S T A T E **O F** **T E N N E S S E E**

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SPECIAL PROVISION

REGARDING

COLD IN-PLACE RECYCLED BITUMINOUS PAVEMENT

Description

This work shall consist of the Cold in Place Recycling (CIR) of existing bituminous pavement and shall include furnishing of all labor, materials, equipment, and transportation of a 100% recycled bituminous pavement. Use CIR technology to place the mixture in accordance with this provision and as directed by the Engineer.

CIR Bituminous Pavement shall not be used as a final riding surface. Protect and maintain the finished surface until it is covered with a surface course.

Materials

Provide Materials as specified in:

Portland Cement…….**901.01**
Water……..**921.01**

Asphalt Cement, PG64-22……..**904.01**
or
Engineered Asphalt Emulsion……**Table 1**

Recycled Asphalt Pavement (RAP):

RAP shall consist of the existing pavement in situ.

Table 1: Engineered Asphalt Emulsion

Test	Procedure	Minimum	Maximum
Saybolt Viscosity Furol (77F) SFS	AASHTO T59	20	100
Sieve Test, % retained (Terminal)	AASHTO T59		0.10
Sieve Test, % retained (Field)	AASHTO T59		0.30
Residue by Distillation, %	AASHTO T59	64	
Oil Distillate, %	AASHTO T59		1
Penetration (77F), 100g/5s, dmm	AASHTO T59	40	90

Provide certifications for Portland Cement, Asphalt Cement and Asphalt Emulsion to the Department.

Utilize Foamed Asphalt Cement or Engineered Asphalt Emulsion to bind the mixture as directed by the plans.

Equipment

A. In-Place Recycling Unit

Provide a single or multi-unit in-place recycler. The in-place recycling unit shall be self-propelled machine(s) with a down cutting milling head that is capable of pulverizing and recycling the existing bituminous pavement to a maximum depth of 5 inches, proportioning the ingredients of the mix design per the job mix formula, and mixing the materials to produce a homogenous product. The machine(s) shall be capable of pulverizing and recycling the full lane width in one pass. The machine(s) shall have the ability to meter the dosage rates of asphalt cement or asphalt emulsion, Portland cement, and water relative to the machine's speed. Individual valves on the spray bar shall be capable of being turned off as necessary to minimize overdosing on subsequent passes. The equipment shall be operated per the manufacturer's recommendations.

The In-Place Recycler shall have means of controlling the proportioning of Portland cement to within 0.1% and all other added ingredients to within 0.25% of the required amount in the approved Job Mix Formula (JMF); except for water in which case the capability of adding up to 5% by weight of the RAP is required.

B. Paver

After mixing, the material shall be placed and spread by means of a bituminous paver per **407.06.A.**

C. Rollers

Provide a minimum of 2 rollers meeting **407.07**. The breakdown roller shall be a vibratory double drum steel roller weighing a minimum of 10 tons. The second roller shall be a pneumatic tire roller weighing a minimum of 20 tons. Additional rollers may be necessary to obtain the required density.

D. Small Tools

Provide small tools per **407.08.**

E. Nuclear Density Gauge

Provide a nuclear density gauge and a technician qualified to operate the instrument for the purposes of quality control.

Design

Obtain representative samples (minimum 350 lb) of the bituminous pavement to be recycled. Sample the pavement throughout the entire length of the project limits. Multiple designs may be required for a single project.

Sampling may be done by coring or by milling a test trench to the depth of recycling shown on the plans. Backfill all core holes or test trench with bituminous pavement prior to opening to traffic. If utilizing cores, reduce the core in a manner representative to the cutting action of the in-place recycler.

Determine the asphalt coated gradation of the RAP per AASHTO T11 & T27. Determine the dry density and optimum moisture content of the RAP per AASHTO T99.

Establish the foamed asphalt or emulsion content at 77°F for both the coarse and medium gradation ranges in Table 2. Additional acceptable ranges of adjusted optimum foamed asphalt or emulsion contents may be determined at 110°F that meet the applicable requirements in Table 3 for the purpose of making field adjustments for hot-weather field conditions.

