# SUDAS Revision Submittal Form

**Status Date:** As of 3/15/2018 **Topic:** Cold-in-place recycling

**Manual:** Design and Specs **Manual Location:** Design Section 5J-2; Spec Section 7090

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**Requested Revision:** See attached.

**Reason for Revision:** Developed new sections for cold-in-place recycling projects.

**Comments:** None.

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**District:** ☐ 1 ☐ 2 ☐ 3 ☒ 4 ☐ 5 ☐ 6

**Initial Comments:** Specs - Add a time for the surface course in addition to the percentage (i.e. no sooner than 14 days - check Iowa DOT Specs). *Note - done.*

**Final Comments:**

**Action:** ☐ Deferred ☐ Not Approved ☐ Approved

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**District:** ☐ 1 ☐ 2 ☒ 3 ☐ 4 ☐ 5 ☐ 6

**Initial Comments:** None.

**Final Comments:**

**Action:** ☐ Deferred ☐ Not Approved ☐ Approved

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**District:** ☒ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6

**Initial Comments:** Specs - One suggested adding "generally" to the dates listed in 3.01, A, 1. Also suggested changing the statements in 3.01, A, 2 to be positive rather than negative. *Note - added "general" to say "general criteria includes" in 3.01, A, 2 and also made the statements positive.*

**Final Comments:**

**Action:** ☐ Deferred ☐ Not Approved ☐ Approved

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**District:** ☐ 1 ☒ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6

**Initial Comments:** Specs - Noted an error in 2.02. *Note - corrected.*

**Final Comments:**

**Action:** ☐ Deferred ☐ Not Approved ☐ Approved

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**District:** ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☒ 6

**Initial Comments:** Specs - Suggested adding the overnight temp to match the design section. Also requested revising 3.11, B to use a more reasonable measurement. *Note - these changes were made.*

**Final Comments:**

**Action:** ☐ Deferred ☐ Not Approved ☐ Approved

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|---|---|
| **District:** | ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☒ 5 ☐ 6 |
| **Initial Comments:** | Specs - A few said they don't see the necessity to pay for JMF; bad precedence to start. Another said it will have to be a site specific JMF and will be more work. What's the cost difference between a regular HMA JMF vs. CIR (percentage)? Add development of JMF to the "includes" item. Add to HMA as well? 3.09 - questioned the 80 degrees - should that be 60 degrees air temp? *Note - the temperature level was clarified.* |
| **Final Comments:** | |
| **Action:** | ☐ Deferred ☐ Not Approved ☐ Approved |

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|---|---|---|
| **District:** | ☒ 1 ☒ 2 ☒ 3 ☒ 4 ☒ 5 ☒ 6 | **2/14/18 Webinar** |
| **Comments:** | None. | |

**Final District Action Summary:**

**Board of Directors Action:**

# Cold-in-Place Recycling

## A. General

Cold-in-place recycling (CIR) is the process of recycling an asphalt pavement in-place with a train of equipment that can range from a single unit to a multi-unit train. In CIR, the existing asphalt pavement is cold milled to produce RAP, which is then further processed, placed, and compacted in one continuous operation on the roadway.

The advantages of CIR over other rehabilitation/reconstruction techniques include:

- Conservation of renewable resources
- Energy conservation compared to other rehabilitation/reconstruction processes
- Surface irregularities are corrected
- A portion of existing cracks are removed and reflective cracks mitigated
- Rutting, potholes, and raveling are eliminated
- Base and subgrades are not disturbed
- Pavement cross-slope and profile are improved
- Reduced traffic disruptions and user inconvenience compared to other rehabilitation/reconstruction techniques
- Reduced or no edge drop-offs
- Cost savings compared to other rehabilitation/reconstruction options

## B. Pavement Assessment

When determining whether the appropriate rehabilitation method is a CIR project the following information should be evaluated:

- Age of the pavement
- Thickness of the existing pavement
- Delamination or evidence of stripped aggregates
- Grade and type of existing binder
- Gradation of existing aggregate
- Presence of any fabric or other geosynthetic interlayers
- Past pavement condition surveys
- Subbase/subgrade support quality
- Utility interference

Age of the existing pavement is a good indicator of the stiffness of the existing binder and the expected hardness during cold planning. It is also an indicator of the quality of the underlying support structure.

