The accepted quantity of Cold In-place Recycle Bituminous Mixture will be paid for at the Contract bid price per square meter [**square yard**] complete and in place.

The accepted quantity of Bituminous Material for Mixture of the type shown on the Plans will be paid for at the Contract bid price per metric ton [**ton**] complete and in place.

The accepted quantity of Bituminous Material for Fog Seal will be paid for at the Contract bid price per liter [**gallon**] complete and in place.

Payment for the cold in-place recycled bituminous mixture will be made on the basis of the following schedule:

Item No.	Item	Unit
2331.604	Cold In-place Recycle Bituminous Mixture	square meter [**square yard**]
2331.609	Bituminous Material for Mixture	metric ton [**ton**]
2355.502	Bituminous Material for Fog Seal	liter [**gallon**]

S-135 (2331) COLD IN-PLACE RECYCLE (CIR) BITUMINOUS MIXTURE FULL RECYCLING TRAIN MIX DESIGN

SP2005-130

This work shall consist of milling the existing bituminous surface, to the depth and width shown on the Plans. The reclaimed asphalt pavement (RAP) shall be crushed, screened, mixed with an asphalt emulsion, water (if required), and other additives (if required). This cold in-place recycled bituminous mixture shall then be placed and compacted in accordance with the applicable Mn/DOT Standard Specifications, the Plans, as directed by the Engineer, and the following:

S-135.1 MATERIALS

Asphalt Emulsion: The type of asphalt emulsion to be used shall be determined by the mixture design. A representative from the asphalt emulsion supplier shall be at the job site at the beginning of the Project to monitor the characteristics and performance of the asphalt emulsion. Throughout the job, the representative shall be available to check on the Project and make adjustments to the asphalt emulsion formulation as required.

Crushed/sized Bituminous Material: The crushed/sized bituminous material shall meet the following gradation requirements:

Sieve Size	Percent Passing
31.5 mm [**1-1/4 inch**]	100%

Note: A 100% passing a 25.0 mm [**1 inch**] sieve size may be used when a finer gradation is required.

The compacted product shall be placed at a thickness of a minimum of two (2) times the nominal size of crushed millings or 63.5 mm [**2.5 inches**], whichever is greater, and to a maximum of 127 mm [**5 inches**].

Mix Design: A preconstruction mix design shall be submitted by the Cold In-Place Recycling Contractor tested in accordance with Appendix 1, using the materials that will be recycled, which was obtained directly from the Project site. Based on cores taken before the Project, more than one mix design may be required. The job mix formula shall meet the criteria of Table 1 and be approved by the Project Engineer or agency. Refer to Appendix 1 - Mix Design Procedures for CIR.

Table 1		
Property	Criteria	Purpose
Compaction effort, Superpave Gyratory Compactor	1.25° angle, 600 kPa stress, 30 gyrations	Density Indicator
Density, ASTM D 2726 or equivalent	Report	Compaction Indicator
Gradation for Design Millings, ASTM C117	Report	
Marshall stability*, ASTM D 1559 Part 5, 40°C	1,250 lb min.	Stability Indicator
Retained stability based on cured stability **	70 % min.	Ability to withstand moisture damage
Indirect Tensile Test, AASHTO TP9-96, Modified in Appendix 2	See Note in Appendix 2	Cracking (Thermal)
Raveling Test, Method Attached, Ambient, Appendix 3	2% max.	Raveling Resistance
* Cured stability tested on compacted specimens after 60°C (140°F) curing to constant weight.		
**Vacuum saturation of 55 to 75 percent, water bath 25°C 23 hours, last hour at 40°C water bath		

Note: An emulsion content of 3% by weight of the milled bituminous material shall be used for bidding purposes prior to the completed design. The actual emulsion content will be adjusted based on the quantity necessary to meet the design requirements in Table 1.

Water: Shall be clear and free of deleterious materials, such as: acid, oil, alkali, organic material, salt, sugar, or other harmful materials.

