Iowa Department of Transportation

MINUTES
OF
IOWA D.O.T. SPECIFICATION COMMITTEE MEETING

March 12, 2009

Members Present:	John Adam	Statewide Operations Bureau
	Jim Berger	Office of Materials
	Roger Bierbaum	Office of Contracts
	Doug McDonald	District 1 - Marshalltown RCE
	Gary Novey	Office of Bridges & Structures
	Tom Reis, Chair	Specifications Section
	John Smythe	Office of Construction
Members Not Present:	Donna Buchwald	Office of Local Systems
	Troy Jerman	Office of Traffic & Safety
	Mike Kennerly	Office of Design
	Bruce Kuehl	District 6 - District Construction
	Dan Redmond	District 4 - District Materials
Advisory Members Present:	Lisa Rold	FHWA
Others Present:	LeRoy Bergman	Office of Local Systems
	Daniel Harness, Secretary	Design
	Kevin Merryman	Office of Construction
	Scott Schram	Office of Materials
	Nicole Streit	District 1 - District Materials

Tom Reis, Specifications Engineer, opened the meeting. The following items were discussed in accordance with the agenda dated March 6, 2009:

1. Article 1105.12, Restrictions on Moving and Use of Heavy Equipment.

The Office of Construction requested a change to provide contractual limits to ensure safe loads are not exceeded on bridges.

2. Section 2114, Class A Subbase.

The Office of Construction requested to delete this section.

3. Article 2301.12, A, Placing Reinforcement.

The Office of Construction requested changes to eliminate listed bid items, work types, and pavement features this article applies to that are addressed by other specifications.

4. Article 2301.34, A, Portland Cement Concrete Pavement.
Article 2301.35, A, Portland Cement Concrete Pavement.

The Office of Construction requested changes to eliminate measurement and payment language that is covered elsewhere in the specifications.

5. Section 4112, Intermediate Aggregate for Portland Cement Concrete.

The Office of Materials requested to add a new section.

6. DS-01XXX, Cold In-Place Recycled Asphalt Pavement.

The Specifications Section requested a discussion and approval of the revisions to the Developmental Specifications for Cold In-Place Recycling.

SPECIFICATION REVISION SUBMITTAL FORM

Submitted by: John Smythe / Wayne A. Sunday	**Office:** Construction	**Item 1**
Submittal Date: February 23, 2009	**Proposed Effective Date:** October, 2009	
Article No.: 1105.12 **Title:** Restrictions On Moving and Use of Heavy Equipment	**Other:**	

Specification Committee Action: Approved with changes as noted.

Deferred:	**Not Approved:**	**Approved Date:** 3/12/09	**Effective Date:** 10/20/09

Specification Committee Approved Text:

1105.12, C, Restrictions on Moving and Use of Heavy Equipment.

Replace the article:

C. Drag lines, cranes, or power shovels shall not be operated with any part of the machine resting upon a pavement, HMA surface, or base course~~, or structure~~ except with approval of the Engineer and in accordance with restrictions in that approval.

Add as Article D:

D. For structures, the following equipment and material loads shall apply:

1. Only legal load vehicles and equipment will be permitted on structures unless approved by the Engineer.

2. Legal load vehicles and equipment will be subject to weight restrictions according to the posted limits.

3. All loads in spans where critical or damaged members, as indicated in the contract documents, are being repaired or replaced shall be subject to the approval of the Engineer.

4. Material loads stored on the structure shall be limited to a maximum weight of 20 tons (20 Mg). Distribution of load shall be governed by the following:

a. If the material load is greater than 200 pounds per square foot (9.5 kPa) and less than 500 pounds per square foot (23.9 kPa), the loaded area will be restricted to an area 5 feet by 10 feet (50 square feet) (1.5 m by 3 m (4.5 m^2)) with a clear spacing of 15 feet (4.6 m) between loaded areas.

b. If the material load is less than or equal to 200 pounds per square foot (9.5 kPa), the loaded area is only restricted by the 20 ton (20 Mg) maximum.

5. Construction vehicles and equipment not involved with the loading and unloading of stored material shall be restricted from operating within 10 feet (3 m) of the area where the material is stored.

All vehicle, equipment, and material loads exceeding the limitations as stated above shall be submitted to the Engineer for checking and review prior to subjecting the loads to the structure. The Contractor shall include in their submittal all details, calculations, and assumptions. The calculations shall be certified by a Professional Engineer licensed to

practice engineering in the State of Iowa.

The above submittal requirements shall also apply to cranes or other construction equipments when:

a. Other components are added resulting in overall weight greater than legally allowed or granted by special permit.

b. The operational weight including construction loads is greater than legally allowed or granted by special permit.

c. Load distribution is altered during operation due to the use of outriggers or other devices.

Renumber Articles D through H as E through I.

1106.03, Storage of Materials.

Add as the second paragraph:

The limitations of Article 1105.12, D shall apply to materials stored on structures.

Comments: The Office of Construction noted that in the past much of this language was covered in the Construction Manual guidance. They suggested changes to make it clear these restrictions apply to all heavy machinery on structures. As the text is now, it could be mistaken to apply only to drag lines, cranes, or power shovels. After the meeting, the Specifications Section determined it would be best to add the language regarding equipment and material loads as a new article and renumber subsequent articles.

The Office of Bridges noted that Article 1106.03 should reference the added text.

Specification Section Recommended Text:

1105.12, C, Restrictions on Moving and Use of Heavy Equipment.

Replace the article:

C. Drag lines, cranes, or power shovels shall not be operated with any part of the machine resting upon a pavement, HMA surface, or base course~~, or structure~~ except with approval of the Engineer and in accordance with restrictions in that approval.

For structures the following equipment and material loads shall apply:

1. Only legal load vehicles and equipment will be permitted on structures unless approved by the Engineer.

2. Legal load vehicles and equipment will be subject to weight restrictions according to the posted limits.

3. All loads in spans where critical or damaged members, as indicated in the contract documents, are being repaired or replaced shall be subject to the approval of the Engineer.

4. Material loads stored on the structure shall be limited to a maximum weight of 20 tons (20 Mg). Distribution of the 20 ton (20 Mg) load shall be governed by the following:

a. If the material load is greater than 200 pounds per square foot (9.5 kPa) and less than 500 pounds per square foot (23.9 kPa), the loaded area is restricted to an area 5 feet by 10 feet (50 square feet) (1.5 m by 3 m (4.5 m^2)) with a clear spacing of 15 feet (4.6 m) between loaded areas.

b. If the material load is less than or equal to 200 pounds per square foot (9.5 kPa), the loaded area is only restricted by the 20 ton (20 Mg) maximum.

5. Construction vehicles and equipment not involved with the loading and unloading of stored material shall be restricted from operating within 10 feet (3 m) of the area where the material is stored.

All vehicle, equipment, and material loads exceeding the limitations as stated above shall be submitted to the Engineer for checking and review prior to subjecting the loads to the structure. The Contractor shall include in their submittal all details, calculations, and assumptions. The calculations shall be certified by a Professional Engineer licensed to practice engineering in the State of Iowa.

The above submittal requirements shall also apply to cranes or other construction equipments when:

a. Other components are added resulting in overall weight greater than legally allowed or granted by special permit.

b. The operational weight including construction loads is greater than legally allowed or granted by special permit.

c. Load distribution is altered during operation due to the use of outriggers or other devices.

Comments:

Member's Requested Change (Redline/Strikeout):

1105.12 RESTRICTIONS ON MOVING AND USE OF HEAVY EQUIPMENT.
The following restrictions shall apply to the moving and use of heavy equipment:

A. Movement of equipment to and from the project shall be in compliance with the laws governing the operation of vehicles on the highways of Iowa. Movement and operation of equipment over completed portions of pavements, HMA surfaces, base courses, and structures which are a part of the project shall be with legal axle loads, except as modified in this article.