Table 2: Gradation Requirements

Sieve Size	Coarse	Medium
1 ½ ”	100	100
1”	85-100	100
¾”	75-92	85-96
No. 4	30-45	40-65
No. 30	1-7	4-14

Produce a mixture that meets the requirements in Table 3, consisting of RAP, 0.5% - 1% Portland cement by weight of RAP, asphalt cement or asphalt emulsion and water using a laboratory pug mixer or a mechanical bucket mixer. Limit the ratio between Residual Asphalt to Portland Cement of 2.5:1 maximum

Table 3: Mix Design Requirements

Test	**Requirement**
Wet Indirect Tensile Strength (ITS), AASHTO T283 (avg of 3 tests)	Minimum 30 psi
Tensile Strength Ratio (TSR), AASHTO T283	Minimum 0.70
Expansion Ratio (if using Foamed Asphalt) • Aggregate Temperature > 25°C • Aggregate Temperature < 25°C	 10 8
Foam Half-Life (if using Foamed Asphalt)	Minimum 6 seconds
Raveling Test, ASTM D7196, 4-hour cure, 25C (if using emulsion)	Maximum 5% loss

A. Dry ITS and TSR Procedure

Produce six samples at or below the optimum moisture content and design AC using a Marshall Hammer (as defined in **106.06**) utilizing 75 blows per side or using a Superpave Gyratory Compactor at 30 gyrations with a 4" mold. Cure all samples at 40°C for 72 hours. Determine the bulk density by AASHTO T275 (except the time each sample is submerged is to be one minute), of each sample and the average of all six. If any individual sample's bulk density is more than 2.5% different from the average discard it and make a new sample.

Place three of the samples in a 25°C water bath such that they are completely submerged for 24 hours. The other three samples shall be stored at ambient temperature during this time.

After 24 hours, test all six samples per AASHTO T283 and record the tensile strength of each sample. Note that the submerged samples shall be removed from the water bath, rolled once across a damp towel to saturated surface dry (SSD) condition and tested immediately.

Average the ITS of the 3 samples left at ambient temperature (dry average) and the 3 samples submerged in the water bath (wet average). The TSR = wet average/dry average

B. Expansion Ratio and Foam Half-Life (if applicable)

Calculate the Expansion Ratio and Foamed Asphalt Half-Life per the Wirtgen 2012 Cold Recycling Manual.

C. Mix Design Submittal

A minimum of one week prior to production work, provide the Department with test results of a minimum of 3 AC contents from a qualified lab and the identify the proposed job mix formula for the following criteria for the Department's approval:

1. Asphalt Cement Content by weight of RAP
2. Portland Cement Content by weight of RAP
3. Gradation for the sieve sizes identified in Table 2
4. Expansion Ratio and Half-Life characteristic and temperature of asphalt cement at the time of dosage into the foaming chamber (if using foamed asphalt).
5. Application and dilution rate (if any) of Engineered Asphalt Emulsion (If using Asphalt Emulsion)
6. Estimated increase in volume (Bulking %) of the compacted CIR Pavement from the existing pavement

Construction Requirements

A. Test Strip

Before beginning full CIR production work, perform a CIR test strip 500 feet long and one-lane width wide at the designed thickness utilizing the approved job mix formula, with testing completed in the last 200 feet of the test strip. Construct the test strip at a location approved by the

Engineer inside the project limits. The test strip is to remain in place as part of the completed work.

Compact the test strip in a continuous and uniform manner over the entire test strip using the equipment and construction procedures intended for the entire project. After each pass of the roller take a reading with a nuclear density gauge using the backscatter method. Compaction is to continue until the density indicated by the nuclear density gauge shows no appreciable increase in density with additional passes (<1 pound per cubic foot). Stop compaction work after construction of the test strip once no appreciable increase in density has been achieved and notify the Engineer.

Once the test strip has reached final compaction, the Engineer shall take a density reading with a nuclear density gauge utilizing the direct transmission method to determine the dry density at 3 locations determined in the last 200 feet of the test strip. The locations shall be selected using a stratified random pattern and at least 1 foot away from any longitudinal joint. The Engineer will establish the average maximum dry density achieved during each test strip as the Target Maximum Density until changed by a subsequent test strip. On the first test strip of the project the Engineer will determine a moisture correction factor (MCF) per the procedure in the appendix for the nuclear density gauge used for acceptance.

Resume CIR production work on the project only once the test strip has been accepted by the Department. Acceptance of the test strip will be constituted by passing results of the Acceptance Test outlined in the **Method of Acceptance** section of this document and demonstration through production documentation of conformance with the job mix formula gradation and proportioning as described in the **Quality Control** section.

If there is a failed test during the test strip, make immediate corrections to the CIR operation. Repair or replace any portion of the test strip found to be deficient prior to resuming production. Perform another CIR test strip for an additional 500 feet after corrective action is taken; if this section is satisfactory to the Engineer, proceed with CIR production.

Establish a moisture correction factor (per the method in the appendix) for the nuclear density gauge used for quality control on the first day of work during the initial test strip construction.

A new test strip may be requested during production to establish a modified roller pattern if there is a change of conditions on the roadway or if 2 consecutive density tests deviate from the established Target Maximum Density by ±3%. Notify the engineer prior to construction of a new test strip.

