*****GENERAL REWRITE – PLEASE READ CAREFULLY.*****

COLD-IN-PLACE RECYCLING of HOT MIX ASPHALT (HMA) PAVEMENT

GENERAL

Cold in-place recycling (CIR) is a method of rehabilitating the existing asphalt pavement surface. As an "in-place" technology, all work takes place on the roadway using the existing asphalt pavement. Generally, material is not wasted or removed. The existing asphalt surface material is cold milled to the specified depth, sized to the specified gradation (maximum particle size), mixed with the specified asphalt stabilizing agents, and placed back on the pavement to the specified width, depth, profile, and cross-slope. This is accomplished in a continuous single-pass operation with the appropriate equipment. The CIR layer is compacted to the required density with rubber-tired and steel-wheeled rollers and can be opened to traffic the same day in most cases. As part of the project, the CIR layer is covered with a new HMA surface course or thin asphalt surface treatment.

This rehabilitation process is normally applied to projects with low volume traffic (i.e., under 2000 vpd) and a structurally adequate pavement section. Projects with insufficient subgrade support should not be candidates for this type of rehabilitation. Projects with higher traffic volumes should do an engineering analysis to determine if this rehabilitation strategy can be successfully applied.

MATERIAL SAMPLING FOR MIX DESIGN

STABILIZING AGENT

The stabilizing agent from the proposed supplier is required for the mix design. A 10-gallon (38 L) sample is needed to prepare the replicates for the range of application rates.

EXISTING PAVEMENT

Samples for mix design testing should be obtained from at least 3 locations. Significant mixture differences in the pavement to be recycled may require separate samples. Samples for mix design obtained from the milled RAP are the most representative, but are rarely possible when the mix designs are performed. If RAP samples are obtained by milling, mill a minimum of 50 feet (15 m) of project length at each sample location. Other methods of sampling for mix design include coring or air-hammer patch areas. All samples shall represent the entire depth of CIR processing. 150 lb. bulk sample is needed to develop the mix design.

DEVELOPING THE MIX DESIGN

STANDARD EMULSION

A mix design is not required for CIR with standard emulsion. The production starts at 0.3 gallons of emulsion per square yard per inch (1.325 l/m^2/25 mm) of CIR compacted thickness. The Engineer may adjust the asphalt stabilizing agent application rate in the field to improve stability or minimize cracking.

FOAMED ASPHALT
The mix design of CIR with foamed asphalt requires a laboratory capable of generating controlled quantities of foamed asphalt. The mix design determines the proper application rate of foamed asphalt to achieve stability under dry and saturated conditions. Indirect tensile testing is used to measure the CIR mixture strength.

The mix design with foamed asphalt is performed by the Iowa DOT Central Asphalt Lab. The current mix design procedure is described in appendix A.

ENGINEERED EMULSION
The mix design of CIR with engineered emulsion requires close coordination with the emulsion supplier to formulate the residual asphalt binder to satisfy the mix design criteria. The mix design determines the emulsion properties and the application rate for the emulsion that satisfy the mix design criteria. A series of tests are used to measure strength and low temperature flexibility.

Procedures for the mix design with engineered emulsion are described in appendix B.

FIELD CONTROL OF ASPHALT STABILIZING AGENT

CALIBRATE AND MONITOR STABILIZING AGENT RATE OF FLOW
The contactor shall provide a positive means of accurately metering the rate of flow and total delivery of the asphalt stabilizing agent. The Engineer should verify the rate of application with production yield checks during construction.

The contractor may use the delivery pump as one of the options to determine total gallons of stabilizing agent used on the project. Pump accuracy is determined by comparing a metered volume or weight, correcting for temperature, against a known volume or weight. The pump must consistently deliver with in ± 1.5% of the required gallons (liters). If the contractor elects to use delivery ticket quantities and production yield, calibration of the pump would not be necessary.

The production yield is determined by comparing the quantity of asphalt stabilizing agent used to the quantity required for the square yards per inch (square meters per centimeter) of compacted thickness as measured. Production yield shall be with in the specified tolerance of the target application rate. The application rate specifies the quantity of standard emulsion, foamed asphalt, or engineered emulsion added to the RAP volume. Use Form #CIR-1, Yield Check to verify the rate of application by yield check.