B. In the case of earthwork and shouldering to be done in connection with either rigid or flexible pavement or pavement widening and resurfacing, earth moving equipment shall not be operated or driven on or across the pavement, except as authorized by the Engineer at designated equipment crossings.

When equipment crossings are specifically permitted, the Contractor shall designate before use the location and number of equipment crossings to be used. The location of all equipment crossings shall be subject to the approval of the Engineer. The Engineer will not approve equipment crossings in areas of limited sight distance or near structures or railroad crossings or at any other location which will place safety of the traveling public in jeopardy. At these equipment crossings, equipment having axle loads greater than the maximum permitted by law may be used.

Equipment crossings shall be 30 feet (10 m) in width measured along the center line of the road to be crossed and shall not be closer than 300 feet (100 m) to each other.

Within the prescribed limits, the Contractor may operate hauling equipment on the surface of the

pavement or on a hauling bridge constructed by the Contractor.

If an equipment crossing is used, the existing driving surface on the through road shall be restored at the end of each day's operation to safely serve traffic at expected speeds. The Contractor may install pavement protection at equipment crossings to reduce the surface restoration at the end of each day's operation.

For each equipment crossing used, the Contractor shall, at the Engineer's option, either replace the pavement or pay the Contracting Authority at the rate of $7,500 dollars on the basis of a two lane pavement.

If a hauling bridge is used, it shall support loaded hauling equipment with no contact with the pavement surface and will be subject to the Engineers approval. When a hauling bridge is used, no pavement replacement or payment to the Contracting Authority will be required.

Pavement protection installations and hauling bridges shall accommodate two lanes of public traffic. They shall be removed from the through road at the close of each day's operations.

C. Drag lines, cranes, or power shovels shall not be operated with any part of the machine resting upon a pavement, HMA surface, base course, ~~or structure~~ except with approval of the Engineer and in accordance with restrictions in that approval.

For structures the following equipment and material loads shall apply:

1. Only legal load vehicles and equipment will be permitted on structures unless approved by the Engineer.

2. Legal load vehicles and equipment will be subject to weight restrictions according to the posted limits.

3. All loads in spans where critical or damaged members, as indicated in the contract documents, are being repaired or replaced shall be subject to the approval of the Engineer.

4. Material loads stored on the structure shall be limited to a maximum weight of 20 tons. Distribution of the 20 ton load shall be governed by the following:

a) If the material load is greater than 200 psf and less than 500 psf, the loaded area is restricted to an area 5 by 10 foot (50 sq ft) with a clear spacing of 15 feet between loaded areas.

b) If the material load is less than or equal to 200 psf, the loaded area is only restricted by the 20 ton maximum.

5. Construction vehicles and equipment not involved with the loading and unloading of stored material shall be restricted from operating within 10 feet of the area where the material is stored.

All vehicle, equipment, and material loads exceeding the limitations as stated above shall be submitted to the Engineer for checking and review prior to subjecting the loads to the structure. The Contractor shall include in their submittal all details, calculations, and assumptions. The calculations shall be certified by a Professional Engineer licensed to practice engineering in the State of Iowa.

The above submittal requirements shall also apply to cranes or other construction equipments when:

a) Other components are added resulting in overall weight greater than legally allowed or granted by

special permit.
b) The operational weight including construction loads is greater than legally allowed or granted by special permit.
c) Load distribution is altered during operation due to the use of outriggers or other devices.

D. Under no conditions shall machines equipped with metal lugs or similar projections on the treads be operated on the surface of a pavement, HMA surface, base course, or structures.

E. For building shoulders on completed pavements of any type, the maximum axle load used for equipment operating on pavement shall not exceed the legal axle load.

F. Crawler type equipment shall not be moved on or off a pavement or base course except at places where the compacted earth adjacent to slab is at least 2 inches (50 mm) higher than the surface of the pavement or base course. When heavy, crawler type equipment is moved on or off the edge of a pavement or base course, an adequate timber approach shall be built at the edge of slab to prevent overloading or otherwise damaging the edge of the slab.

G. Compacting equipment having axle loads greater than 20,000 pounds may be used on the work under the following provisions:

1. The equipment shall be transported to and from the work and across the bridges on the work in compliance with laws of the State of Iowa.

2. For compaction of subbase, the weight (mass) of the equipment used shall not be greater than that of compaction equipment used in correction of the roadbed for grade and cross section.

3. For compaction of base course, the weight (mass) of the equipment used shall not be greater than the weight of the equipment used in compaction of the subbase on which the base is placed.

4. For compaction of surface courses, the weight (mass) of the equipment shall not be greater than that of equipment used in compaction of the base on which the surface course is placed.

H. For grading or any other type of work, no equipment having an axle load greater than 50,000 pounds shall be operated over a culvert except as may be authorized by the Engineer.

Reason for Revision: Provide contractual limitations to ensure safe loads are not exceeded on bridges.

County or City Input Needed (X one)			**Yes**	**No** X	
Comments:					
Industry Input Needed (X one)			**Yes**	**No** X	
Industry Notified:	**Yes**	**No**	**Industry Concurrence:**	**Yes**	**No**
Comments:					

SPECIFICATION REVISION SUBMITTAL FORM

Submitted by: John Smythe / Kevin Merryman	**Office:** Construction	**Item 2**
Submittal Date: November 18, 2008	**Proposed Effective Date:** October 2009	
Section No.: 2114 **Title:** Class A Subbase	**Other:**	

Specification Committee Action: Approved as is.

Deferred:	**Not Approved:**	**Approved Date:** 3/12/09	**Effective Date:** 10/20/09

Specification Committee Approved Text: See Specification Section Recommended Text.

Comments: The Office of Construction noted that use of Class A subbase could actually be detrimental to pavement life.

Specification Section Recommended Text: See Member's Requested Change.

Comments:

Member's Requested Change (Redline/Strikeout):

Section 2114. Class A Subbase.

Delete the entire section.

Reason for Revision: Class A Subbase is no longer used in Iowa. Many pavements built using stabilized bases have exhibited early deterioration due to lack of adequate drainage. Water becomes trapped between the pavement and base material and cannot escape. This saturates the pavement and causes loss of pavement section due to freeze thaw damage. Other options should be considered if stabilized bases are desired.

County or City Input Needed (X one)			**Yes**	**No** X	
Comments:					
Industry Input Needed (X one)			**Yes**	**No** X	
Industry Notified:	**Yes** X	**No**	**Industry Concurrence:**	**Yes**	**No**
Comments:					

SPECIFICATION REVISION SUBMITTAL FORM

Submitted by: John Smythe / Kevin Merryman	**Office:** Construction	**Item 3**
Submittal Date: January 20, 2009	**Proposed Effective Date:** October, 2009	
Article No.: 2301.12, A **Title:** Placing Reinforcement	**Other:**	

Specification Committee Action: Approved as is.

Deferred:	**Not Approved:**	**Approved Date:** 3/12/09	**Effective Date:** 10/20/09

Specification Committee Approved Text: See Specification Section Recommended Text.

Comments: The Office of Local Systems asked what should be done if the concrete around the tie bar cannot be consolidated. The Office of Construction explained the bars would need to be drilled in.

Specification Section Recommended Text:

2301.12, A, Placing Reinforcement.

Add as second sentence of first paragraph:

For slip form paving, tie bars may be installed after vibration, provided the concrete is consolidated around the bars.