B. Weather Limitations

Place CIR bituminous pavement only when the atmospheric temperature is a minimum of 50°F and rising. Do not proceed with the work if the National Weather Service predicts freezing within 48 hours.

The surface temperature of the existing pavement to be recycled shall be a minimum of 50°F measured in the shade.

Do not work during precipitation events. Do no work if there is standing water on the pavement to be recycled.

C. Construction

If required due to project constraints and the swelling of the CIR bituminous pavement; remove and take possession of excess existing pavement by milling prior to CIR work such that the CIR Bituminous pavement is constructed to the required thickness.

Pulverize and recycle the existing bituminous pavement to a depth and width as specified. Proportion the ingredients of the mix design per the job mix formula and mixing the materials to produce a homogenous product. Remove rubberized crack filler, durable pavement markers, loop wires, and other similar materials from the roadway as observed during the recycling process. Shredded materials that cannot be completely removed from the processed RAP may be incorporated into the recycled mix if the Contractor can demonstrate that those added materials will not adversely affect the uniformity, smoothness, and compaction of the recycled pavement.

Overlap adjacent CIR passes a minimum of 3 inches along each longitudinal joint and a minimum of 2 feet along transverse joints. Adjust the application rate of Asphalt Cement, Asphalt Emulsion and Portland Cement inside the joint overlap area so as to not cumulatively exceed the dosage rates established in the JMF.

Place, spread, and strike off the mixture to the established line, grade, thickness, and elevation using the approved paver.

Ensure the mat has a uniform texture not showing any signs of segregation, tearing, or shoving of the bituminous mixture. If there are any signs of not producing a uniform mixture, stop paving until condition is corrected.

Compact the CIR bituminous material to the target maximum density established during the CIR test strip process.

After compaction is complete, monitor the moisture content of the in-place mixture with a nuclear density gauge daily. Allow the CIR bituminous pavement to cure prior to covering with the final wearing surface until the corrected moisture content shows no appreciable change on consecutive days. After the curing period is complete, maintain the surface in condition for safe movement of traffic.

Release traffic onto the finished surface no sooner than 2 hours after recycling. If additional protection of the CIR surface is desired or if the CIR surface is raveling under traffic, protect the surface by applying a fog seal per **403.05.C,** at a diluted rate of 0.05 to 0.15 gallons per square yard based on a dilution rate of one-part emulsified asphalt to one part water, to the finished CIR Bituminous Surface. Immediately after applying the fog seal, apply sand meeting the material requirements of **903.06.B** at a minimum rate of 2 pounds per square yard to the surface as a blotting material.

Repair any damage to the surface at no cost to the Department prior to covering with the final wearing surface.

D. Quality Control

Monitor the results of the following tests at a minimum frequency specified. If any of the quality control tests show failing results take immediate corrective action. Record all test results both passing and failing.

1. Gradation

During production, sample the unmixed RAP from the drum at a minimum of once per day. To accomplish this, metering in of the Asphalt Cement, Asphalt Emulsion, Portland Cement, and water shall be momentarily halted while the drum continues to mill for a section not longer than 100 feet.

Perform a gradation in the field, via a mobile shaker or hand shaking, on the sampled (asphalt coated) RAP and verify that it conforms to the Maximum Aggregate Size requirements of Table 2. If the gradation is out of tolerance, adjust production to bring the gradation back into specification.

2. Moisture Content of the Mixture

Daily and after any work stoppages, due to precipitation, check the corrected moisture content of the mixture with a nuclear density gauge per the procedure in the appendix. Adjust the water being metered into the mixture as necessary to stay at or within 0.25% of the moisture content listed on the JMF. Control the mixture such that it does not exceed the optimum moisture content.

3. Conformance to Job Mix Formula

Provide printed or electronic tickets and a summary at the end of each day's CIR production to the Engineer. The ticket shall show the yield in tons of RAP processed, and the dosage rate of water, Portland Cement and Asphalt Cement or Asphalt Emulsion. Monitor the readouts throughout production. Stop CIR production when the dosage rate of Portland cement is greater than 0.1% or any other ingredient of the mix is greater than 0.25% from the stated dosage on the job mix formula. Make the necessary corrections to meet the Job Mix Formula.

Provide a daily report of all quality control tests and corrective actions (if any) to the Engineer at the end of the shift's production. Work shall not continue without the previous day's quality control documentation. If, in the Engineer's judgement, Quality Control processes are not followed, stop the work until the issue is resolved. If the work represented by the quality control documentation is unacceptable, rework or remove and replace the unaccepted work at no additional cost to the Department.