The thickness of the existing pavement affects treatment depth. Generally CIR projects involve depths of 3 to 4 inches with some as thin as 2 inches and some up to 5 inches provided good compaction can be accomplished. Treatment depths should be a minimum of three times the maximum size of the aggregate to aid compaction. CIR treatment depths should extend through delaminated or poorly bonded lifts to prevent those sections from being loosened and removed during the cold planning process thus creating uneven treatment depths.

Knowledge of the existing binder grades affects the mix design for the CIR product. Soft binders or binders containing solvents tend to be less stable, which may signal the need for additives such as cement, lime, or new aggregate. Harder binders may call for additional recycling agents since less activation of the existing binder occurs. Specialty mixtures such as open-graded drainage layers, open-graded friction courses, and stone matrix asphalt will affect the mix design and construction techniques.

If fabric or other geosynthetic interlayers are present, the recycled depth must either extend below the interlayer so that it is removed, or be a minimum of 1 inch above it to prevent tearing of the fabric and delamination of the pavement above the fabric.

In addition to record information, a field inspection is needed to determine the condition of the existing pavement. The current type, severity, and frequency of pavement distress should be documented. Pavements that have structurally sound bases but surface distresses, such as cracking, rutting, and raveling are prime candidates for CIR. The CIR process can be effective in mitigating cracking if the new layer removes about 70% of the depth of the cracks

Two elements of structural capacity need to be evaluated. The first is what pavement thickness should be developed to address the needs of the anticipated traffic mix over the life of the rehabilitation project. Generally, the new CIR layer has structural coefficients of 0.30 to 0.35 per inch. The actual structural coefficient is based on the amount and type of recycling agents and if additives are used. If the traffic mix calls for additional pavement, an asphalt or concrete overlay can be added to address the structural needs.

The second structural element relates to the ability of the remaining pavement structure to support the recycling equipment during the construction process. Pavements with extensive base failures are not good candidates for CIR. The assessment of the load carrying capacity of the remaining pavement and underlying subbase and subgrade becomes more important for thinner sections. Equipment used for CIR is generally heavy and without sufficient structure; the equipment can punch through the remaining material and into the subgrade.

Three means of determining the strength of the remaining pavement include ground penetrating radar (GPR), dynamic cone penetrometer (DCP), and falling weight deflectometer (FWD). It is important to undertake this testing at the same time of year when moisture conditions in the remaining pavement base, subbase, and subgrade are similar to those at the anticipated time of construction.

Field samples from the existing pavement should be collected to obtain representative material throughout the project area. The gradation of the RAP and properties of the mineral aggregate will affect the amounts of recycling agent, additives, and on final mix performance.

The final assessment includes accessibility for the equipment, especially in urban areas. Although the exact equipment to be used by the successful bidder is not known, an evaluation using typical equipment should be made. Such things as small radii, T-intersections, bridges, overhanging vegetation, and many surface utility structures will influence whether CIR is the appropriate rehabilitation technique to apply. Small cold planers may be needed to facilitate the recycling of the entire roadway.

The presence, frequency, and elevation of utility structures needs to be evaluated. Manholes, valves and other structures should be lowered to a point a minimum of 2 inches below the CIR treatment depth; generally involving removal of the casting. A steel plate should then be installed over the manholes. After the CIR treatment and placement of any overlay, the manholes can be adjusted to match the surface elevations. Special treatment of utility structures that cannot be lowered may involve milling the material around the structure with smaller equipment.

## C. Mix Design

The mix design is a laboratory procedure that establishes the job mix formula (JMF) to meet the project requirements for long-term service life of the recycled pavement. Mix design procedures that use Superpave principles are the most widely used. The procedures use either Superpave Gyratory Compactor or 75-blow Marshall Compaction. Mixture evaluations should address initial and cured strength, resistance to moisture-induced damage, raveling resistance, and resistance to thermal cracking.