Comments:

Member's Requested Change (Redline/Strikeout):

2301.12 PLACING REINFORCEMENT AND PLACING DOWEL AND TIE BARS.

A. Placing Reinforcement.
Reinforcement shall be installed prior to vibration so as to be in the intended position in the completed pavement in accordance with Article 2404.06. For slip form paving, tie bars may be installed after vibration provided the concrete is consolidated around the bars. Reinforcing bars may be supported by approved chairs or may be placed in position by a machine or method subject to approval of the Engineer.

Reinforcement for bridge approach sections shall be supported by approved continuous bolsters with runners. The supports shall be placed transversely across the approach and spaced longitudinally no greater than 4 feet (1.2 m). For double reinforced approach sections the top layer of reinforcing may be chaired off the bottom layer of reinforcing using approved continuous high chairs with runners, provided they are positioned directly above the continuous bolsters with runners supporting the bottom layer of reinforcing. Epoxy coated reinforcing steel shall be held in place with epoxy or plastic coated bar supports and epoxy or plastic coated tie wires. Continuous bolsters with runners and continuous high chairs with runners, either plastic or steel, shall meet the requirements of Materials I.M. 451.01.

When welded wire fabric reinforcement is used, the concrete shall first be struck off at the elevation specified for the fabric reinforcement, and the sheets of fabric shall be placed as indicated in the contract documents. The sheets of fabric shall be flat, and care shall be used in handling and placing the fabric to ensure its installation in the proper position. The balance of the concrete shall then be deposited and vibrated in a manner to not displace or distort the fabric. Sheets that have become bent or kinked may be

rejected.

Alternate methods of placing welded wire fabric reinforcement will be considered for approval.

Reason for Revision: Tie bars have been installed after vibration for many years when using slip form paving methods. This is typically accomplished by use of a tie bar inserter for centerline joints and insertion through side forms of a paver for construction joints. This is an acceptable practice as long as the concrete is consolidated around the bar after insertion. The above change updates the specification to the current practice.

County or City Input Needed (X one)			**Yes**	**No** X	
Comments:					
Industry Input Needed (X one)			**Yes** X	**No**	
Industry Notified:	**Yes** X	**No**	**Industry Concurrence:**	**Yes** X	**No**
Comments: Industry had no comment on the change.					

SPECIFICATION REVISION SUBMITTAL FORM

Submitted by: John Smythe / Kevin Merryman	**Office:** Construction	**Item 4**
Submittal Date: January 20, 2009	**Proposed Effective Date:** October, 2009	
Article No.: 2301.34, A **Title:** Method of Measurement (PCC Pavement) **Article No.:** 2301.35, A **Title:** Basis of Payment (PCC Pavement)	**Other:**	

Specification Committee Action: Approved as is.

Deferred:	**Not Approved:**	**Approved Date:** 3/12/09	**Effective Date:** 10/20/09

Specification Committee Approved Text: See Specification Section recommended text.

Comments: None.

Specification Section Recommended Text:

2301.34, A, Portland Cement Concrete Pavement.

Replace the first paragraph:

The quantity of Standard or Slip-Form Portland Cement Concrete Pavement of the type specified in square yards (square meters), will be the quantity shown in the contract documents ~~and applies to pavement, concrete pavement widening, side street connections, crossovers, ramps, acceleration and deceleration lanes or auxiliary lanes, and concrete paved shoulders. The coring requirements for thickness do not apply to detour pavements, paved drives, and temporary pavements~~.

Replace the third paragraph:

The division of sections, lots, ~~number of lots, lot sizes,~~ and core locations ~~shall~~ will be in accordance with Materials I.M. 346.

2301.35, A, Portland Cement Concrete Pavement.

Replace the first sentence of the first paragraph:

The Contractor will be paid the contract unit price for Standard or Slip-Form Portland Cement Concrete Pavement of the type specified per square yard (square meter) ~~and applies to pavement, concrete pavement widening greater than 6 feet (1.8 m), side street connections, ramps, acceleration and deceleration lanes or auxiliary lanes, and concrete paved shoulders~~.

Comments:

Member's Requested Change (Redline/Strikeout):

2301.34 METHOD OF MEASUREMENT.

A. Portland Cement Concrete Pavement.

The quantity of Standard or Slip-Form Portland Cement Concrete Pavement of the type specified in square yards (square meters), will be the quantity shown in the contract documents. ~~and applies to pavement, concrete pavement widening, side street connections, crossovers, ramps, acceleration and deceleration lanes or auxiliary lanes, and concrete paved shoulders. The coring requirements for thickness~~

~~do not apply to detour pavements, paved drives, and temporary pavements.~~

The thickness of pavement constructed will be determined from core depths as follows:

The division of sections, lots, ~~number of lots, lot sizes,~~ and core locations ~~shall~~ will be in accordance with Materials I.M. 346.

At locations determined by the Engineer, the Contractor shall cut samples from the pavement, as directed above, by drilling with a core drill of a size that will provide samples with a 4-inch (101.6 mm) outside diameter. The Contractor shall restore the surface by tamping low-slump concrete into the hole, finishing and texturing. The Engineer will witness the core drilling, identify, and measure the cores immediately. The Engineer will measure the cores and determine the thickness index in accordance with Materials I.M. 346. After measurement on the grade, the Contractor shall deliver the cores to the Engineer's office or field laboratory. When cores are not measured on the grade, the Engineer will take immediate possession of the cores.

Coring of pavement and other work for thickness determination may be waived by the Engineer for sections of the same design thickness less than 5,000 square yards (4200 square meters). Only sections which are cored shall be included in the thickness index determination. Areas not cored shall be paid for at the contract unit price.

2301.35 BASIS OF PAYMENT.

A. Portland Cement Concrete Pavement.
The Contractor will be paid the contract unit price for Standard or Slip-Form Portland Cement Concrete Pavement of the type specified per square yard (square meter). ~~and applies to pavement, concrete pavement widening greater than 6 feet (1.8 m), side street connections, ramps, acceleration and deceleration lanes or auxiliary lanes, and concrete paved shoulders.~~ Payment for the quantities of pavement in square yards (square meters) will be at a percentage of the contract unit price in accordance with the following schedule:

Reason for Revision: Applicability of 2301.34 and 2301.35 is determined either by reference from other articles in the specification to this article or by IM 346. It is not necessary, or desirable, to list bid items, work types, or pavement features that these articles apply to since other contract documents address this.

County or City Input Needed (X one)			**Yes**	**No** X	
Comments:					
Industry Input Needed (X one)			**Yes**	**No** X	
Industry Notified:	**Yes** X	**No**	**Industry Concurrence:**	**Yes**	**No**
Comments:					

SPECIFICATION REVISION SUBMITTAL FORM

Submitted by: Jim Berger	**Office:** Materials	**Item 5**
Submittal Date: 2009.02.25	**Proposed Effective Date:** October, 2009	
Article No.: 4112 **Title:** Intermediate Aggregate for Portland Cement Concrete	**Other:**	

Specification Committee Action: Approved as is

Deferred:	**Not Approved:**	**Approved Date:** 3/12/09	**Effective Date:** 10/20/09

Specification Committee Approved Text: See Specification Section Recommended Text. The table in Article 4112.03, A should be as follows:

Aggregate Quality	Maximum Percent Allowed	Test Method
Alumina [(a)]	0.5	Iowa DOT Materials Laboratory Test Method 222
A Freeze	6	Iowa DOT Materials Laboratory Test Method 211, Method A
Clay Lumps	0.5	I.M. 368

(a) If the Alumina value fails, determine the A Freeze value for specification compliance.