Fog Seal Emulsion: If required, shall be CSS-1h, CSS-1 or approved equal conforming to Mn/DOT 3151.2E.

Other Additives – If necessary, additives may be used to meet the requirements in Table 1. In the case that an additive is used, the type and allowable usage percentage must be described in the submitted design recommendation.

Addition of crushed Reclaimed Asphalt Pavement (RAP) material - If available, RAP material may be added at the discretion of the Engineer if the RAP material meets the requirements in Table 2.

The crushed RAP shall be free from vegetation and all other deleterious materials, including silt and clay balls. It shall meet the requirements for Deleterious Materials given in Table 2. The crushed RAP shall not exceed the maximum size requirement in "Crushed/sized bituminous material", and when blended with the design millings shall produce a product which meets the specifications given in Table 1.

Table 2. Additional Crushed RAP		
Tests	Method	Limit
Deleterious Materials: Clay Lumps and Friable Particles in Aggregate, % max	ASTM C 142 or AASHTO T112	0.2 recommended
Maximum size, 100% Passing, Sieve Size	ASTM C 136 or AASHTO T 27	31.5 mm [**1-1/4 inch**]

Additional aggregate - Based on the results of the mix design or other requirements, the bidder shall determine if additional aggregate is required. Any additional aggregate shall meet the requirements in Table 3, and it shall be graded to produce a product that meets the specification given in Table 1.

Table 3. Additional Aggregate		
Tests	Method	Limit
Los Angeles abrasion value, % loss	AASHTO T 96	40 max for Surface mix 50 max for Base mix
Sand Equivalent,%	ASTM D-2419	60 minimum
Maximum size, 100% Passing, Sieve Size	ASTM C 136 or AASHTO T 27	31.5 mm [**1-1/4 inch**]
Water absorption %	AASHTO T 85	5 max.

S-135.2 CONSTRUCTION REQUIREMENTS

A. Equipment

A Full Recycling Train is required. This is a multi-unit train with milling, screening/crushing, and mixing units, used to process the material.

Milling: The Contractor shall furnish a self-propelled machine capable of milling the existing bituminous surface to the depth shown on the Plans, in a single pass, and to a minimum width of not less than 3.8 m [**12.5 feet**]. This machine shall have automatic depth and cross-slope controls and maintain a constant cutting depth. The automatic depth controls shall maintain the cutting depth to within plus or minus 6 mm [**1/4 inch**] of the depth shown on the Plans.

Crushing/sizing: The material shall be crushed and sized prior to mixing with emulsion. The unit shall have a "closed circuit" system capable of continuously returning oversized material to the crusher. All of the reclaimed asphalt pavement (100%) shall be processed to the maximum size requirements as specified.

Mixing: The pug mill type mixing unit shall be equipped with a continuous weighing system of the milled and sized material, coupled/interlocked to a computer controlled liquid metering device for the asphalt emulsion and other additives. The machine shall be capable of automatically metering liquids with a variation of not more than plus or minus 0.2 percent by weight of mix from the specified percentage. The asphalt emulsion pump should be of sufficient capacity to allow emulsion contents up to 3.5% by weight of pulverized bituminous material. The unit shall be equipped with facilities so that the Contractor can verify and calibrate these items by a method acceptable to the Engineer.

Pick-up machine: The pick-up machine shall be capable of removing the entire windrow of cold in-place recycled bituminous material down to the remaining underlying material.

Paver: The paver shall meet the requirements of Mn/DOT 2331.3C2a.

Alternatively to the equipment listed in Mixing, Pick-up machine, and Paver, a self-propelled paver with on-board pugmill and emulsion tank can be used. Millings must be added directly to the hopper. The paver shall be equipped with a belt scale for the continuous weighing of the pulverized and sized bituminous material and a coupled/interlocked computer controlled liquid metering device. The mixing unit shall be an on-board completely self-contained pugmill. The liquid metering device shall be capable of automatically adjusting the flow of asphalt emulsion to compensate for any variation in the weight of pulverized material coming into the mixer. The metering device shall deliver the amount of asphalt emulsion to within ± 0.2 percent of the required amount by weight of pulverized bituminous material (for example, if the design requires 3.0 percent, the metering device shall maintain between 2.8 percent to 3.2 percent). Also, automatic digital readings shall be displayed for both the flow rate and total amount of pulverized bituminous material and asphalt emulsion in appropriate units of weight and time.