The mix design should include the following steps:

- Obtain samples from the existing pavement
- Determine binder content and gradation of the extracted aggregate
- Crush the materials and determine gradation
- Select type and grade of bituminous recycling agent
- Select type and grade of recycling additive, if required
- Prepare and test specimens
- Establish job mix formula

The JMF should specify the type and grade of bituminous recycling agent, optimum recycling agent content, mix water content, any additive type and quantity, if used, and laboratory compacted maximum density at the optimum moisture content.

## D. Recycling Agents and Additives

1. **Recycling Agents:** The correct selection of the type and grade of recycling agent is critical for proper performance of the CIR project. The most common types of recycling agents are emulsified asphalts and foamed asphalts.

   Emulsified asphalt consists of an asphalt binder, water, and an emulsifier. They can be formulated with ingredients to enhance specific mixture properties, to aid production and/ or constructability. Ingredients added can include solvents, cutters, rejuvenating agents, accelerants, retarders, water reducers, polymers, and peptizers. The chemistry of the emulsified asphalt and the reclaimed materials (RAP, granular materials, and water) has a major influence on the stability and breaking-time of the emulsified asphalt. Thus, it is important to confirm the compatibility of the emulsified asphalt with the remaining materials in the mix design process.

   Foamed asphalt is a mixture of air, water, and hot asphalt. It occurs when a small amount of cold water is introduced into hot asphalt binder inside an expansion chamber. The water causes the asphalt binder to expand rapidly into millions of bubbles resulting in a foam. The foaming occurs as the water changes states from a liquid to a vapor and expands from 8 to 15 times its original volume. In the foam state, the asphalt binder's viscosity is greatly reduced and its surface area is greatly increased enabling it to be readily dispersed throughout the recycled materials.

2. **Recycling Additives:** Chemical additives are used with recycling agents to improve early strength gain, increase rutting resistance, and improve the moisture resistance of CIR mixes. Chemical additives such as cement or lime have been successfully used. Cement can be added in dry or slurry form. Cement contents should be kept low to prevent shrinkage cracking. The typical cement content should be 0.25% to 1.0% with a minimum ratio of asphalt residue to cement at 3 to 1.

   Quicklime or hydrated lime is usually added in slurry form, although hydrated lime can be added in dry form. Lime is typically added at 1.0 to 1.5% by dry weight of RAP.

# E. Construction

Prior to initiation of recycling work, the existing roadway should be prepared by removing any excess dirt, mud, vegetation, standing water, combustible materials, oils, raised roadway markings, and other objectionable materials by sweeping, blading, or other approved methods. Paint stripes are typically just recycled into the material.

Traffic loop wires, rubberized crack fill materials, thermoplastic marking materials, and concrete patches should be removed. Utilities should be lowered to minimize stopping of the CIR train.

Depending on the RAP gradation, bulking of the material can be 10% to 15%. If the roadway has vertical constraints, such as meeting the existing curb and gutter elevations, and will involve additional surface thickness, it may be necessary to pre-mill a wedge at the curb or remove and haul from the site material milled across the entire surface width.

Once construction begins, the recycling agent should be metered by weight of RAP using a meter calibrated to within 0.5% of the specified rate. Complete coating of the RAP with emulsified asphalt is not necessary at the time of mixing. Further coating takes place during spreading and compaction.

If foamed asphalt is used, the CIR equipment must contain a heating system capable of maintaining the temperature of the asphalt flow components in order to maintain the expansion ratio. The binder injection system should contain two independent pumping systems and spray bars to apply the foamed asphalt separately from the water needed for compaction.

CIR is a variable process. The JMF provides a starting point but changes in gradation of RAP can occur, resulting in workability impacts. The appearance of the mixture after initial compaction can indicate if adjustments are necessary. Adjustments to mix water, recycling agents, and additive contents may be necessary. These changes should only be made by experienced personnel.

Compaction of CIR mixtures requires more energy than hot or warm mix asphalt. This is due to the high internal friction developed between mix particles, the higher viscosity of the binder due to aging, and cold compaction temperatures. Typically two or three rollers are used with at least one pneumatic roller weighing 22 to 25 tons and at least one double drum vibratory roller weighing 10 to 12 tons. Main compaction rollers should have a drum width of at least 5.5 feet and have working water spray bars to prevent material pickup. When foamed asphalt is used, the compaction commences immediately after placement. Emulsified asphalt mixtures should be compacted as the mixture begins to break, turning from brown to black.