The table in Article 4112.03, B should be as follows:

Maximum Permissible Amounts of Objectionable Materials	Maximum Percent Allowed	Test Method
Coal and carbonaceous shale	0.5	Materials I.M. 372
Total of all shale, similar objectionable materials, coal, and iron combined.	1.0	Materials I.M. 372
Organic materials, except coal.	0.01	Iowa DOT Materials Laboratory Test Method 215
Unsound chert particles retained on 3/8 inch (9.5 mm) sieve (Nonstructural concrete)	3.0	Materials I.M. 372
Unsound chert particles retained on 3/8 inch (9.5 mm) sieve (Structural concrete)	2.0	Materials I.M. 372

Note: Chert particles which break into three or more pieces when subjected to the freezing and thawing test will be considered unsound.

Chert in aggregate produced from limestone sources is defined as unsound when any of the fractions of the crushed or uncrushed chert do not meet the soundness requirements.

Comments: The Office of Construction noted the QMC Developmental Specification will need to be revised.

The Specifications Section discussed the references to AASHTO T 113 in Article 4112.03, B, with the Office of Materials. It was agreed that these references should be changed to Materials I.M. 372 to line up with Table 4115.02-2. In addition, the reference to I.M. 215 should be changed to Iowa DOT Materials Test Method 215.

Specification Section Recommended Text:

4112, Intermediate Aggregate for Portland Cement Concrete.

Add a new section:

Section 4112, Intermediate Aggregate for Portland Cement Concrete.

4112.01 DESCRIPTION.

Crushed carbonate stone chips or pea gravel from approved sources as described in Materials I.M. 409. Coarse natural sand resulting from disintegration of rock through erosional processes, without addition of crushed over-sized material may be used in place of the intermediate and fine aggregate.

For crushed limestone or dolomite chips, meet the durability class required for the coarse aggregate. Acquire uncrushed pea gravel or coarse sand from any PCC approved durability class gravel. When the gravel durability is lower than the coarse aggregate durability requirements, the pea gravel is not to exceed 15% of total aggregate in the mix. Aggregate meeting the requirements of Article 4117 will be considered coarse sand.

4112.02 GRADATION.

A. Intermediate Aggregate.
For gradations, intermediate aggregate is considered coarse aggregate. Meet the following gradation limits:

Sieve Size	% Passing
1/2 inch (12.5 mm)	100
No. 4 (4.75 mm)	0-10

B. Coarse Sand.
Meet the following gradation limits:

Sieve Size	% Passing
1/2 inch (12.5 mm)	100
3/8 inch (9.5 mm)	90 – 100
No. 4 (4.75 mm)	75 – 95
No. 8 (2.36 mm)	60 – 90
No. 30 (600 µm)	10 – 60
No. 200 (75 µm)	0 – 1.5

4112.03 QUALITY.

A. Intermediate Crushed Stone.
Meet the following quality requirements:

Aggregate Quality	Maximum Percent Allowed	Test Method
Alumina [(a)]	0.5	Iowa 222
A Freeze	6	Iowa 211, Method A
Clay Lumps	0.5	I.M. 368

(a) If the Alumina value fails, determine the A Freeze value for specification compliance.

B. Pea Gravel and Coarse Sand.
The portion of coarse sand passing the No. 4 (4.75 mm) sieve shall meet the quality requirements of Article 4110.

For pea gravel and the portion of coarse sand retained on the No. 4 (4.75 mm) sieve, meet the

following quality requirements:

Maximum Permissible Amounts of Objectionable Materials	Maximum Percent Allowed	Test Method
Coal and carbonaceous shale	0.5	AASHTO T 113
Total of all shale, similar objectionable materials, coal, and iron combined.	1.0	AASHTO T 113
Organic materials, except coal.	0.01	I.M. 215
Unsound chert particles retained on 3/8 inch (9.5 mm) sieve (Nonstructural concrete)	3.0	I.M. 372
Unsound chert particles retained on 3/8 inch (9.5 mm) sieve (Structural concrete)	2.0	I.M. 372

Note: Chert particles which break into three or more pieces when subjected to the freezing and thawing test will be considered unsound.

Chert in aggregate produced from limestone sources is defined as unsound when any of the fractions of the crushed or uncrushed chert do not meet the soundness requirements.

Comments:

Member's Requested Change (Redline/Strikeout):

Section 4112. Intermediate Aggregate for Portland Cement Concrete.

4112.01 DESCRIPTION.

Crushed carbonate stone chips or pea gravel from approved sources as described in Materials I.M. 409. Coarse natural sand resulting from disintegration of rock through erosional processes, without addition of crushed over-sized material may be used in place of the intermediate and fine aggregate.

For crushed limestone or dolomite chips meet the durability class required for the coarse aggregate. Acquire uncrushed pea gravel or coarse sand from any PCC approved durability class gravel. When the gravel durability is lower than the coarse aggregate durability requirements the pea gravel is not to exceed 15% of total aggregate in the mix. Aggregate meeting the requirements of Article 4117 will be considered coarse sand.

4112.02 GRADATION.

A. Intermediate Aggregate.

For gradations, intermediate aggregate is considered coarse aggregate. Meet the following gradation limits:

Sieve Size	% Passing
1/2 inch	100
No. 4	0-10

B. Coarse Sand

Meet the following gradation limits:

Sieve Size	% Passing
1/2 inch	100
3/8 inch	90 – 100
No. 4	75 – 95
No. 8	60 – 90

No. 30	10 – 60
No. 200	0 – 1.5

4112.03 QUALITY.

A. Intermediate Crushed Stone

Meet the following quality requirements:

Aggregate Quality	Maximum Percent Allowed	Test Method
Alumina (a)	0.5%	Iowa 222
A Freeze	6%	Iowa 211, Method A
Clay Lumps	0.5%	I.M. 368

(a) If the Alumina value fails, the A Freeze value shall be determined for specification compliance.

B. Pea Gravel and Coarse Sand

For coarse sand, the portion passing the No. 4 sieve must meet the quality requirements of Article 4110.

For pea gravel and the portion of coarse sand retained on the No. 4 (4.75 mm) sieve meet the following quality requirements:

Maximum Permissible Amounts of Objectionable Materials	Maximum Percent Allowed	Test Method
Coal and carbonaceous shale	0.5%	AASHTO T113
Total of all shale, similar objectionable materials, coal, and iron combined.	1.0%	AASHTO T113
Organic materials, except coal.	0.01%	I.M. 215
Unsound chert particles retained on 3/8 inch sieve (Nonstructural concrete)	3.0%	I.M 372
Unsound chert particles retained on 3/8 inch sieve (Structural concrete)	2.0%	I.M 372

Note: Chert particles which break into three or more pieces when subjected to the freezing and thawing test will be considered unsound.

Chert in aggregate produced from limestone sources is defined as unsound when any of the fractions of the crushed or uncrushed chert do not meet the soundness requirements.

Reason for Revision:

New Section 4112. Needed since intermediate aggregates are being used in barrier rail, pre cast industry, and QMC mixes.

County or City Input Needed (X one)	**Yes**	**No** X
Comments:		

Industry Input Needed (X one)			**Yes** X	**No**	
Industry Notified:	**Yes** X	**No**	**Industry Concurrence:**	**Yes** X	**No**
Comments:					

SPECIFICATION REVISION SUBMITTAL FORM

Submitted by: Tom Reis	**Office:** Specifications	**Item 6**
Submittal Date: 2009.02.27	**Proposed Effective Date:** January, 2009	
Article No.: DS-01076 **Title:** Developmental Specifications for Cold In-Place Recycled Asphalt Pavement	**Other:**	

Specification Committee Action: Approved with changes as noted.

Deferred:	**Not Approved:**	**Approved Date:** 3/12/09	**Effective Date:** 6/16/09

Specification Committee Approved Text: See attached Draft DS.