Rollers: The rollers shall meet the requirements of Mn/DOT 2331.3H3a. A minimum of two rollers shall be required. When cold in-place recycling depths of 75 mm [**3 inches**] or more, one of the two rollers shall be a 28 to 33 metric ton [**25 to 30 ton**] pneumatic roller equipped with a watering device to prevent material

from adhering to the tires. The 28 to 33 metric ton [**25 to 30 ton**] pneumatic roller should be used for breakdown rolling. The Steel-Wheeled rollers shall meet the requirements of Mn/DOT 2331.3H3a(1).

Distributor: The distributor shall meet the requirements of Mn/DOT 2321.3C1.

Broom: A self-propelled power broom for removal of loose particles and other materials from the CIR surface. The broom shall have positive control on the downward pressure applied to the surface.

B. Construction Operations

Vegetation: Grass and other vegetation shall be removed from the edge of the existing pavement to prevent contamination of the pulverized bituminous material during the milling operation.

Milling: The existing pavement shall be milled to the required depth and width as indicated on the Plans. Recycling shall be in a manner that does not disturb the underlying material in the existing roadway. The milling operation shall be conducted so that the amount of fines occurring along the vertical faces of the cut will not prevent bonding of the cold recycled materials. The pulverized bituminous material shall be processed by screening, and crushing, to the required gradation. When a paving fabric is encountered during the CIR operation, the Contractor shall make the necessary adjustments in equipment or operations so that at least ninety percent (90%) of the shredded fabric in the recycled material is no more that 3200 mm^2 [**5 square inches**]. Additionally, no fabric piece shall have any dimension exceeding a length of 100 mm [**4 inches**]. These changes may include, but not be limited to, adjusting the milling rate and adding or removing screens in order to obtain a specification recycled material. The Contractor shall be required to waste material containing over-sized pieces of paving fabric as directed by the Engineer. When the Contractor is aware that paving fabric exists, such as indicated on the Plans, the Contractor will not receive additional payment. However, if the Contractor is not made aware of the paving fabric, than the Contractor shall receive additional payment for any necessary adjustments in equipment and operations.

Mixing: The recycled material shall be produced through a mixing unit capable of processing the pulverized material and asphalt emulsion and water to a homogeneous mixture. The asphalt emulsion and water shall be incorporated into the pulverized bituminous material at the initial rate determined by the mix design(s) and approved by the Engineer. The total water content may include that amount added at the milling head, and may also include addition at the mixing unit if available. Sampling and mix design may determine different levels of asphalt emulsion at various portions of the Project.

Paver: The material shall be spread using a self-propelled paver meeting the requirements in Section A. Heating of the paver screed will not be permitted. A pick-up machine may be used to transfer the windrowed material into the paver hopper if using a conventional paver. The pickup machine must be within 45 m [**150 feet**] of the mixing unit. The recycled material shall be spread in one continuous pass, without segregation and to the lines and grades established by the Engineer.

Compaction: Compacting of the recycled mix shall be completed using rollers meeting the requirements of Section A. Rolling patterns shall be established to achieve a maximum density determined by nuclear density testing. Rolling shall be continued until no displacement is occurring or until the pneumatic roller(s) is (are) walking out of the mixture. Double drum steel roller(s), either operating in a static or vibratory mode, shall do final rolling to eliminate pneumatic tire marks and to achieve density. Vibratory mode should only be used if it is shown to not damage the pavement. The selected rolling pattern shall be followed unless changes in the recycled mix or placement conditions occur and a new rolling pattern is established at that time. Rolling or roller patterns shall change when major displacement and/or cracking of the recycled material is occurring. Rolling shall start no more than 30 minutes behind the paver. Finish rolling shall be completed no more than one hour after milling is completed. When possible, rolling shall not be started or stopped on uncompacted material but with rolling patterns established so that they begin or end on previously compacted material or the existing pavement.

