INDIANA DEPARTMENT OF TRANSPORTATION
OFFICE OF MATERIALS MANAGEMENT

MIX DESIGN PROCEDURE FOR COLD IN-PLACE (CIR) WITH ASPHALT EMULSION ITM 592-16P

1.0 SCOPE

1.1 This method covers the procedure for mix design of Cold In-Place Recycled pavements.

1.2 This ITM may involve hazardous materials, operations, and equipment and may not address all of the safety problems associated with the use of the test method. The user of the ITM is responsible for establishing appropriate safety and health practices and determining the applicability of regulatory limitations prior to use.

2.0 SIGNIFICANCE AND USE

2.1 This ITM is used to determine the appropriate mix design for an individual asphalt roadway by ensuring the sampled material with corresponding mix design meets specification requirements.

2.2 This ITM is used to perform mix design procedure for Cold In-Place Recycling with Asphalt Emulsion.

3.0 REFERENCES.

3.1 AASHTO Standards

T 11 Materials Finer Than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing

T 27 Sieve Analysis of Fine and Coarse Aggregates

T 166 Bulk Specific Gravity (G_{mb}) of Compacted Hot Mix Asphalt (HMA) Using Saturated Surface-Dry Specimens

T 209 Theoretical Maximum Specific Gravity (G_{mm}) and Density of HMA

T 245 Resistance to Plastic Flow of Bituminous Mixtures Using Marshall Apparatus

T 269 Percent Air Voids in Compacted Dense and Open Asphalt Mixtures

3.2 ASTM Standards

D7196 Standard Test Method for Raveling Test of Cold Mixed Emulsified Asphalt Samples

4.0 TERMINOLOGY. Definitions for terms and abbreviations shall be in accordance with the Department's Standard Specifications, Section 101.

4.1 CIR- Cold In-place Recycling

4.2 RAP- Reclaimed Asphalt Pavement

4.3 Constant mass- shall be defined as the mass at which further drying does not alter the mass by more than 0.05 percent in 2 hours.

5.0 APPARATUS.

5.1 Laboratory, capable of maintaining room temperature 77±9°F (25±5°C)

5.2 Mechanical shaker with the appropriate screens to size material based on the gradations provided.

5.3 Superpave Gyratory Compactor.

5.4 Mechanical Bucket Mixer with a bowl measuring 10-12 inches in diameter shall be used. The bowl should be capable of rotating on its axis at 50 to 75 revolutions per minute. The mixer shall use a paddle which makes contact with the bottom and sides of the bowl and shall rotate on its axis at twice the bowl rotation rate, in the opposite direction of the bowl rotation.

5.5 Laboratory Crushing Machine, capable of crushing sampled material to pass the 1.5 inch sieve. If required by pavement sample type. Field millings do not require further crushing.

5.6 Conditioning Chamber, capable of maintaining a temperature of 50± 2˚F (10±1˚ C), at specified humidity, if required.

5.7 Oven, of appropriate size, capable of maintaining temperatures of 104±4°F (40±2° C) and 140± 2˚F (60± 1˚C).

5.8 Scale, capable of showing a reading to the nearest 0.1 gram.

5.9 Miscellaneous lab equipment; scoops, pans, mixing bowls, containers

5.10 Vacuum system, capable of subjecting contents to partial vacuum of 25.0 to 30.0 mm of Hg.

6.0 SAMPLING.

6.1 A mix design shall be performed with the materials to be encountered during construction, including in-place pavements, surface treatments, additional aggregate, asphalt emulsion and other additives. If construction materials change significantly between the time of sampling and construction, additional mix designs shall be performed to establish a representative mix for the project.

6.2 Samples of the existing pavement are collected as cores, test pits or milled RAP. Samples of the entire depth of pavement shall be collected; cutting cores to the appropriate depth to represent field treatment shall be completed in the laboratory.

6.3 Composition of in-place pavement should be examined. Location and placement of collected pavement cores shall accurately reflect minor variations in the pavement and form a representative sample of the entire project. Each mix design requires a minimum sample size of 350 lbs.

6.4 Samples from significantly different pavement sections shall be grouped separately, with separate mix designs performed for each section. Examples of these variations include: large patches, and significantly different asphalt mixes.

7.0 PREPARATION OF TEST SPECIMENS.

7.1 Core Sample Preparation Procedure

7.1.1 Pavement cores shall be cut to a depth that accurately represents the CIR treatment to take place, also accounting for pre-milling that may take place in the field.

7.1.2 Sampled RAP shall be crushed using a laboratory crusher or other methods. All material shall be crushed to pass the 1.5 inch sieve, although care should be taken to avoid fracturing the aggregate. Heat shall not be applied to the sampled RAP during the crushing process.