Comments: The Office of Materials noted some additional changes may be needed. Article 01XXX.02, C, the last sentence of the indented paragraph after the second paragraph states, "The mix design will determine the target asphalt temperature and percent of water injected into the asphalt to achieve optimum foaming." This only applies to foamed asphalt. Article 01XXX.03, A, references Article 2001.13 for the spreader. The Office of Materials noted they have removed that reference and added the text "…a machine capable of spreading the CIR material in a uniform layer at the desired thickness and width in a uniformly loose condition..." The Office of Contracts expressed concern with the language that the spreader would be approved by the Engineer. They wanted to know how contractors would know if their spreader is approved when they are preparing their bids. The Office of Construction added they have not been satisfied with the results produced by contractors using spreaders. They expressed concern that contractors will not be able to achieve the quality required by the Developmental Specification.

The Office of Local Systems commented that most contractors doing CIR are already using pavers. The Specifications Section asked if it would create problems if only pavers were allowed. It was pointed out this could cause some contractors to invest in machinery they may not need if they can meet the specifications with a spreader. The Office of Contracts noted that if the spreader meets the specifications, then approval of the Engineer shouldn't be needed. The Specification Section noted they can run this Developmental Specification by County Engineers with language that allows only pavers. If the County Engineers don't approve of that language, the above language regarding spreaders will be added, but the requirement for the Engineer's approval will not be included. Pavers will be required on Primary roads. The Committee approved this action. (**NOTE:** The Specifications Engineer contacted 18 counties and of the counties responding, they overwhelmingly supported requiring a paver to be used and not allowing a spreader.)

The Office of Materials noted in Article 01XXX.03, C, the first sentence of the first paragraph has been changed to, "The Contractor shall mill the existing pavement to the specified ~~constant~~ nominal depth and lane width in one pass." They also pointed out the second paragraph of DS-01076.03, H, should not be the second paragraph of the proposed DS-01XXX.03, G, but should be the second paragraph of the proposed DS-01XXX.03, H with changes as indicated. The Office of Construction expressed concerns with this paragraph. They feel that working days should not be charged during the time the Contractor is waiting for the CIR to achieve proper moisture content, since this is a drying period and not an actual curing period. Their understanding is that the Office of Contracts adds working days to the contract period to allow for this drying period. The Office of Construction noted that since this is a drying period, and not a curing period, it should not be considered the controlling operation.

The Committee agreed that working days should not be charged during the CIR drying period and the Office of Contracts should not add working days to the contract period to allow for the drying period. The Office of Construction emphasized that working days would not be charged if the Contractor is unable to work because they are waiting for the CIR to dry. The Office of Contracts asked where this

would be explained. The Office of Construction explained they will discuss this with their field personnel.

Specification Section Recommended Text: See attached Draft DS.

Comments: The Specification Committee recommended at the November 13, 2008 meeting to have the DS reviewed by a small group of users and their comments have been incorporated into the DRAFT.

Member's Requested Change: **(Do not use 'Track Changes', or 'Mark-Up'. Use ~~Strikeout~~ and Highlight.**

Reason for Revision: Updates to reflect revised Materials I.M. 504, change to the "cured" moisture content to reflect current practice, and elimination of engineered emulsion.

County or City Input Needed (X one)			**Yes**	**No**	
Comments:					
Industry Input Needed (X one)			**Yes**	**No**	
Industry Notified:	**Yes**	**No**	**Industry Concurrence:**	**Yes**	**No**
Comments:					

Draft DS-01XXX
(Replaces DS-01076)

Iowa Department of Transportation

~~****THIS IS A GENERAL REWRITE. PLEASE READ CAREFULLY.****~~

DEVELOPMENTAL SPECIFICATIONS FOR COLD IN-PLACE RECYCLED ASPHALT PAVEMENT

Effective Date
January 21, 2009

THE STANDARD SPECIFICATIONS, SERIES OF 2001, ARE AMENDED BY THE FOLLOWING MODIFICATIONS. THESE ARE DEVELOPMENTAL SPECIFICATIONS AND SHALL PREVAIL OVER THOSE PUBLISHED IN THE STANDARD SPECIFICATIONS.

Replace all of Section 2318 of the Standard Specifications with the following:

01XXX.01 DESCRIPTION.
Cold in-place recycling (CIR) consists of milling the existing asphalt pavement, processing and mixing the recycled asphalt pavement with an asphalt stabilizing agent and water (if required), and placing and compacting this mixture.

01XXX.02 MATERIALS.

A. Asphalt Stabilizing Agent.
~~Unless otherwise specified in the contract documents, t~~The asphalt stabilizing agent ~~shall~~ will be specified in the contract documents and will ~~at the Contractor's option,~~ be one of the following:

1. Standard Asphalt Emulsion (HFMS-2s) meeting the requirements of Section 4140 of the Standard Specifications shall be used on Primary and Interstate projects. CSS-1 emulsion meeting the requirements of Section 4140 of the Standard Specifications may be used in place of HFMS-2s on other projects ~~when the traffic permitted on the CIR layer is less than 500 ADT~~.

2. Foamed Asphalt using PG 52 -34 or PG 46 -34 asphalt binder meeting the requirements of Section 4137 of the Standard Specifications may be used on Interstate, Primary, Secondary, and local projects.

~~**3.** Engineered Emulsion meeting the requirements of the mix design.~~

B. Recycled Asphalt Pavement.
The processed recycled asphalt pavement (RAP) is intended to conform to the following gradation. The gradation may be revised with the approval of the Engineer, but the top size of the material shall not exceed 50% of the depth of the compacted recycled mat.

Sieve Size	% Passing
1 1/2 inch (37.5 mm)	98 to 100
1 inch (25 mm)	90 to 100

C. Mix Design.

A mix design process will not be performed for standard asphalt emulsion or foamed asphalt unless otherwise stated in the contract documents. ~~A mix design is required for engineered emulsion.~~ The following application rates per square yard per inch of compacted thickness will be used when no mix design is performed.

Asphalt Stabilizing Agent	Application Rate per square yard per inch (per m^2 per 25 mm)	
Standard Asphalt Emulsion	0.30 gallons (emulsion)	1.325 L
Foamed Asphalt	0.0011 tons (asphalt binder)	1.175 kg
~~Engineered Emulsion (estimate only)~~	~~0.40 gallons (emulsion)~~	~~1.775 L~~

When a mix design is required, the following provisions shall apply:

~~**1. Mix Design using Foamed Asphalt.**~~

The Contractor ~~will~~ shall provide the Engineer with a representative 150 pound (22 kg) bulk sample of the existing pavement surface as directed by the Engineer following the sampling options in ~~Appendix A~~ Materials I.M. 504 and 10 gallons (38 L) of the intended asphalt stabilizing agent. The Engineer will provide the details of the mix design to the Contractor no later than 6 weeks after receiving the samples. The mix design will be performed by the Central Materials Laboratory as per Materials I.M. 504, Appendix A and will establish the amount of asphalt binder to incorporate into the RAP. The mix design will determine the target asphalt temperature and percent of water injected into the asphalt to achieve optimum foaming.

~~**2. Mix Design using Engineered Emulsion.**~~

~~The Contractor shall submit a mix design to the Engineer and the District Materials Engineer for approval two weeks before the anticipated CIR start date. The mix design shall follow IM 504 Appendix A .~~

01XXX.03 CONSTRUCTION REQUIREMENTS.

Except in specific cases when permitted by the Engineer, the Contractor shall perform CIR between May 1 and October 1.

The Contractor shall not perform recycling operations when the ambient temperature is below 60°F (15°C); when the weather is foggy or rainy; or when weather conditions are such that proper mixing, placing, and compacting the recycled material cannot be accomplished.

