State of Illinois
Department of Transportation
Bureau of Local Roads and Streets

SPECIAL PROVISION FOR COLD IN-PLACE RECYCLING (CIR) AND FULL DEPTH RECLAMATION (FDR) WITH EMULSIFIED ASPHALT MIX DESIGN PROCEDURES

Effective: April 1, 2012
Revised: June 1, 2012

All references to Divisions, Sections, and Articles in this Special Provision shall be construed to mean specific Divisions, Sections, and Articles in the Standard Specifications for Road and Bridge Construction adopted by the Department of Transportation.

Laboratory Temperature and Humidity Control
Each laboratory performing mix designs shall have heating, ventilation, and air conditioning (HVAC) equipment that maintains a room temperature of 68 to 86 ºF (20 to 30 ºC) and relative humidity of less than 60 percent.

Sampling and Processing
A minimum sample size of 350 lb (160 kg) is needed for each mix design. Bulk samples of the recycled layer thickness shall be obtained from either test pits or cores. Each layer shall be examined to confirm thickness and material.

The bituminous layers shall be crushed. A washed gradation of the crushed bituminous layer(s) shall be performed according to AASHTO T 27 and reported and meet the following requirement(s).

Sieve Size		Percent Passing	
		FDR Crushed Gradations	
		Ideal	Less Suitable
2 in.	50 mm	100	
1 1/2 in.	37.5 mm	87 – 100	
1 in.	25 mm	77 – 100	100
3/4 in.	19 mm	66 – 99	99 – 100
1/2 in.	12.5 mm	67 – 87	87 – 100
3/8 in.	9.5 mm	49 – 74	74 – 100
No. 4	4.75 mm	35 – 56	56 – 95
No. 8	2.36 mm	25 – 42	42 – 78
No. 16	1.18 mm	18 – 33	33 – 65
No. 50	300 µm	10 – 24	24 – 43
No. 200	75 µm	4 – 10	10 – 20

Sieve Size		Percent Passing		
		FDR Crushed Gradations		
		Fine	Medium	Coarse
1 1/2 in.	37.5 mm	100	100	100
1 in.	25 mm	100	100	85-100
3/4 in.	19 mm	95-100	85-96	75-92
No. 4	4.75 mm	55-75	40-55	30-45
No. 30	600 µm	15-35	4-14	1-7
No. 200	75 µm	1-7	0.6-3	0.1-3

Washed gradation (AASHTO T 27) and sand equivalent (ASTM D 2419, Method B) shall be performed and reported for any granular layer. The washed gradation (AASHTO T 27) of combined layers shall be performed and reported. If combined layers include an aggregate layer, the sand equivalent (ASTM D 2419, Method B) shall be performed and reported.

All washed gradations shall be dried at no greater than 104 °F (40 °C).

Mixing and Compaction

1. FDR with Emulsified Asphalt. Perform Modified Proctor compaction according to ASTM D 1557, Method C to determine optimum moisture content (OMC) at peak dry density. OMC shall be defined by a best-fit curve from a minimum of four points. Material containing 20 percent or more passing the No. 200 sieve shall be mixed with target moisture, sealed, and set aside a minimum of 12 hours. All other material shall be set aside a minimum of 3 hours. If a material contains less than 4 percent passing the No. 200 sieve, then this testing is not required.

   Select the water content of specimens, not including water in the emulsified asphalt, based on sand equivalent value (SE) from the combined materials.

   - 60 to 75 percent of OMC if SE ≤ 30
   - 45 to 65 percent of OMC if SE > 30

   If a material contains less than 4 percent passing the No. 200 sieve or if no peak develops with the OMC curve, then fix the moisture content between 2 and 3 percent.

   Specimens shall be mixed with the required amount of water before the addition of emulsified asphalt. Specimens shall be mixed with the appropriate amount of water and allowed to sit sealed according to the same guidelines as used for Modified Proctor specimens.

   Samples shall have a weight before addition of water and emulsfied asphalt to produce 2.75 to 3.25 in. (70 mm to 80 mm) tall compacted specimens.

   Choose four emulsified asphalt contents that will bracket the design emulsified asphalt content. Recommended emulsified asphalt content percentages: 1.5, 2.0, 2.5, 3.0, 3.5, or 4.0. The following specimens shall be created:

   - A minimum of two specimens at each of four emulsified asphalt contents shall be produced for short-term strength testing.
   - Four specimens at each of four emulsified asphalt contents shall be produced for the strength and retained strength tests.