7.1.3 Spread material into flat pans.

7.1.4 Dry material in a 104±4°F (40±2° C) oven.

7.1.5 Remove from oven once material reaches constant mass

7.1.6 Using Laboratory Screen Shaker, screen and separate sized material to prepare for batching procedure.

7.2 Asphalt Emulsion Content Selection

7.2.1 Mix designs shall be performed using an asphalt emulsion that meets all requirements detailed in Table 1. Choose at least three asphalt emulsion contents from the following recommended asphalt emulsion contents for each design gradation: 1.5, 2.0, 2.5, 3.0, 3.5, and 4.0.

Table 1. CIR Asphalt Emulsion Material Specification

Test	Procedure	Minimum	Maximum
Viscosity, Saybolt Furol, at 77˚F (25˚C), SFS	AASHTO T59	20	100
Sieve Test, No. 20 (850 µm), retained on sieve, %	AASHTO T59		0.10
Storage Stability Test, 24 hr, %	AASHTO T59		1
Distillation Test, Residue from distillation to 347 ±9˚F (175 ±5˚C), %	AASHTO T59 (See Note 1)	64.0	
Oil Distillate by volume, %	AASHTO T59		1
Penetration, 77˚F (25˚C), 100 g, 5 s, dmm	AASHTO T49	50	200

Note 1—Modified AASHTO T59 procedure – distillation temperature of 347 ±9°F (175 ±5°C) with a 20 minute hold.

7.3 Batching Procedure

7.3.1 A mix design is performed using the gradations shown in the following table. The gradation chosen for the medium, as well as coarse gradations shall be identical for wash gradation, Maximum Specific Gravity, and Marshall Stability Testing. Only material passing the 1-inch sieve shall be used to manufacture specimens when using 100mm gyratory molds.

Table 2. Gradation Criteria

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

7.3.2 Batch the following specimens according to Table 2 for the selected asphalt contents.

7.3.2.1 Prepare 2 washed gradation specimens for each design gradation with a minimum of 2500g specimens for each gradation.

7.3.2.2 Prepare 4 Maximum Specific Gravity Specimens for each design gradation. Two specimens will be tested at the highest asphalt emulsion content and two specimens at the lowest asphalt emulsion content. Minimum weight requirement for Maximum Specific Gravity Specimens is 2500 g per specimen.

7.3.2.3 Prepare 4 pills per emulsion content for each design gradation for Marshall Stability Testing. The total specimen weight shall be the amount that will produce a 60 to 65 mm tall specimen using a 100 mm diameter gyratory mold (approximately 1000 g per specimen is typical), compacted according to Marshall Stability Pill Preparation.

7.3.2.4 Prepare 2 raveling pills per asphalt emulsion content at medium gradation. The total specimen weight shall be the amount that will produce a 65 to 75 mm tall specimen using a 150 mm diameter gyratory mold (approximately 2500 g per specimen is typical), compacted according to Raveling Pill Preparation.

7.4 Coating Procedure.

7.4.1 Mixing occurs at room temperature. One specimen shall be mixed at a time. Typically 1.5 to 3.0 percent water is added to replicate existing moisture and added water in the field. This design moisture content shall be selected and used throughout a design. Any other additives are combined in a manner and order similar to field production.

7.4.2 Record design moisture content selected for each gradation.

7.4.3 Using a mechanical bucket mixer, begin mixing batched RAP at 50-75 revolutions/minute.

7.4.4 Add design moisture content to RAP millings.

7.4.5 Mix for 60 seconds.

7.4.6 Add asphalt emulsion to mixer.

7.4.7 Mixing time with asphalt emulsion shall not exceed 60 seconds.

7.5 Maximum Specific Gravity Specimen Preparation.

7.5.1 After coating procedure detailed in 7.4, spread and transfer each specimen to individual shallow containers.

7.5.2 Cure in a 140±2˚F (60±1˚C) oven, for at least 16 hours but no more than 48 hours. Care should be taken not to over-dry the specimens.

7.5.3 Remove specimens from oven once reaching constant mass.

7.5.4 After curing, gently break up clusters that have formed in the specimen. Care should be taken to avoid fracturing aggregate.

7.5.5 Let cool to room temperature before continuing to Maximum Specific Gravity Test procedure detailed in 8.2.

7.6 Marshall Stability Pill Preparation.

7.6.1 After coating procedure detailed in 7.4, compact specimens using a Superpave gyratory compactor with a 100mm diameter room temperature mold, at 1.25˚ external angle, 87 psi (600 kPa) ram pressure, at 30 gyrations.