To determine optimum compaction operations, a control strip between 500 and 1,000 feet long should be established. Many contractors begin breakdown rolling with one or two passes of a static drum roller. Pneumatic rollers and vibratory rollers follow up and then the finish rolling is completed with the static double drum roller. The rolling pattern established on the test strip should compact the mixture between 95% and 105% of the target density. The final compacted surface should be free of ruts, bumps, indentations, and segregation of aggregates while conforming to the designed profile and cross-section.

Minimum temperatures for construction are typically set at 60° F with overnight ambient temperatures of 35° F. Construction should not proceed if rainy weather is forecasted.

The CIR mixture must adequately cure before secondary compaction is completed, if needed, or the surface course is placed. Curing periods can be as short as a few hours or as long as several weeks depending on temperature, rainfall, humidity levels, type of recycling additive, if used, and which recycling agent was used. The most common curing period is 2 to 3 days.

A light fog seal may be required to prevent raveling of the CIR surface prior to placing the surface course. The fog seal should be composed of emulsified asphalt diluted up to 60% by volume with water. Typical application rates are 0.05 to 0.12 gallons per square yard. If a sand blotter is needed, it should be applied at 2 to 3 pounds per square yard.

If the recycling agent is emulsified asphalt, secondary compaction may be necessary after curing to remove minor consolidation in the wheel path caused by traffic. Secondary compaction is best completed on warmer days when the pavement temperature is above 80° F.

Due the high void content, a surface course is required to be placed over the CIR mixture to protect the mixture from moisture intrusion. For low traffic roadways, seal coats, slurry seals, and microsurfacing can be used. For higher traffic facilities, overlays of either concrete or asphalt are typically used. Prior to placement of any surface treatment, the surface should be cleaned with a power broom or sweeper to remove all loose materials. If the overlay uses asphalt, a tack coat of emulsified asphalt should be applied to provide for good bond. If an unbonded concrete overlay is used an asphalt or geosynthetic fabric interlayer must be used.

## F. References

Asphalt Recycling and Reclaiming Association (ARRA). *Basic Asphalt Recycling Manual.* FHWA. Second Edition, 2015.

# COLD-IN-PLACE PAVEMENT RECYCLING

## PART 1 - GENERAL

### 1.01 SECTION INCLUDES

Cold-in-place recycling (CIR) of asphalt roadways

### 1.02 DESCRIPTION OF WORK

Includes milling and mixing of existing asphalt materials, addition of recycling agents and additives if required, compaction of the reclaimed materials, and curing of the compacted street.

### 1.03 SUBMITTALS

Comply with Division 1 - General Provisions and Covenants as well as the following:

A. Prepare and submit the job mix formula to the Engineer for approval prior to initiating full recycling operations.

B. Provide quality control test results.

### 1.04 SUBSTITUTIONS

Comply with Division 1 - General Provisions and Covenants.

### 1.05 DELIVERY, STORAGE, AND HANDLING

Comply with Division 1 - General Provisions and Covenants.

### 1.06 SCHEDULING AND CONFLICTS

Comply with Division 1 - General Provisions and Covenants.

### 1.07 SPECIAL REQUIREMENTS

None.

### 1.08 MEASUREMENT AND PAYMENT

**A. Cold-in-place Recycling:**

1. **Measurement:** Measurement will be in square yards for the area of roadway recycled.

2. **Payment:** Payment will be at the unit price per square yard of roadway recycled.

3. **Includes:** Unit price includes, but is not limited to, milling and sizing of existing asphalt layers; protecting street fixtures; adding and mixing recycling agents and additives, if required; supplying and incorporating water; compacting the reclaimed mix; shaping of the mix; removing any loose or excess material; and final clean up.

**B. Bituminous Recycling Agents:**

1. **Measurement:** Measurement will be in gallons of asphalt emulsion or foamed asphalt furnished and incorporated.