4. Half-Life (if using Foamed Asphalt Only)

Once per day verify the Half-Life of the foamed asphalt. If it does not meet the design requirements, stop CIR production. Make the necessary corrections to the process to meet the design requirements.

5. Density

Routinely perform density checks throughout the project with a nuclear density gauge, via either direct transmission or backscatter. If indicated results are less than 97% of the Target Maximum Density, perform additional compaction work to the section until the density increases to at least 97% of the Target Maximum Density. If the problem persists, stop CIR production, and make changes to the standard rolling pattern to correct the issue.

The Department will not take quality control density readings.

Method of Acceptance

The Department shall accept the mixture based on the In-place Density. The Engineer will perform the in-place density for acceptance testing. The in-place density shall be tested by direct transmission method with a nuclear density gauge per SOP 7-1. In-Place Density Testing shall be done on a lot basis. A standard lot shall be a maximum of 5000 feet by 1 lane width maximum. Subdivide the lot into 5 equal sized sublots. One nuclear density gauge test will be taken per sublot and the results of all 5 sublots averaged to represent the lot. Testing locations shall be determined by random number for the longitudinal direction. Testing location for the transverse location shall be: 1 foot from the left edge of the mat, left wheel path, center, right wheel path, and 1 foot from the right edge; in a random order with each spot being used once in the 5 sublots. Test results are final, no additional test will be considered prior to computing payment.

Table 4: In-place Density Pay Factors

Percentage of Target Maximum Density of the Lot	Deduction Factor
97.0-103%	0.00
96.0-96.9% or 103.1-104.0%	0.03
95.0-95.9% or 104.1-105.0%	0.05
<95.0% or >105.0%	0.10[1]

[1]At the Engineer's discretion the completed work may be left in place at the indicated pay factor or removed and replaced at no additional cost to the Department. If removed and replaced, the new construction will be tested for acceptance as stated above.

Method of Measurement

The Department will measure CIR Bituminous Pavement by the square yard for the depth specified.

The Department will measure Asphalt Cement, Engineered Asphalt Emulsion and Portland Cement separately from the CIR Bituminous Pavement. Measurement is to be based on the production records of actual material utilized in the CIR process. The entire quantity accepted of the Asphalt Cement or Asphalt Emulsion and Portland Cement must be accounted for by materials certifications by the ton in accordance with **109**.

The Department will not measure and pay for bituminous material, water, and sand used for fog sealing of the CIR surface.

Basis of Payment

The Department will pay for accepted quantities, complete in place, at the contract prices as follows:

Item No.	Description	Unit
308-01.10	Cold In-place Recycled Bituminous Pavement	Square Yard
308-01.12	Asphalt Cement (PG 64-22) Cold In Place Recycled	Ton
308-01.15	Engineered Asphalt Emulsion	Ton
309-10.01	Portland Cement	Ton

Such payment shall be full compensation for any additional materials, labor, equipment, and incidentals necessary for the proper performance of the work for Cold In-Place Recycled Bituminous Pavement at the depth specified.

Such payment shall be full compensation for any additional material, labor, equipment, and incidentals necessary for the Asphalt Cement, Engineered Asphalt Emulsion, and Portland Cement in the CIR Bituminous Pavement process.

Acceptance for In-Place Density

The Department will apply a deduction for CIR Bituminous Pavement, not as a penalty but as liquidated damages, for failure to meet in-place density requirements in Table 4. The Department will make deductions in monies due the Contractor based on in-place density requirements in Table 4 under the item for In-place Density Deduction.

In place Density Deduction = Area (SY) x Bid Price x Deduction Factor

APPENDIX

PROCEDURE FOR DETERMINING CORRECTED MOISTURE CONTENT WITH NUCLEAR DENSITY GAUGE

Background: The moisture measurement derived from a nuclear density gauge is based on the hydrogen content of the material. Due to the presence of hydrogen in asphalt cement, it is necessary to establish a correction factor of the CIR material during the test strip to correct the moisture content readings utilized for quality control and acceptance.

Procedure:

1. Record the moisture content with a nuclear density gauge on the test strip.

2. Sample a minimum of 1000 g of the CIR material behind the paver, place into a plastic bag, and seal the bag until moisture testing can take place. Determine the moisture content by AASHTO T329.

3. The MCF will be positive or negative calculated per:

   MCF = Laboratory Moisture Content – Nuclear density gauge Moisture Content

4. Adjust the moisture contents of the nuclear density gauges for all quality control and acceptance during the work by:

   Corrected Moisture Content = Nuclear density gauge Moisture Content + MCF.

   Note keep the sign associated with the MCF calculated in step 3 when inserting it into the equation in step 4.