement Analyzer, AASHTO TP63, 140ºF, Wet, 8000 cycles, Modified in Section 3.7 | 8mm Maximum | Rut Resistance |
| Indirect Tensile Test, AASHTO T-322, Modified in Section 3.8 | See Note in Section 3.8 | Cracking (Thermal) |
| * Cured strength tested on compacted specimens after 140°F curing to constant weight. | | |
| **Vacuum saturation of 55 to 75 percent, water bath 77°F 24 hours | | |



For rutting and cracking testing, begin with the highest emulsion content that meets the Tensile Strength requirement, and then reduce emulsion content if other tests do not pass. This way will help reduce the amount of trials that need to be run. The design emulsion content shall be the highest emulsion content that satisfies the minimum tensile strength requirement and satisfies the other requirements of Table 410:3.

## 5.0 REPORT

5.1 The report shall contain the following minimum information: Optimum emulsion content as a percentage of RAP weight and corresponding density, air void level, and absorbed water; Tensile strength and retained Tensile strength at recommended emulsion contents, Rut Resistance (APA), and Thermal Cracking initiation temperature. Include the emulsion designation, company name, plant location, and residue content.