The nuclear testing device shall be furnished and operated by the Contractor. The furnishing of the nuclear testing device and operator shall be considered incidental to the furnishing and placing of the cold in-place recycled bituminous mixture and shall not be compensated for separately.

After the completion of compaction of the recycled material, no traffic, including that of the Contractor, shall be permitted on the completed recycled material for at least two (2) hours. After two hours rolling traffic may be permitted on the recycled material. This time may be adjusted by the Engineer to allow establishment of sufficient cure so traffic will not initiate raveling. After opening to traffic, the surface of the recycled pavement shall be maintained in a condition suitable for the safe movement of traffic. All loose particles that may develop on the pavement surface shall be removed by power brooming.

Any damage to the completed Cold In Place Recycled bituminous material shall be repaired by the Contractor prior to the placement of the hot mix asphalt concrete surface course, or other applicable surface treatment, and as directed by the Engineer.

The completed cold recycled material surface shall not vary more than 6 mm [**¼ inch**] from the lower edge of a 3 meter [**10 foot**] straight edge placed on the surface parallel and transversely to the centerline.

Before placing the hot mix asphalt concrete surface course, or other applicable surface treatment, the Cold In Place Recycled bituminous material shall be allowed to cure until the moisture of the material is reduced to 2.0 percent or less.

The Contractor shall reshape and compact the in-place aggregate shoulder prior to placing the first overlay course, in accordance with Mn/DOT 2105.3G. Compaction shall be achieved by the Quality Compaction Method in accordance with Mn/DOT 2211.3C2.

C. Quality Control/Quality Assurance

The Contractor or supplier shall be responsible for the quality control.

Mn/DOT shall be responsible for quality assurance.

Quality Control

Pulverized Bituminous Material Sizing - Two (2) gradations shall be performed each day on the moist millings (which must be air dried) using the following sieves: 31.5 mm [**1.25 inch**], 25.0 mm [**1.0 inch**], 19.0 mm [**¾ inch**], 12.5 mm [**½ inch**], 9.5 mm [**3/8 inch**], 4.75 mm [**No. 4**], 2.36 mm [**No. 8**], 1.18 mm [**No. 16**], and 600 μm [**No. 30**]. The resulting gradation shall be compared to the mix design gradations to determine any necessary changes to emulsion content (see Appendix 1). Sampling procedures shall generally be in accordance with ASTM D979 or AASHTO T168.

In addition to the two gradations per day, a sample shall be obtained each 0.8 km [**½ mile**] before emulsion addition and screened using a 31.5 mm [**1.25 inch**] sieve (or smaller sieve if required) to determine if the material is meeting the maximum particle size requirement.

Asphalt Emulsion Content – Emulsion content shall be checked and recorded for each segment in which the percentage is changed. Emulsion content changes shall be made based upon mix design recommendations, which are based upon different mix designs for road segments of varying construction. Asphalt emulsion content can be checked from the belt scale totalizer and asphalt pump totalizer.

Water Content – Water content at the milling head shall be checked and recorded for each segment in which the percentage is changed. This information shall be gathered from the water metering device, which can be checked from the belt scale totalizer to verify daily quantities used. Water content changes shall be made based on mixture consistency, coating, and dispersion of the recycled materials.

Mixture Testing – On the first full day of recycling, samples will be gathered for testing mixture results from the design given as described in Table 1. The samples should be taken following ASTM D3665 and D979. If samples of the emulsion/recycled asphalt pavement mixture are taken, the specimens must be compacted

within 15 minutes of sampling and tested as required in Table 1. The samples must be screened through a 25.0 mm [**1 inch**] screen if 100 mm [**4 inch**] specimens are to be compacted. If samples of the recycled asphalt pavement prior to emulsion addition are taken, they must be put into a sealed plastic container to not allow any loss of moisture. Samples must be mixed with the field emulsion within 24 hours and tested as required in Table 1. The results shall be provided to the Project Engineer. If the results fail to meet the design criteria, daily sampling will continue until the mix meets the design specifications.