A. Equipment.

The Contractor shall furnish a self-propelled machine capable of milling the existing asphalt pavement to the depth shown in the contract documents in one pass. The machine shall be equipped with automatic depth control, maintain a constant cutting depth and width, uniform grade, and uniform slope. It shall also be capable of producing the properly sized RAP or additional screening and crushing will be required.

The Contractor shall furnish equipment capable of mixing the RAP and asphalt stabilizing agent into a homogeneous CIR mixture. The equipment shall meet the requirements of Article 2001.22, F, of the Standard Specifications and provide a positive means, including visual display, for accurately controlling the rate of flow and total delivery of the asphalt stabilizing agent into the mixture in relation to the quantity of RAP being recycled. The asphalt stabilizer application system shall be capable of adjusting for the width of recycling such that overlapped CIR mixture maintains the designed asphalt stabilization content.

When foamed asphalt stabilizing agent is used, the asphalt foaming system shall accurately and

uniformly inject the specified percent of water into the hot asphalt binder. The equipment shall be fitted with a test nozzle to provide field samples of foamed asphalt. Tankers supplying the hot asphalt binder shall be equipped with a thermometer to continuously measure the temperature of the asphalt in the bottom third of the tank.

The Contractor shall use a bituminous paver meeting the requirements of Article 2001.19 of the Standard Specifications ~~or a spreader meeting the requirements of Article 2001.13 of the Standard Specifications~~ to place the CIR material. Heating the screed of the bituminous paver will not be permitted.

Rollers for compacting the CIR material shall meet the requirements of Article 2001.05 of the Standard Specifications. As a minimum, the Contractor shall have for use a self-propelled double drum vibratory steel roller and a self-propelled 25 ton (25 Mg) or greater pneumatic tire roller. The vibratory roller may be used in the static or vibratory mode.

B. Preparation.
Prior to initiating the recycling operation, the Contractor shall clear all vegetation and debris within the width of pavement to be recycled in accordance with Article 2212.04, A, of the Standard Specifications.

C. Milling the Existing Pavement.
The Contractor shall mill the existing pavement to the specified constant depth and width in one pass. The RAP shall be processed to the required gradation. When specified in the contract documents or when approved by the Engineer, the pavement surface may be pre-milled to the slope specified in the contract documents ~~a uniform 2% cross slope~~. RAP from pre-milling shall be removed from the project.

When the plans note that the milling operation will encounter a paving fabric, the Contractor shall make the necessary adjustments in equipment or operations so that no fabric piece has any dimension exceeding a length of 4 inches (100 mm). The Contractor shall remove RAP containing over-sized pieces of paving fabric.

D. Mixing the Recycled Material.
During recycling operations, the Contractor shall apply the asphalt stabilizing agent to the RAP at the specified application rate. The Engineer may vary the application rate of asphalt stabilizing agent as required by existing pavement conditions. The Contractor shall determine the amount of additional water needed to facilitate uniform mixing with the asphalt stabilizing agent and to achieve a stable pavement layer above the minimum specified density. The water may be added prior to or concurrently with the asphalt stabilizing agent. Adding water to facilitate uniform mixing shall not adversely affect the asphalt stabilizing agent.

E. Placement of the Recycled Material.
The Contractor shall deposit the CIR mixture in a windrow, spreader~~,~~ or paver (as required by Article 01XXX.03, A), or loaded into trucks, without segregation.

The Contractor shall place and finish the CIR mixture in one continuous pass, without segregation. Unless otherwise noted in the contract documents, the surface of the CIR lift shall have a uniform cross-slope ~~of 2%~~ as specified in the contract documents, but at no time shall the lift thickness be less than 2 inches (50 mm). When a pick-up machine is used to feed the windrow into the paver hopper, the pick-up machine shall be capable of picking up the entire windrow to the underlying material.

F. Compaction and Density.
The field density for Interstate and Primary Roads shall be a minimum of 94% of laboratory density based on the dry weight of compacted material in accordance with ~~Appendix A~~ Materials I.M. 504. The field density for all other roads shall be a minimum of 92%.

The Contractor shall perform initial rolling with a pneumatic tired roller. The Contractor shall perform final rolling to eliminate pneumatic tire marks by using steel wheel rollers, either in static or vibratory mode.

The Contractor shall discontinue any type of rolling resulting in cracking, movement, or other types of pavement distress until such time the problem can be resolved.

If there is a significant change in mix proportions, weather conditions, or other controlling factors the Engineer may require construction of test strips to check target density.

G. Opening the CIR Layer to Traffic.
After compaction is complete, the Contractor ~~will~~ shall determine when the CIR layer is stable to open to traffic. ~~After opening to traffic, the surface of the recycled pavement shall be maintained in a condition suitable for the safe movement of traffic. Excessive loose particles that may develop on the pavement surface shall be removed by power brooming.~~

~~**H. Placement of Surface Course.**~~
~~Any subsequent HMA overlay or surface treatment will not be allowed until the moisture content of the CIR layer is no more than 0.3% above the residual moisture content or 1.5%, which ever is greater. The Engineer may adjust this drying period depending on field conditions.~~

~~On projects with less than 2500 ADT, t~~The Contractor has 14 calendar days after the CIR layer is complete and initially achieves the allowable moisture content to place the first lift of HMA overlay or specified surface treatment. Any damage to the CIR layer after the 14 calendar days shall be corrected at the Contractor's expense.

~~On projects with more than 2500 ADT, the Contractor has 10 working days after the CIR layer initially achieves the allowable moisture content to place the first lift of HMA overlay or specified surface treatment. This working day limitation applies separately for each day of CIR rehabilitation. Any damage to the CIR layer after the 10 working days shall be corrected at the Contractor's expense.~~

H. Placement of Surface Course.
Subsequent HMA overlay or surface treatment will not be allowed until the moisture content of the CIR layer is no more than 0.3% above the residual moisture content or 2.0%, which ever is greater. The Engineer may adjust this drying period depending on field conditions. ~~The CIR shall be retested until the moisture content is at or below 2.0%.~~ The CIR shall be retested until the moisture content is at or below the limits stated above.

01XXX.04 QUALITY CONTROL
The Contractor shall be responsible for quality control of the materials and CIR process. The Contractor shall test the items listed below at the frequency listed in Materials I.M. 204. All samples shall be taken and delivered by the Contractor to the District Materials Laboratory in accordance with ~~Appendix A~~ Materials I.M. 504. Each day of CIR operation shall be defined as a lot for quality control sampling and testing.

A. Asphalt Stabilizing Agent.
The asphalt stabilizing agent shall be sampled and tested according to Materials I.M. 204.
The asphalt stabilization agent shall be applied at the target application rate within ±0.06 gallon per square yard per inch (0.25 L/m^2/25 mm) for standard ~~and engineered~~ emulsion and within ~~(~~±0.000165 tons per square yard per inch (0.175 kg/m^2/25 mm) for foamed asphalt~~) of the target application rate~~.

B. Binder Temperature using Foamed Asphalt.
When foamed asphalt is used, the asphalt binder shall be maintained at a temperature within ±20°F (10°C) of 310°F (155°C) or the optimum temperature established by the mix design. The injection water shall be maintained at the target ±0.5%. The foaming characteristics of each new tanker load

will be verified by measuring a sample from the equipment's test nozzle.