2. **Payment:** Payment will be at the unit price per gallon of asphalt emulsion or foamed asphalt furnished and incorporated.

**1.08 MEASUREMENT AND PAYMENT (Continued)**

**3. Includes:** Unit price includes, but is not limited to, furnishing and placing of materials and mixing the agent into the recycled mix.

**C. Chemical Recycling Additives:**

**1. Measurement:** Measurement will be in tons of chemical recycling additives.

**2. Payment:** Payment will be at the unit price per ton of chemical recycling additives.

**3. Includes:** Unit price includes, but is not limited to, furnishing and placing of materials and mixing the agent into the recycled mix.

**D. Fixture Adjustment:** Comply with Section 6010 for adjustment of manholes and intakes and Section 5020 for adjustment of water valves and fire hydrants.

**E. Surface Course:** Comply with Section 7011 or Section 7021 for overlay pavement.

## PART 2 - PRODUCTS

### 2.01 MATERIALS

**A. Bituminous Recycling Agent:** Use asphalt emulsion (HFMS-2s or CSS-1) meeting the requirements of Iowa DOT Section 4140, or foamed asphalt using PG 52-34S asphalt binder meeting the requirements of Iowa DOT Sections 2318 and 4137.

**B. Chemical Recycling Additives:**

1. Cement complying with Iowa DOT Article 4101.01, A.

2. Hydrated lime complying with AASHTO M 216.

3. If approved by the Engineer, use other proprietary products according to the manufacturer's requirements.

**C. Water:** Comply with Iowa DOT Section 4102**.** Potable water obtained from an approved supply does not need to be tested**.**

### 2.02 JOB MIX FORMULA

Compile a job mix formula using an analysis of the existing asphalt pavement layers and the required strength of the recycled pavement section as specified in the contract documents. The job mix formula will identify the recycling agent and any additives; the rates for the recycling agent and additive, if needed; and the rate of water to reach the optimum moisture content. Tolerances should be included to allow the Contractor to adjust the mixture so that it is placed successfully.

## PART 3 - EXECUTION

### 3.01 EQUIPMENT

**A. General:**

1. Perform cold-in-place recycling between May 1 and October 1.

2. Perform recycling operations when weather conditions are such that proper mixing, shaping, and compacting the recycled mix can be accomplished. General criteria includes:
   a. The ambient daytime temperature is above 60°F.
   b. For night work, the following day's forecasted high temperature is above 60°F.
   c. The weather is not foggy or rainy.

**B. Equipment:**

1. Furnish a self-propelled machine capable of milling the existing paving material to the width and depth specified in the contract documents. Ensure the equipment meets the following:
   a. Equipped with automatic depth control to maintain a constant depth and width.
   b. Capable of milling the existing roadway to the required gradation in one pass.
   c. Accurately controls the rate of flow and total delivery of the recycling agent and additives, if needed, into the recycled mixture in relation to the speed and quantity of the material being recycled.
   d. Capable of mixing the recycled material and any recycling agent and additive required by the job mix formula into a homogeneous mixture.

2. If specified, use an asphalt foaming system that accurately and uniformly adds the specified percent of water to the hot asphalt binder. Use equipment fitted with a test nozzle to provide field samples of the foamed asphalt. Equip tankers supplying the hot asphalt binder with a thermometer to continuously monitor the temperature of the asphalt in the bottom third of the tank.

3. Use a bituminous paver complying with Iowa DOT Article 2001.19. Heating the screed will not be allowed.

4. Have the following rollers available for use:
   a. Double drum steel roller (static and vibratory)
   b. Pneumatic tire roller (25 ton or greater)

### 3.02 PREPARATION

Prior to initiating the recycling process, undertake the following tasks:

A. Identify and protect all affected utilities.

B. Remove excess dirt, vegetation, raised pavement markings, standing water, and any other objectionable materials.

### 3.03 UTILITIES

All utilities within the project limits should be protected prior to the milling. Locate and lower manholes, water valve boxes, and other fixtures a minimum of 2 inches below the bottom of the recycled section. Re-set manhole castings, water valves, and other fixtures to the proper elevations following completion of the compaction of the recycled mixture and placement of any surface course. Protect stormwater intakes by preventing recycled material from entering the drainage system.