Depth of Pulverization (Milling) - The nominal depth shall be checked on both outside vertical faces of the cut each 0.2 km [**1/8 mile**]. The station and depth shall be recorded.

Recycled Material Compacted Density - A wet density shall be determined using a nuclear moisture-density gauge generally following the procedures for ASTM D2950, backscatter measurement. A rolling pattern will be established such that a maximum density is achieved with the rollers specified, based on relative nuclear density readings. However, care should be taken not to over-roll the mat based on visual observations of check cracking or shoving. A new rolling pattern shall be established if the material being recycled changes.

Cold Recycled Material Cross Slope / Smoothness - The cold recycled material cross slope shall be checked regularly during spreading using a level. The smoothness shall not vary more than 6 mm [**¼ inch**] from the lower edge of a 3 meter [**10 foot**] straight edge placed on the surface parallel and transversely to the centerline after rolling is completed.

Quality Assurance

Pulverized Bituminous Material Sizing - One gradation shall be performed each day on the moist millings (which must be air dried) using the following sieves: 31.5 mm [**1.25 inch**], 25.0 mm [**1.0 inch**], 19.0 mm [**¾ inch**], 12.5 mm [**½ inch**], 9.5 mm [**3/8 inch**], 4.75 mm [**No. 4**], 2.36 mm [**No. 8**], 1.18 mm [**No. 16**], and 600 μm [**No. 30**]. The resulting gradation shall be compared to the mix design gradations to determine any necessary changes to emulsion content. Sampling procedures shall generally be in accordance with ASTM D979 or AASHTO T168.

Asphalt Emulsion – The asphalt emulsion shall be received on the job site at a temperature no greater than 49ºC [**120ºF**]. Sample the first shipment, then submit one sample per 189 271 liters [**50,000 gallons**] (approximately 180 metric tons [**200 tons**]). Samples shall be obtained from the shipping trailers prior to unloading into the Contractor's storage units. The testing shall meet the following requirements:

Test		Minimum	Maximum
Residue from distillation, %	ASTM D244[1]	64.0	66.0
Oil distillate by distillation, %	ASTM D244[1]		0.5
Sieve Test, %	ASTM D244[1]		0.1
Penetration (TBD[2]), 25°C, dmm	ASTM D5	-25%	+25%

[1] Modified ASTM D244 procedure – distillation temperature of 177°C [**350°F**] with a 20 minute hold. The ASTM D244 vacuum distillation procedure may be substituted once the maximum oil distillate is satisfied.

[2] TBD – to be determined by the CIR design prior to emulsion manufacture for Project. Penetration range will be determined on the design requirements for the Project and will be submitted to the Agency for approval prior to Project start.

D. Restrictions

Cold In-Place recycling operations shall be completed when the atmospheric temperature measured in the shade and away from artificial heat is 10°C [**50^0 F**] and rising. Also, the weather shall not be foggy or rainy. The weather forecast shall not call for freezing temperature within 48 hours after placement of any portion of the Project.

The hot mix bituminous overlay shall be placed on the CIR bituminous mixture within 30 days.

E. Thickness and Surface Requirements

Upon completion of placement and compaction, the finished surface shall show no variations greater than 6 mm [**1/4 inch**] from the edge of a 3 meter [**10 foot**] straightedge resting on any two points and laid parallel to and/or at right angles to the centerline. *All deviations from this tolerance shall be corrected at no additional cost to the Department*.