- Two specimens shall be produced for maximum specific gravity.

A mechanical mixer shall be used that has a bowl with a diameter of 10 to 12 in. (250 to 300 mm). It shall rotate on its axis at 50 to 75 revolutions per minute. A mixing paddle which makes contact with the bottom and side of the bowl shall rotate on its axis at twice the bowl rotation rate and in the opposite rotation direction as the bowl.

Aggregate material and emulsified asphalt shall be mixed at a temperature of 68 to 79 °F (20 to 26 °C). Water shall be mixed for 60 seconds. Emulsified asphalt shall be mixed for 60 seconds. If other materials are added, such as lime or cement, then they shall be introduced in a similar manner as they will be on the project. For example, if lime is incorporated a day or more before emulsified asphalt addition, then it shall be added to the wet aggregate a day or more before mixing with emulsified asphalt. If lime is incorporated as a slurry, then it shall be incorporated as a slurry in the laboratory.

Loose specimens shall be cured individually in plastic containers of 4 to 7 in. (100 to 175 mm) height and 6 in. (150 mm) diameter. Specimens shall be cured at 104 °F (40 °C) for 30 ± 3 minutes. No further mixing or aeration shall occur during this time.

Specimens shall be compacted in a Superpave gyratory compactor (SGC) at a vertical pressure of 87 psi (600 kPa), an angle of 1.25°, and a mold of 6 in. (150 mm) diameter for 30 gyrations. After the last gyration, 87 psi (600 kPa) ram pressure shall be applied for 10 seconds. The mold shall not be heated.

2. CIR with Emulsified Asphalt. The specimen size shall be the amount that will produce a 2.4 to 2.6 in. (60 to 65 mm) tall specimen.

Choose three emulsified asphalt contents that bracket the estimated recommended emulsified asphalt content. Recommended emulsified asphalt content percentages: 1.5, 2.0, 2.5, 3.0, 3.5, 4.0. The following specimens shall be created:

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

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 emulsified asphalt. Mixing shall occur at ambient temperature. One specimen shall be mixed at a time. Mixing time with emulsified asphalt should not exceed 60 seconds.

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 4 in. (100 mm) mold at 1.25° angle, 87 psi (600 kPa) ram pressure, and 30 gyrations. The mold shall not be heated.

Curing after Compaction

1. FDR with Emulsified Asphalt. Specimens (except STS specimens) shall be cured for 72 hours at 104 °F (40 °C). The bottom of the specimens shall rest on racks with slots or holes for air circulation. After curing, specimens for moisture conditioning shall be cooled at ambient temperature a maximum of 24 hours; specimens for dry strength shall cool at ambient temperature or 77 °F (25 °C) and be tested at the same time as the moisture-conditioned specimens.

   Specimens for Rice (maximum theoretical) specific gravity shall be cured at the same conditions as the compacted specimens, except they can be tested after cooling a maximum of 24 hours.

2. CIR with Emulsified Asphalt. Extrude specimens from molds immediately after compaction. Carefully remove paper disks.

   Place specimens in 140 °F (60 °C) 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 (maximum theoretical) specific gravity should be dried to constant weight (less than 0.05 percent weight loss in 2 hours). Care should be taken not to over-dry the specimens.

   Cure compacted specimens to constant weight (less than 0.05 percent weight loss in 2 hours), but no more than 48 hours and no less than 16 hours. After curing, cool specimens at ambient temperature a minimum of 12 hours and a maximum of 24 hours.

Short-Term Strength (STS) Test (FDR with Emulsified Asphalt Only)

A modified Hveem cohesiometer apparatus shall be used to test early strength (1 hour). This apparatus and procedure generally conforms to ASTM D 1560, Section 13 with the following exceptions:

- It shall have the capability of testing 6 in. (150 mm) diameter specimens.
- It shall have a shot flow rate of 5.95 ± 0.11 lb/min (2700 ± 50 g/min).
- Specimens shall be cured before compaction according to Section 5, and cure each specimen at each emulsified asphalt content for 60 ± 5 min at 77 °F (25 °C) and 10 to 70 percent humidity after compaction and before testing.