## 3.04 CONTROL STRIP

Construct a control strip during the first day of production to verify that the equipment, construction methodology, and workmanship meet the specifications. Adequately size the control strip to verify that the optimal rates of water, recycling agent, and additives can be achieved. Establish a rolling pattern that will result in optimum compaction. The Engineer may waive the control strip provided the Contractor provides proof that the work will meet the specifications based on previous experience using the same equipment, personnel, and materials.

## 3.05 MILLING THE PAVEMENT

Mill the existing asphalt pavement and underlying areas to initiate the recycling process.

A. Mill the full specified depth of the asphalt layers in a single pass.

B. Verify the gradation of the pulverized material meets the specifications.

C. Provide a 3 inch overlap of the longitudinal joint and 24 inches between transverse joints

## 3.06 RECYCLING AGENT APPLICATION

For single unit recycling trains, add the bituminous agent in the cutting drum. For two-unit trains, add it in the mix paver and for multi-unit trains add the bituminous agent in the pugmill. Ensure residual asphalt content is ± 0.5% of the target established in the job mix formula. Maintain foamed asphalt binder ± 20°F of the optimum temperature established by the job mix formula.

## 3.07 RECYCLING ADDITIVES

Add chemical recycling agents as additives to applications that use bituminous recycling agents at the rates specified by the job mix formula. Apply the chemical additive in dry or slurry form by adding it on the pavement ahead of the milling operation, adding it directly to the mixing chamber, or spraying it over the cutting teeth of the milling machine.

## 3.08 COMPACTION

Ensure recycled material is ± 2% of the optimum moisture content.

**A. Timing:** Compact the mixed recycled roadway materials based on the type of recycling agent used as follows.

1. **Asphalt Emulsion:** Complete compaction at or just after the emulsion breaks.

2. **Foamed Asphalt:** Initiate immediately after mixing and complete prior to the mixture drying out.

**B. Process:** Follow the rolling pattern established with construction of the control strip regarding type and size of roller. Perform initial rolling with the pneumatic tired roller and final rolling with the steel wheeled roller. Set the vibratory amplitude/frequency, tire pressure for pneumatic, and static weight of all rollers based on the depth of the recycled mixture to be compacted. Uniformly compact the mixture to a minimum of 94% of maximum dry density according to AASHTO T 134 on a moving average of five consecutive tests with no individual test below 92%.

**C. Shaping:** Complete rolling to achieve specified density. Ensure the crown of the compacted recycled roadway is within 6 inches of the established centerline, unless otherwise specified in the contract documents.

## 3.09 SECONDARY COMPACTION

If necessary, complete secondary compaction to eliminate wheel marks and minor consolidation caused by construction traffic prior to opening. Complete secondary compaction during daylight hours and when the minimum ambient temperature is 60°F. Suspend operations if cracking of the mat occurs.

## 3.10 SMOOTHNESS

Ensure surface of recycled base course is free of bumps, ruts, indentations, segregation of aggregates and conforms to the required elevations. Check surface with a 10 foot straightedge and correct any irregularity 3/8" or larger. Complete corrective measures at no cost to the contracting agency.

## 3.11 SURFACE COURSE

Protect the CIR surface from damage prior to adding the surface course. Any damage will be repaired at Contractor's expense. Restrict application of overlays and other surface treatments until the moisture content of the CIR layer is no more than 0.3% above the residual moisture content or 2.5%, whichever is greater. Place first lift of surface within 14 calendar days after CIR layer has reached the moisture content value. Sweep all loose material from CIR surface prior to completing the surface course. Place surface course according to Section 7011 for PCC and 7021 for HMA overlays.

## 3.12 QUALITY CONTROL

The Contractor is responsible for the quality control of the materials and the CIR process.

A. Sample and test the asphalt recycling agent according to Iowa DOT Materials I.M. 204.

B. Apply the asphalt recycling agent at the target application rate ± 0.06 gallon per square yard per inch for standard emulsion and ± 0.33 pounds per square yard per inch for foamed asphalt.

END OF SECTION