During the curing period, the surface of the cold in-place recycled bituminous mixture may be sealed, if necessary, to prevent raveling, as determined by the Engineer. A minimum amount of emulsion should be employed since the intent is to not seal the surface such that curing is precluded. Fog sealing shall be accomplished with CSS-1h or CSS-1 emulsion applied at an approximate rate of 0.23 to 0.45 liters per square meter [**0.05 to 0.10 gallons per square yard**] of dilute asphalt emulsion (50/50 mix of emulsion and water by volume). The fog seal, if required, shall be applied in accordance with Mn/DOT 2355.3. The Project Engineer shall be contacted prior to fog sealing. If, in the opinion of the Engineer, the recycled base surface is not subject to raveling prior to the application of the sealant, the Engineer has the right, as provided in Mn/DOT 1402, to delete the item, Fog Seal, from the Contract and not be subject to a value engineering proposal by the Contractor.

The Contractor shall be responsible for maintaining the finished surface of the cold in-place recycled material in a smooth, compacted condition free of ruts, distortion, potholes, loose aggregate, and to the grade and cross-section tolerances previously stated, until the first bituminous course required by the Contract is completed. All loose aggregate that develops on the surface of the recycled pavement shall be removed by power brooming. A rotary power broom capable of cleaning the road surface and removing loose particles shall be provided within 24 hours notice, if directed by the Engineer.

The Contractor shall repair any of the previously mentioned deficiencies to the completed cold in-place recycled bituminous mixture to the satisfaction of the Engineer. Said repair(s) shall be made at no additional cost to the Department. Failure to perform corrections shall be considered unacceptable work as per Mn/DOT 1512.

S-135.3 MEASUREMENT

Cold In-place Recycle Bituminous Mixture shall be measured by the Square meter [**Square yard**].

The Bituminous Material for Mixture of the type shown on the Plans or as specified in the Special Provisions will be measured by the Metric ton [**ton**]. Water added to aid mixing is incidental.

Bituminous Material for Fog Seal applied on the road will be measured by volume at 15 degrees Celsius [**60 degrees Fahrenheit**] in Liter [**Gallon**].

S-135.4 PAYMENT

Payment for the accepted quantities of cold in-place recycle bituminous mixture at the Contract bid prices per unit of material shall be compensation in full for all costs of constructing the cold in-place recycled bituminous mixture as specified, including any additives as permitted or required.

The accepted quantity of Cold In-place Recycle Bituminous Mixture will be paid for at the Contract bid price per Square meter [**Square yard**] complete and in place.

The accepted quantity of Bituminous Material for Mixture of the type shown on the Plans will be paid for at the Contract bid price per Metric ton [**ton**] complete and in place.

The accepted quantity of Bituminous Material for Fog Seal will be paid for at the Contract bid price per liter [**gallon**] complete and in place.

Payment for the cold in-place recycled bituminous mixture will be made on the basis of the following schedule:

Item No.	Item	Unit
2331.604	Cold In-place Recycle Bituminous Mixture	Square meter [**Square yard**]
2331.609	Bituminous Material for Mixture	Metric ton [**Ton**]
2355.502	Bituminous Material for Fog Seal	Liter [**Gallon**]

S-135.5 APPENDIX 1

Mix Design Procedures for CIR (Cold In-place Recycling) Material

Sampling and Processing: Obtain 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. Cores shall be cut in the laboratory to the depth specified for the CIR Project. Cores shall be crushed in the laboratory. Perform a mix design using the medium gradation and a minimum of one of the fine or coarse gradations using the following recycled asphalt pavement millings criteria.

	Fine	Medium	Coarse
31.5 mm [**1.25 inch**]	100	100	100
25.0 mm [**1.0 inch**]	100	100	85-100
19.0 mm [**¾ inch**]	95-100	85-96	75-92
4.75 mm [**No. 4**]	55-75	40-55	30-45
600 μm [**No. 30**]	15-35	4-14	1-7
75 μm [**No. 200**]	1-7	0.6-3	0.1-3

The mix design shall be performed on these crushed millings. Gradation of the millings after crushing shall be determined by ASTM C117 and C136 (dried at no greater than 40°C [**104°F**]).