7.6.2 Extrude specimen from mold immediately after compaction.

7.6.3 Cure compacted specimens in a 140±2˚F (60±1˚C) oven, at least 16 hours but no more than 48 hours.

7.6.4 Remove specimens from oven once reaching constant mass.

7.6.5 Let cool to room temperature before continuing.

7.6.6 Measure and record pill heights to be used for Stability calculation.

7.6.7 Determine and Record Bulk Specific Gravity (G_{mb}) of each specimen in accordance with AASHTO T 166.

7.6.8 Calculate and Record % Air Voids of each specimen in accordance with AASHTO T 269.

7.6.9 Begin Marshall Stability Test Procedure, ensuring dry tested pills are at constant mass prior to stability testing per 8.3.

7.7 Raveling Pill Preparation.

7.7.1 After coating procedure detailed in 7.4, compact specimens in a Superpave gyratory compactor using a 150 mm diameter room temperature mold, at 1.25˚ external angle, 87 psi (600 kPa) ram pressure, and 20 gyrations.

7.7.2 Extrude specimen from mold immediately after compaction.

7.7.3 Place in flat pan.

7.7.4 Condition compacted specimens in conditioning chamber for 4 hours± 5 minutes at 50±2˚F (10±1˚ C), at specified humidity if required.

7.7.5 Begin Raveling Test Procedure per 8.4.

8.0 PROCEDURE.

8.1 Washed Gradation Sieve Analysis.

8.1.1 Perform Sieve Analysis on washed gradation specimens in accordance with AASHTO T 11 and T 27.

8.1.2 Washed gradations shall be dried at no greater than 104±4˚F (40±2˚ C) in an oven.

8.1.3 Remove specimens from oven once constant mass is reached.

8.1.4 Determine if sample gradation is within recommended gradation bands limits, record results.

8.1.5 Record gradation results for each gradation at the following sieves 1-1/2", 1", 3/4", 1/2", 3/8", #4, #8, #16, #30, #50, #100, #200.

8.2 Maximum Specific Gravity Test Procedure.

8.2.1 Maximum Specific Gravity Specimens shall be prepared according to Coating Procedure per 7.4 and Maximum Specific Gravity Specimen Preparation per 7.5.

8.2.2 Determine and record Theoretical Maximum Specific Gravity of each specimen in accordance with AASHTO T 209.

8.2.3 Calculate and Record the Average Theoretical Maximum Specific Gravity for each asphalt emulsion content measured.

8.2.4 Calculate Average Theoretical Maximum Specific Gravities for remaining asphalt emulsion contents using interpolation of the measured Maximum Theoretical Specific Gravities.

8.3 Marshall Stability Testing Preparation and Procedure.

8.3.1 Marshall Stability Pills shall be prepared according to Coating Procedure per 7.4 and Marshall Stability Pill Preparation per 7.6. Dry and Moisture Conditioned Marshall Stability Pills are to be conditioned and tested concurrently. Moisture Conditioned specimens shall be conditioned using Vacuum Saturation.

8.3.2 Moisture Conditioned Pill Procedure.

8.3.2.1 Using the vacuum system in accordance with AASHTO T 209, place specimen in vacuum container using a spacer to support specimen 1 in. (25mm) above bottom of container.

8.3.2.2 Fill container with water to a level at least 1 in. (25 mm) above top of specimen. Record mass of container and container with

8.3.2.3 Apply vacuum for a short time (typically 5 to 15 seconds).

8.3.2.4 Remove vacuum.

8.3.2.5 Remove specimen from water.

8.3.2.6 Damp dry the specimen by blotting it with a damp towel and record saturated surface dry (SSD) mass.

8.3.2.7 Calculate the volume of air voids, Va, as follows:

$$Va = \frac{Pa \times E}{100}$$

Where:

Va = volume of air voids, cm^3
Pa = percent air voids as determined in 7.6.8
E = volume of the specimen, cm^3

8.3.2.8 Calculate degree of saturation of the specimen as follows:

$$S' = \frac{100(B\prime - A)}{V_a}$$

Where:

S’ = degree of saturation, %.
B’= mass of the SSD specimen after partial vacuum, g
A = mass of the dry specimen in air, g
Va = Volume of air voids, cm^3

If degree of saturation is below 55%, repeat previous steps to reach appropriate degree of saturation. If saturation is above 75%, sample is damaged and must be discarded.

If saturation is between 55 and 75 percent, proceed to the following step.