If the standard emulsion is diluted, the target application rate must be adjusted by the amount of emulsion dilution. Dilution is not normally performed for CIR applications because it adds excess water to the CIR mixture.

ADJUSTMENT OF STABILIZING AGENT CONTENT
The Engineer must approve any revision in the asphalt stabilizing agent content. Changes in the content, particularly a reduction, may have a significant impact on the long term performance of the CIR layer. The Engineer and Contractor should consider adjustments to the CIR operations before reducing the asphalt stabilizing agent content.

STABILIZING AGENT SAMPLING
A one-quart (one-liter) sample of stabilizing agent shall be obtained each day. The sample from the first day and one each week shall be forwarded to the District Materials Engineer for testing. The other samples shall be retained for submission in the event of a failing test. The District Materials Laboratory will determine the percent residual binder of the emulsion sample or perform DSR tests on binder samples.. The Central Materials Laboratory may conduct further qualifying tests as required in Materials I.M. 204.

The sample should be taken from the supply tanker. A plastic bottle must be used to sample emulsions and a metal tin must be used for hot asphalt binder (foamed asphalt application).

FIELD CONTROL OF CIR MIXTURE

MIXTURE SAMPLING
Sample loose CIR mixture from the roadway using sampling methods described in Materials I.M. 322. One 40 pound (15 kg) sample placed in an airtight bag or container will be required per day. Each sample must be taken from the roadway after the RAP and stabilizing agent have been mixed and placed by the screed and before rolling.

The sample shall be promptly delivered to the District Materials Laboratory for density determination. Additional samples should be taken when a significant change in the RAP or CIR mixture occurs.

LABORATORY TESTING PROCEDURE

1. Remove a representative 1000 g sample to determine the moisture content of the mixture. Dry the entire sample to a constant dry mass in an oven at a temperature not to exceed 275°F (135°C). Record all weight measurements to the nearest 0.5 g.

Moisture content will be calculated using the following formula:

$$\%\,\text{Moisture} = \frac{(\text{Wet Sample Mass} - \text{Dry Sample Mass})}{\text{Dry Sample Mass}} \times 100$$

Example: Given: Wet Sample Mass = 1017.0 g
Given: Dry Sample Mass = 985.5 g

$$\%\ \text{Moisture} = \frac{(1017.0 - 985.5)}{985.5} \times 100 = 3.2\%$$

Note: If the measured moisture content is below 3.5%, increase the moisture content in

the sample to 4.0% before compaction.

2. Split the remainder of the bulk sample and prepare two 4000 g gyratory specimen for 6-inch (150 mm) diameter gyratory molds from each split sample. Molds shall be at room temperature. Do not use paper disks. Use plastic disks, wax-paper disks, or coat the base and head plate with a thin layer of light oil. Compact each sample to 25 gyrations. Determine the bulk wet density of the compacted specimen as follows.

3. Pre-weigh the gyratory mold with the base plate. Determine the mass of each mold to the nearest 0.5 g. Charge the mold with the CIR mixture and record the total mass to the nearest 0.5 g. Determine the mass of the specimen by subtracting the mass of the mold and base plate The height of the specimen may be recorded from the gyratory compactor at the completion of the compaction process.

The required height, of the compacted specimen, is 115 $\pm$ 5 mm. If the height needs to be adjusted, the amount of CIR needed is determined by the following formula:

$$\text{Adjusted weight of the mixture} = \frac{115 \text{ (weight of mixture used)}}{\text{Specimen height obtained}}$$

Note: If the Laboratory Density is determined by Marshall Method, the following variations apply.

The material should be screened to remove particles larger than 1 inch. This will help produce a more consistent lab density using 4 inch molds.

Split out a 1200 g. Marshall specimen for the 4-inch diameter Marshall molds. Marshall molds shall be pre-measured and pre-weighed. Determine the mass of each mold to the nearest 0.5 gram. Determine the inside diameter of each mold to the nearest 0.001 inch. Volume tables, for each mold, should be prepared to the nearest 0.01 inch of measured height.