The following calibrations shall be made.

- The counter balance should be positioned exactly so that the hinged plate just barely remains horizontal when the top brackets and empty bucket are in place. This ensures that there is no force on the sample until shot begins to flow into the bucket.
- The gap between the bars of the switch that turns off the flow of shot should have a gap of 0.75 in. (18 mm) when there is 3000 g of shot in the bucket. During this adjustment the locking bolt that prevents the plate from moving is in place.

Cohesion shall be tested as follows.

1. Tare the balance with the empty bucket weight.
2. Center the specimen on the unit.
3. Place plates on top of sample and press down while adjusting the outer lower nuts up until they just contact the bottom of the plate.

4. Use a torque wrench or torque-meter to tighten the nuts on the specimen to a maximum of 1.6 foot pound 2.6 (N m).
5. Gently support the bar so the unit does not move when the pin is pulled releasing the hinged plate.
6. Pull pin and push open valve to start the flow of shot.
7. After the unit shuts off the flow of shot, immediately put the locking pin in place and then record the weight of shot.
8. Loosen top nuts to remove plates and rotate specimen 90°.
9. Repeat procedure on the other axis of the specimen.
10. Calculate short-term strength as follows:

$$STS = \frac{SW}{15(0.031h + 0.0027h^2}$$

Where:
SW = *Shot Weight in grams*
h = *height in cm*

11. A total of two results will be obtained for each specimen at each emulsified asphalt content, and a total of four results will be obtained at each emulsified asphalt content.

Volumetric Measurements

Determine bulk specific gravity (ASTM D 6752) of the specimens. Keep specimens in bags until testing or vacuum saturation is performed. ASTM D 2726 may be used to determine bulk specific gravity if specimens' absorption is less than or equal to 2 percent of water by volume.

Determine Rice (maximum theoretical) specific gravity (ASTM D 2041) except as noted in the Mixing, Compaction, and Curing after Compaction sections.

Determine air voids at all emulsified asphalt contents used in the design.

Mechanical Measurements

1. FDR with Emulsified Asphalt. Perform ITS testing according to ASTM D 4867. Specimens shall be conditioned at 77 °F (25 °C) for two hours before testing. Vacuum saturate half the specimens at each emulsified asphalt content to a minimum 55 percent of the voids filled with water. Soak for 24 hours at 77 °F (25 °C) before testing.
2. CIR with Emulsified Asphalt. Determine corrected Marshall Stability (ASTM D 1559) at 104 °F (40 °C) 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.

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

Raveling Test (CIR with Emulsified Asphalt Only)

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 g ± 15 g. The prepared sample must be able to be secured under the abrasion head, and centered for an 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 0.4 in. (10 mm) 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. The Hobart 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 in mass. The 2700 g is an approximate weight to give 2.8 ± 0.2 in. (70 ± 5 mm) 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 emulsified asphalt 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 6 in. (150 mm) gyratory compaction mold and compacted to 20 gyrations. If the sample height is not 2.8 ± 0.2 in. (70 ± 5 mm), 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 the specified temperature and humidity (if required) for 240 ± 5 minutes. The temperature shall be maintained at 50 ± 3.5 ºF (10 ± 2 ºC).
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 0.2 in. (5 mm) if abrasion allows.
9. The samples shall be abraded for 15 minutes and immediately weighed.
10. The Percent Raveling Loss shall be determined as follows:

    $$PRL = 100 \times \frac{W_P - W_A}{W_p}$$

    Where: PRL = Percent Raveling Loss
    W_P = Weight of Sample Prior to Testing
    W_A = Weight of Sample After Testing

11. The average of the two specimens shall be reported as the Percent Raveling Loss. If there is a difference of > 0.5 percent raveling loss between the two test specimens, the Raveling Test shall be repeated. If both of the test specimens have a Percent Raveling Loss of > 10 percent, the two test results shall be averaged and the maximum 0.5 percent difference between test specimens shall not be required.

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

Emulsified Asphalt Content Selection
The emulsified asphalt content selected shall result in the mixture meeting the mix design requirements of the FDR or CIR with emulsified asphalt special provision.

Report
All mix design test results shall be reported to the Department. All additional additives and bituminous material shall be reported to the Department.