Samples shall be prepared with a sample splitter. An alternative method is to dry, screen and recombine millings in the laboratory to target gradation. Suggested screens are 12.5 mm [**1/2 inch**], 9.5 mm [**3/8 inch**], 4.75 mm [**No. 4**], 2.36 mm [**No. 8**], 600 μm [**No. 30**], and pan. Scalp oversize with a 25.0 mm [**1 inch**] screen when using 100 mm [**3.94 inch**] diameter compaction molds.

Mixing: Specimen size: the amount that will produce a 61.0 mm to 66.0 mm [**2.4 to 2.6 inch**] tall specimen; use ASTM D2041 to determine the size for Rice specific gravity.

Number of specimens: Four (4) per emulsion content for a total of six (6) for long-term stability and six (6) for moisture testing for three (3) emulsion contents. Two (2) specimens are required for Rice specific gravity; test at the highest emulsion content in the design and back calculate for the lower emulsion contents.

Recommended emulsion contents: 1.5%, 2.0%, 2.5%, 3.0%, 3.5%, 4.0%. Choose three emulsion contents that bracket the estimated recommended emulsion content.

Add moisture that is expected to be added at the milling head, typically 1.5 to 2.5 percent.

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

Mixing of test specimens shall be performed with a mechanical bucket mixer. Mix the CIR RAP millings thoroughly with water first, then mix with emulsion. Mixing shall occur at ambient temperature. One specimen shall be mixed at a time. Mixing time with emulsion should not exceed 60 seconds.

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

Specimens shall be compacted with a Superpave gyratory compactor (SGC) in a 100 mm mold at 1.25° angle, 600 kPa ram pressure, and 30 gyrations. The mold shall not be heated.

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

Place specimens in 60°C [**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.

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.

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.

Measurements: Determine bulk specific gravity (density) of each compacted (cured and cooled) specimen according to ASTM D2726 or equivalent; however, the mass of the specimen in water (measurement C) can be recorded after one minute submersion.

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

Determine Rice (maximum theoretical) specific gravity, ASTM D2041, except as noted in Item 4 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.

Determine air voids at each emulsion content.

Determine corrected Marshall stability by ASTM D1559 at 40°C [**104°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.

Moisture Susceptibility: Perform same conditioning and volumetric measurements on moisture-conditioned specimens as on other specimens. Vacuum saturate to 55 to 75 percent, soak in a 25°C [**77°F**] water bath for 23 hours, followed by a one hour soak at 40°C [**104°F**]. Determine corrected Marshall stability. The average moisture conditioned specimen strength divided by the average dry specimen strength is referred to as retained stability.

Thermal Cracking – see Appendix 2

Raveling – see Appendix 3

Emulsion Content Selection: The properties of the specimens at design emulsion content shall meet the properties in Table 1.

Report: The report shall contain the following minimum information: Gradation of RAP; amount and gradation of virgin aggregate or additional RAP, if any; recommended water content range as a percentage of dry RAP; optimum emulsion content as a percentage of dry RAP and corresponding density, air void level, and absorbed water; Marshall stability and retained stability at recommended moisture and emulsion contents, Raveling %, and Thermal Cracking initiation temperature. Include the emulsion designation, company name, plant location, and residue content.

S-135.6 APPENDIX 2

Procedures for performing AASHTO TP9-96 for CIR Design Specimens

NOTE: Procedure for critical cold temperature selection

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 CIR layer in the pavement structure. Use 98 percent reliability.

Perform the indirect tensile testing (IDT) according to AASHTO TP9-96 with the following exceptions:

1. Specimens using the medium gradation shall be 150 mm [**6 inches**] in diameter and at least 115 mm [**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 suggested for this. Test specimens shall be cured at 60ºC [**140°F**] 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 50 mm [**2 inches**] in height. Perform bulk specific gravity after cutting.

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

3. Select two temperatures at 10ºC [**50°F**] intervals that bracket the required specification. For example, if the required specification temperature is –25ºC [**-13°F**], then select testing temperatures of –20ºC [**-4°F**] and –30ºC [**-22°F**]. A temperature of –10ºC [**14°F**] or –40ºC [**-40°F**] should then be selected to complete the third required temperature.

4. 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.