C. Profile and Cross-Slope Testing.
When directed by the Engineer, the Contractor shall measure the profile of the center of each lane of compacted CIR mat with a profilograph. Bumps and dips in the profile greater than 1 inch in 25 feet (25 mm in 7.6 m) shall be corrected. Cross-slope of the compacted CIR mat shall be within 0.4% of the desired slope. ~~When directed by the Engineer, the Contractor shall measure the profile of the center of each lane of the compacted CIR mat with a profilograph.~~ The Contractor will be paid $400 per lane-mile ($250 per lane-km) for profiling the length directed by the Engineer. ~~Acceptable corrective measures include profile milling or blading and recompaction within 24 hours of the initial placement or HMA leveling course. Corrective measures shall be at the Contractor's expense.~~

Bumps, dips, and cross-slope shall be corrected by the Contractor to meet the limitations noted in the previous paragraph. Corrective measures may involve profile milling, blading, and recompaction within 24 hours of the initial placement, or placement of a HMA leveling course. Corrective measures shall be at no additional expense to the Contracting Authority.

D. Moisture and Density Tests.
The Contractor shall perform nuclear gauge moisture and density tests in accordance with ~~Appendix A~~ Materials I.M. 504 within 24 hours of completing each lot at locations determined by the Engineer. During each lot of CIR production, the Contractor shall furnish a 40 pound (18 kg) sample, sealed in plastic, of loose CIR mixture from a location determined by the Engineer and deliver the sample as soon as possible after sampling to the District Materials Laboratory daily for density determination. The Quality Index for density does not apply. Sublots that do not achieve the minimum required density shall be recompacted within 2 calendar days after the CIR layer was placed to meet the target density.

01XXX.05 METHOD OF MEASUREMENT.

A. Cold In-Place Recycled Asphalt Pavement.
The Engineer will compute the area in square yards (square meters) from the measured longitudinal length of pavement and the width of pavement specified in the contract documents.

B. Asphalt Stabilizing Agent.
The Engineer will measure the Asphalt Stabilizing Agent in gallons (liters) at 60°F (15°C) for standard ~~or engineered~~ emulsion, or tons (megagrams) for asphalt binder, through a calibrated pump used for metering the total delivery of the agent or through delivery ticket quantity.

01XXX.06 BASIS OF PAYMENT.

A. Cold In-Place Recycled Asphalt Pavement.
The Contractor will be paid the contract unit price per square yard (square meter) for Cold In-Place Recycled Asphalt Pavement. This payment shall be full compensation for all labor, material including mixing water, and equipment necessary for milling, mixing, spreading, placing, shaping, and compaction of the completed Cold In-Place Recycled Asphalt Pavement.

B. Asphalt Stabilizing Agent.
The Contractor will be paid the contract unit price per gallon (liter) or ton (megagram) for Asphalt Stabilizing Agent. This payment shall be full compensation for all labor, materials, and equipment necessary for furnishing the stabilizing agent.

Appendix A – Instructions for Cold In-place Recycled Asphalt 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.

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 this appendix.

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 this appendix.

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. 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 30 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:

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

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

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

2. Split the remainder of the bulk sample and prepare a 4000 g gyratory specimen for 6-inch (150 mm) gyratory molds from each split sample. If the measured moisture content is below 3.5%, increase the moisture content in the sample to 4.0% before compaction. 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. After compaction, remove the specimen from the mold and measure the height to the nearest 0.1 mm using a dial indicator or suitable caliper. Take a minimum of four measurements, compute the average of the measurements, and round the average to the nearest 0.5 mm.

If the specimen is too tender to handle or distorts when removed from the mold, the height of the specimen may be recorded from the gyratory compactor at the completion of the compaction process.

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

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

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

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

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

NOTE: Variations in laboratory dry density of more than 3 pounds per cubic foot (50 kg/m^3) between successive samples shall be investigated promptly. Testing of additional samples should be included in the investigation.

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. 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

During the first 2 working days, 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.

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

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.

PROFILE AND CROSS-SLOPE TESTING

The Engineer will perform an onsite inspection to determine if the profile and cross-slope of the finished CIR layer is acceptable. If the Engineer and Contractor cannot agree on locations that have unsatisfactory profile, the Engineer can direct the Contractor to run a profiler on the sections in question. The results of the profile measurement that do not comply with the specified limits shall be corrected by the Contractor to the satisfaction of the Engineer.

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, 1.5% 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 1.5%, that

section of CIR layer may never achieve the standard 1.5% 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.

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

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

3)

4) 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.

TIMELY OVERLAY OF CIR LAYER

Many CIR layers are opened to traffic before the HMA overlay or chip seal are placed. This places the CIR layer at risk of raveling and the pavement structure at risk of base failure if traffic and climate conditions are unfavorable. The owner agency accepts this risk when the CIR layer is open to traffic. The specifications establish a reasonable period of time for the Contractor to begin placing the overlay during which the owner agency assumes the risk. After this period, the Contractor becomes liable for any damage before the HMA overlay is placed.

The period of time is dependent on the level of traffic using the route. Most CIR projects are covered under the lower traffic criteria. The Contractor is given a reasonable period of time to coordinate the start of the HMA overlay after the entire CIR layer is complete. Under the higher traffic criteria, the Contractor is expected to recognize the additional effort required to coordinate the CIR and HMA overlay.

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).

MIX DESIGN METHOD FOR CIR WITH FOAMED ASPHALT

The mix design for CIR with foamed asphalt is performed by the Iowa DOT Central Laboratory. The primary steps in the mix design process are:

- Determine the optimum foaming characteristics of the asphalt binder.
- Determine the optimum moisture content of the RAP for compaction.

- Prepare, compact, and cure CIR mixture over a range of foamed asphalt contents
- Determine the optimum foamed asphalt content for the CIR mixture.

1. DETERMINE THE OPTIMUM FOAMING CHARACTERISTICS

By foaming the asphalt binder, the viscosity of the asphalt is significantly reduced to permit uniform mixing with cold RAP material. The ability to foam asphalt is controlled by the asphalt binder temperature and the amount of water injected into the asphalt. These values generally range from 280 to 320ºF (135 to 160ºC) and 1.5 to 3.5% injected water. The foamed is measured by the expansion ratio and half-life. The foam expansion ratio will increase (5 times to 15 times) as the amount of water injected increases. The half-life of the foam decreases (15 seconds to 5 seconds) as the amount of water injected increases. These conflicting conditions are merged to select the best foam properties for the project. An expansion ratio of 10 and half-life of 10 seconds are suitable for most CIR projects.

The specification sets the temperature and injection water at values that are acceptable for most binders used for CIR in Iowa when a mix design is not performed.

2. DETERMINE THE OPTIMUM COMPACTION MOISTURE

CIR mixture is compacted to a maximum density through the lubricating affect of the free moisture in the mixture. This is not the moisture injected into the asphalt binder to create foam. To determine the optimum compaction moisture, a group of RAP samples are compacted with different moisture contents. The resulting dry densities are plotted to determine the optimum moisture required for compaction. Mix designs prepared over the last several years indicate that the moisture required to achieve maximum RAP density is approximately 4 percent.

Once the optimum moisture content is determined, the value is adjusted down slightly to account for the foamed asphalt added to the mixture

3. PREPARE MIXTURES

The bulk sample of RAP may require additional processing to achieve a gradation that passes the 1 inch (25 mm) sieve. The RAP is dried in open pans at room temperature, sieved into 3 size fractions (+3/8 inch, +1/8 inch, pan)(+9.5 mm, +2.36 mm, pan), and re-blended to achieve uniform samples.

Prepare a blending chart to determine what amounts of foamed asphalt will be added to the RAP. A minimum of three foamed asphalt contents should be selected. The preferred contents are 1.5%, 2.0%, 2.5%, and 3.0%.

Each batch should have sufficient mixture to compact three 4 inch (100 mm) gyratory samples. The dry RAP sample and compaction water are added to the mixing bowl and mixed for 45 to 60 seconds. The foamed asphalt is sprayed into the damp RAP while the mixer continues to mix the sample. Continue mixing for an additional 60 seconds.