Prepare three specimens by using the Marshall hammer and applying 75 blows to each side. Remove the mold from the base and weigh the mold and specimen to the nearest 0.5 gram. Determine the mass of the specimen by subtracting the mass of the mold. Remove the specimen from the mold and measure the height to the nearest 0.001 inch using a dial indicator or suitable caliper. Take a minimum of four measurements, average them, and round the average to the nearest 0.01 in.

4. Compute the laboratory wet density using the following equation.

$$\text{Gyratory Laboratory Wet Density (kg/m}^3\text{)} = \frac{\text{Specimen Mass (g)}}{\text{Specimen Height (mm)}} \times 56.588$$

Gyratory Laboratory Wet Density (lb/ft^3) = metric wet density (kg/m^3) × 0.062436

$$\text{Marshall Laboratory Wet Density (lb./ft.}^3\text{)} = \frac{\text{Specimen Mass (grams)}}{\text{(453.6 gms/lb.)(Specific Volume, ft.}^3\text{)}}$$

5. Compute the laboratory dry density using the following equation.

$$\text{Laboratory Dry Density (lb/ft}^3 \text{ or kg/m}^3\text{)} = \frac{\text{Laboratory Wet Density}}{(100 + \text{Percent Moisture})} \times 100$$

NOTE: A difference in the character of the CIR (Coarser or finer) or wet weather conditions can effect the laboratory density. Variations in laboratory dry density of more than 3 pounds per cubic foot (50 kg/m^3) between successive samples shall be investigated promptly.

If the investigation determines the character of the CIR has changed, the corresponding dry density result representing the lot shall be used. An identifiable difference in pavement may be the cause of the change.

Unexplained variations or variations caused by rain, effecting the dry density by more than 3 pounds per cubic foot for successive Lots, shall be averaged with the previous days dry density result. The average of both days will be reported as the dry density result representing the current day's lot.

FIELD DENSITY TESTING PROCEDURE

The project inspection personnel shall select and mark the field density test locations. Each day of CIR production shall be divided into approximately equal sublots per IM 204. A random location in each sublot shall be selected for moisture and density testing.

The Contractor will determine the in-place density and moisture using a nuclear gauge in direct transmission mode at the maximum allowable probe depth in accordance with IM 334. The nuclear gauge moisture measurements shall be adjusted by the correction factor below to account for the asphalt binder in the mixture. The dry density and percent of lab density of each test location is determined using the following equations. Report both values to one decimal place. Sublots that do not achieve the specified minimum percent density should be re-rolled immediately and re-tested. The optimum condition for re-rolling is when the CIR layer is warm (typically in the afternoon).

Field Compacted Dry Density = Gauge Wet Density – Gauge Moisture + Correction Factor

$$\text{Percent Laboratory Density} = \frac{\text{Field Compacted Dry Density}}{\text{Laboratory Gyratory Dry Density}} \times 100$$

Example:

Field Compacted Gauge Wet Density		2090.6 =	130.5
Gauge Moisture	-168.2	=	-10.5
Correction Factor	+120.2	=	7.5
Field Compacted Dry Density	2042.6 kg/m³	=	127.5 lb./ft.³

DETERMINE THE CORRECTION FACTOR

The first day, the Contractor will sample approximately 1000 g of CIR mixture at each density test location (minimum of 10 locations) to determine the in-place moisture content. Each sample shall be properly sealed, transported to the Contractor's laboratory, and measured for moisture content. Use the paired nuclear gauge moisture content measurements and in-place (laboratory) moisture content measurements to determine the correction factor. Compute the actual in-place moisture for each of the sampled test locations using the following equation.

$$\text{Actual In place Moisture (lb/ft}^3 \text{ or kg/m}^3) = \frac{(\text{Laboratory \% Moisture}) \times (\text{Nuclear Guage Wet Density})}{\text{Laboratory \% Moisture} + 100}$$

Example (for one set of paired values)

Nuclear Gauge Wet Density = 2090.6 kg/m³ (130.5 lb/ft³)
Laboratory % Moisture = 2.3%

$$\text{Actual In place Moisture} = \frac{(2.3)\times(2090.6)}{(2.3+100)} = \frac{4808.38}{102.3} = 47\text{kg/m}^3 = \frac{(2.3)\times(130.5)}{(2.3+100)} = \frac{300.2}{102.3} = 2.9\text{lb/ft}^3$$

Compute the average of the actual in-place moisture contents for the paired tests and compute the average of the nuclear gauge moisture readings for the same moisture sample locations. Then compute the correction factor using the following equation.