5. The environmental chamber must be capable of temperatures down to –40ºC [**-40°F**].

6. 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).

S-135.7 APPENDIX 3

Procedures for Performing the Raveling Test on Recycled Asphalt Specimens

The apparatus used for the raveling test is a modified A-120 Hobart mixer and abrasion head (including hose) used in the Wet Track Abrasion of Slurry Surfaces Test (ISSA TB-100). The rotation speed for the raveling test is not modified from ISSA TB-100. The ring weight is removed from the abrasion head for the raveling test below. The weight of the abrasion head and hose in contact with the specimen should be 600 +/- 15g [**21.2 +/- 0.5 ounces**]. The prepared sample must be able to be secured under the abrasion head, and centered for accurate result, allowing for free movement vertically of the abrasion head. The device used for securing and centering the sample must allow a minimum of 10 mm [**0.4 inch**] of the sample to be available for abrasion. The Hobart mixer will need to be modified to allow the sample to fit properly for abrasion. The modification may be accomplished by adjusting the abrasion head height, or the height of the secured sample. A Raveling Test Adapter can be purchased through Precision Machine and Welding, Salina, KS, (785) 823-8760. Please reference the Hobart Model number A-120 when ordering. The C-100 and N-50 Models are not acceptable for this test procedure due to differences in size and speed of rotation.

1. Split out two recycled asphalt samples from the medium gradation, or field sample, to a quantity of 2700 g [**6 pounds**] in mass [**weight**]. The 2700 g [**6 pounds**] is an approximate weight to give 70 +/- 5 mm [**2.8 +/- 0.2 inches**] of height after compaction.

2. The recycled asphalt sample should be placed in a container of adequate size for mixing.

3. Field or design moisture contents should be added to each of the recycled asphalt samples and mixed for 60 seconds.

4. The design emulsion content shall be added to each of the recycled asphalt samples and mixed for 60 seconds.

5. The samples shall be placed immediately into a 150 mm [**6 inch**] gyratory compaction mold and compacted to 20 gyrations. If the sample height is not 70 +/- 5 mm [**2.8 +/- 0.2 inches**], the recycled asphalt weight should be adjusted.

6. After compaction, the samples shall be removed from the compaction mold and placed on a flat pan to cure at ambient lab temperature (18-24ºC [**65-75ºF**]) for 4 hours +/- 5 minutes.

7. The specimens shall be weighed after the curing, just prior to testing.

8. The specimens shall be placed on the raveling test apparatus. Care should be taken that the specimen is centered and well supported. The area of the hose in contact with the specimen should not have been previously used. It is allowable to rotate the hose to an unworn section for testing. The abrasion head (with hose) shall be free to move vertically downward a minimum of 5 mm [**0.2 inches**] if abrasion allows.

9. The samples shall be abraded for 15 minutes and immediately weighed.

10. The % Raveling loss shall be determined as follows: ((Wt. Prior to test – Wt. After abrasion)/Wt. Prior to test) * 100.

11. The average of the two specimens shall be reported as the % Raveling loss. There should not be a difference of 0.5% Raveling Loss between the two test specimens for proper precision. A difference of >0.5 percent will require the test to be repeated. If both of the samples have a Raveling Loss of >10% the numbers shall be averaged and the precision rule will be waived.

Note: If field mix samples are taken, Steps 2, 3, and 4 shall be omitted.

S-135.8 For questions about the CIR process contact Jerry Geib at (651) 779-5937.

S-136 (2331) BITUMINOUS PAVEMENT CRACK TREATMENT

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This work consists of sealing random transverse and longitudinal cracks in the bituminous pavement in accordance with the Plans and the applicable Mn/DOT Standard Specifications.

Rout and Seal: Transverse cracks less than or equal to 19 mm [**0.75 inches**] wide shall be routed, cleaned and sealed.

Clean and Seal: Transverse cracks greater than 19 mm [**0.75 inches**] wide and longitudinal cracks shall be cleaned and sealed (without routing) following the same procedures used for routed cracks.