4. COMPACT AND CURE MIXTURES

The gyratory compactor is used to compact each sample to 25 gyrations. Extrude the specimen and place it in the oven to cure at 105ºF (40ºC) for 72 hours. Remove the specimens from the oven and allow them to cool to room temperature.

5. TEST MIXTURES

Measure the volume and mass of each specimen and determine the density. Sort the specimens into equal sublots based on height and density for further testing.

Dry condition the samples of one sublot in an oven at 77ºF (25ºC) for 2 hours. The other sublot of specimens are placed in a 77ºF (25ºC) water bath for 20 minutes, vacuum saturated (50mm Hg) for 50 minutes, and then allowed to rest in the 77ºF (25ºC) bath for an additional 10 minutes.

Perform the indirect tensile test (IDT) and calculate the average IDT strength for each sublot. Plot the average IDT wet and dry strength for each foamed asphalt content.

6. MIX DESIGN REPORT

The mix design report will provide the results for optimum foam characteristics, optimum compaction moisture content, and optimum foamed asphalt content. Specific report values include:

- Asphalt binder temperature for foaming (ºF or ºC)
- Percent injection water for foaming (% of asphalt by weight)
- Optimum compaction moisture content (% of dry RAP by weight)
- Optimum asphalt foam content (% of dry RAP by weight)

MIX DESIGN METHOD FOR CIR WITH ENGINEERED EMULSION

The mix design for CIR with engineered emulsion is performed by the Contractor. The primary steps in the mix design process are:

- Process, dry, sieve, and blend the RAP.
- Select the engineered emulsion.
- Prepare, compact, and cure CIR mixture over a range of emulsion contents.
- Determine the engineered emulsion content for the CIR mixture.

1. PREPARE THE RAP SAMPLE

The bulk sample of RAP may require additional crushing to meet the gradation band shown. The RAP is dried in open pans at room temperature, sieved into a minimum of 3 size fractions (+3/8 inch, +1/8 inch, pan)(+9.5 mm, +2.36 mm, pan), and re-blended to achieve uniform samples.

Sieve Size	%passing
1.5 inch (37.5 mm)	100
1.0 inch (25 mm)	100
3/4 inch (19 mm)	85-95
No. 4 (4.75 mm)	40-55
No. 30 (600 µm)	5-15
No. 200 (75 µm)	0.5-3

2. SELECT THE ENGINEERED EMULSION

Standard asphalt binder grades used for asphalt emulsions may not have appropriate characteristics to achieve the desired CIR mixture properties. By trial and error, the designer must select the base asphalt grade for the emulsion.

3. PREPARE MIXTURES

Prepare a blending chart to determine what amounts of engineered emulsion will be added to the RAP. A minimum of three emulsion contents should be selected. The preferred contents are 2.0%, 2.5%, 3.0% and 3.5%.

In addition to the engineered emulsion, 1.5% water is added to represent the water used in the milling process.

The dry RAP sample and 1.5% water are added to the mixing bowl and mixed for 45-60 seconds. The engineered emulsion is added to the damp RAP while the mixer continues to mix the sample. Mixing continues for an additional 60 seconds. A set of three specimens can be prepared in each batch.

4. COMPACT AND CURE MIXTURES

Specimens shall be compacted immediately after mixing. Do not use paper disks. Specimens shall be compacted with a gyratory compactor in a 4-inch (100 mm) mold at 1.25 degree angle, 87 psi (600 kPa) ram pressure, and 30 gyrations. The mold shall not be heated. Extrude specimens from molds immediately after compaction. Place each specimen in a small container to account for material loss from the specimens during curing.

Cure compacted specimens in 140ºF (60ºC) forced draft oven for 48 hours. After curing, cool specimens at ambient temperature for 12 hours.

5. TEST MIXTURES

~~**A.** Determine bulk specific gravity (density) of each compacted (cured and cooled) specimen according to ASTM D 2726 or equivalent; however, the mass of the specimen in water (measurement C) should be recorded after 1 minute of submersion.~~

~~**B.** Determine specimen heights according to ASTM D 3549 or equivalent. Alternatively, the height can be obtained from the gyratory compactor readout.~~

~~**C.** Sort the specimens into equal sublots based on height and density for further testing.~~

~~**D.** For the three specimens of one sublot, determine corrected Marshall stability by ASTM D 1559 Part 5 at 100ºF (40ºC) 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.~~

~~**E.** For the three specimens from the other sublot, vacuum saturate to 55% to 75%, soak in a 75ºF (25ºC) water bath for 23 hours, followed by a 1 hour soak at 100ºF (40ºC). Determine corrected Marshall stability.~~

~~**F.** Compute the retained strength as the average moisture conditioned Marshall stability strength divided by the average dry Marshall stability strength.~~

~~**G.** Perform the thermal cracking test for critical cold temperature. The temperature is based on FHWA LTPPBind software for 50% reliability at 3 inches (75 mm) below the pavement surface. The required temperature for the specification is –20ºC. Perform the indirect tensile testing according to AASHTO T 322 with the following exceptions:~~

~~1) Specimens shall be 6 inches (150 mm) in diameter and at least 4 1/2 inches (115 mm) in height and compacted to the design density and emulsion content determined from the Marshall Stability Testing. Trial specimens are needed to establish the number of gyrations for compacting the 6-inch (150 mm) specimens. Test specimens shall be cured at 140ºF (60°C) for 72 hours. After curing, two specimens shall be cut from each compacted specimen to 2 inches (50 mm) in height.~~

~~2) Measure the bulk specific gravity of each cut specimen.~~

~~3) Test two specimens at each of three test temperatures (-20ºC, -10ºC, 0ºC).~~

~~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 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 three temperatures).~~

~~**H.** Perform the raveling test. 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 (International Slurry Seal Association; 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 (mass) of the abrasion head and hose in contact with the specimen should be 1.3 pounds ± 0.5 ounce (600 g ± 15 g). 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 3/8 inch (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. 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) Prepare two samples at the design moisture content and emulsion content. The size of each sample should be sufficient to meet the compacted specimen dimensions described below. (note: 6 pounds (2.7 kg) is an approximate weight (mass) to meet the criteria).

2) After mixing, place the mixture into a 6 inches (150 mm) gyratory compaction mold and compacted to 20 gyrations. The compacted specimen height shall be 2 3/4 inches ± 1/4 inch (70 mm ± 5 mm).

3) Extrude the samples from the compaction mold and placed on a flat pan to cure at a temperature of 50ºF +/- 2ºF (10ºC +/- 1ºC) for 4 hours ± 5 minutes.

4) The specimens shall be weighed after curing, just prior to testing.

5) 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 1/4 inch (5 mm) if abrasion allows.

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

7) The percent raveling loss shall be determined as follows:

$$\text{Raveling Loss} = \frac{(\text{Weight Before Test} - \text{Weight After Abrasion})}{\text{Weight Before Test}} \times 100$$

8) The average of the two specimens shall be reported as the Percent 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% 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.

I. Determine if the selected engineered emulsion within the emulsion content range tested meets the following properties. If not, repeat the design with another engineered emulsion.

Test	**Criteria**	**Purpose**
Marshall stability	1,000 lb. (567 kg) min.	Stability under traffic
Retained strength	70% min.	Ability to withstand moisture damage
Thermal Cracking	-20ºC max.	Resist low temperature cracking
Raveling Test	2% max.	Raveling Resistance

6. MIX DESIGN REPORT

The mix design report will provide the following results at the optimum engineered emulsion content:

- Engineered emulsion base asphalt PG grade
- RAP gradation
- Mixture dry density (lb/ft^3 or kg/m^3)
- Marshall stability (lb or kg)
- Percent retained strength (%)
- Critical low temperature (C)
- Percent raveling loss (%)