Correction Factor = Avg Gauge Moisture - Avg Actual Moisture

Example:

Average of Gauge Moisture	177.8	11.1
Average of Actual In-Place Moisture	- 57.7	- 3.6
Correction Factor:	120.1 kg/m³	7.5 lb./ft.³

Use Form #CIR-2, Determination of Moisture Correction Factor for showing the determination of a correction factor. This correction factor may seem large. It represents the asphalt binder in the CIR mixture. The nuclear gauge measures both asphalt binder and water in the moisture reading.

NOTE: Any significant change in the characteristics or components of the asphalt pavement being recycled requires a new correction factor.

DETERMINE RESIDUAL MOISTURE CONTENT OF THE PAVEMENT PRIOR TO CIR

Before the Contractor can place the HMA overlay or thin asphalt surface treatment over the CIR, the moisture content of the CIR layer must drop to one of two specified levels, 2.0%, or 0.3% above residual moisture. The criteria for 0.3% above residual moisture recognizes the impact of the in-situ moisture content of the pavement structure in a given location. If the residual moisture content is above 2.0%, that section of CIR layer may never achieve the standard 2.0% criteria.

To use the 0.3% above residual moisture criteria, the Engineer and Contractor should sample and test the asphalt pavement prior to initiating the CIR production. The samples should be taken at locations that represent the different drainage characteristics over the length of the project. For example, cut sections and fill sections may have different residual moisture in the top 3 to 4 inches (75 to 100 mm) of the asphalt pavement.

The samples should be taken during normal pavement conditions, not immediately after a rain event. Postpone sampling until 5 calendar days after a rain.

Each sample must be cut dry. No wet coring. Dry sawing and impact air-hammers should be used. The sample should represent the proposed depth of CIR rehabilitation. Immediately bag and seal the samples and send them to the District Materials Lab to determine the residual moisture content.

DETERMINE IN-PLACE MOISTURE CONTENT OF FINISHED CIR LAYER

The in-place moisture content must comply with specifications prior to applying a subsequent HMA surface or thin asphalt surface treatment. Two sample locations should be tested from each day of completed CIR to determine the moisture content of the CIR layer. Inclement weather or project conditions may require additional samples representing questionable areas to determine acceptable moisture levels.

Moisture content of the material may be determined by one of the following methods.

1. Use the same nuclear gauge that was used for density determination taking into account the moisture correction factor for asphalt content. The following equation will convert the nuclear gauge readings to percent moisture.

$$\%\,\text{Moisture} = \frac{\text{guage moisture (lb/ft}^3\text{ or kg/m}^3\text{) - correction factor (lb/ft}^3\text{ or kg/m}^3\text{)}}{\text{guage wet density (lb/ft}^3\text{ or kg/m}^3\text{)} - \text{guage moisture (lb/ft}^3\text{ or kg/m}^3\text{)} + \text{correction factor (lb/ft}^3\text{ or kg/m}^3\text{)}} \times 100$$

Example: $\%\text{Moisture} = \dfrac{(9.1\ \text{lb/ft}^3 - 7.5\ \text{lb/ft}^3)}{(130.5\ \text{lb/ft}^3 - 10.5\ \text{lb/ft}^3 + 7.5\ \text{lb/ft}^3)} \times 100 = 1.3$

2. Using a different nuclear gauge and establishing a new correction factor using the procedure previously noted under field density testing.

3. Extract 1000 g of material from the sample location. Dry the entire sample to a constant dry mass in an oven at a temperature not to exceed 275ºF (135ºC) or on a hot plate at a low temperature setting.

FIELD REPORT

Report daily results on Form #CIR-3, Daily Cold-In-Place Asphalt Recycling Report. All CIR forms can be found in the Asphalt Section of the Iowa DOT Web Page (www.dot.state.ia.us/materials/acc.htm).