8.3.2.9 Immediately submerge correctly saturated specimens in a 77 ±2˚F (25 ±1˚C) water bath for 23 hours.

8.3.2.10 Transfer specimens into a 104±4˚F (40±2˚ C) water bath for one hour.

8.3.2.11 See step 8.3.3.2 for testing of conditioned specimens.

8.3.3 Dry Pill Procedure.

8.3.3.1 Dry specimens are conditioned in an oven at 104±4˚F (40±2˚ C) for 2 hours prior to Marshall Stability Testing.

8.3.3.2 Follow procedure for testing Marshall Stability in accordance with AASHTO T 245 except as noted for specimen preparation, compaction and conditioning. Dry and moisture conditioned specimens are to be tested concurrently.

8.4 Raveling Test. Raveling Specimens shall be prepared according to Coating Procedure per 7.4 and Raveling Pill Preparation per 7.7.

8.4.1 Immediately after conditioning is complete, record the mass of each specimen.

8.4.2 Proceed directly to testing of specimen in accordance with ASTM D7196 test procedure using an abrasion time of 15 minutes.

8.4.3 Follow calculation for % Mass Loss in accordance with ASTM D7196.

8.4.4 Calculate Average % Mass Loss for each asphalt emulsion content tested.

9.0 CALCULATIONS.

9.1 Marshall Stability Calculations

9.1.1 Using the previously measured height of each pill, calculate corrected maximum load (Marshall Stability) for each Marshall Stability pill as detailed in AASHTO 245 Table 2.

9.1.2 Calculate and Record average corrected maximum load (Average Stability) at each asphalt emulsion content for moisture conditioned and dry pills separately.

9.1.3 Calculate and Record Retained Marshall Stability (%) for each asphalt emulsion content at each gradation using the following equation:

$$\text{Retained Marshall Stability (\%)} = \frac{Average\ Moisture\ Conditioned\ Specimen\ Stability}{Average\ Dry\ Specimen\ Stability}$$

9.2 Selecting a Final Design Asphalt Emulsion Content.

9.2.1 One asphalt emulsion content is selected per design gradation that meets or exceeds all mix design requirements detailed in Table 3.

9.2.2 Report one asphalt emulsion content per design gradation that meets or exceeds all mix design requirements detailed in table 3.

Table 3. CIR with Asphalt Emulsion Mix Design Requirements

Test Method	CIR	Test Purpose
Gradation for Design Millings, AASHTO T 11, T 27	Reported	
Design Moisture Content, %	Reported	Dispersion of Emulsion
Superpave Gyratory Compaction, 1.25˚ angle, 87 psi (600 kPa)	30 gyrations at 100 mm	Laboratory Density Indicator
Bulk Specific Gravity (Density), AASHTO T 166	Reported	Laboratory Density Indicator
G_{mm} (Maximum Theoretical) Specific Gravity, AASHTO T 209	Reported	Laboratory Density Indicator
Air Voids, % ,AASHTO T 269	Reported	Laboratory Density Indicator
Marshall Stability, lbs (kg), AASHTO T 245 at 104ºF (40 ºC)	1250 lbs (567 kg) minimum	Stability Indicator
Retained Stability, %	70% minimum	Moisture Damage Resistance
Raveling Test, 50˚ F (10˚ C), %, ASTM D7196	2% maximum	Raveling Resistance
Additional Additive(s) Corrective Aggregate Portland Cement, %	 Report (See Note 2) 1.0% maximum	
Emulsified Asphalt Distillation Residue, % (See Note 3) Residue Penetration, dmm Optimum Emulsion Content, % Asphalt Emulsion to Portland Cement Ratio	 Report Report Report 3:1 minimum	

Note 2—Report shall include type/gradation and producer/supplier.

Note 3— Modified AASHTO T59 procedure – distillation temperature of 347 ±9°F (175 ±5°C) with a 20 minute hold.

10.0 REPORT. All mix design test results shall be reported to the Department per Table 4. All additional additives and bituminous material shall be reported to the Department.

Table 4. Reported Results

Selected Criteria	**Medium Gradation**	**Coarse Gradation**
Gradation Selection	Within recommended bands	Within recommended bands
Water Content		
Emulsion Content		
Design Emulsion Content Selection	**Medium Gradation**	**Coarse Gradation**
Final Design Asphalt Emulsion Content	Passing all Table 3 requirements	Passing all Table 3 requirements

Test Results	**Medium Gradation**	**Coarse Gradation**
Sieve Analysis	Average at each Emulsion Content	Average at each Emulsion Content
Maximum Theoretical Specific Gravity		
Bulk Specific Gravity		
Air Voids, %		
Marshall Stability, lbs		
Conditioned Marshall Stability, lbs		
Retained Stability, %		
Raveling Test, % Loss		