Recommended Construction Guidelines
For
Cold Central Plant Recycling (CCPR)
Using Bituminous Recycling Agents
CR102

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NOTICE

It is not intended or recommended that these guidelines be used verbatim within a specification. Owner Agencies should use them to help establish their particular project specification. Owner Agencies should understand that all geographical areas and pavement rehabilitation/preservation projects are unique and the availability of materials and equipment may vary as well. ARRA assumes no liability for utilization of these guidelines by any individual or entity. Contact ARRA for answers to questions and for a list of ARRA member Contractors and Suppliers.

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1. General

Cold Central Plant Recycling (CCPR) shall consist of milling Reclaimed Asphalt Pavement (RAP) from roadways within the project limits and stockpiling in the general vicinity of the project. The stockpiled RAP shall be sized to a specified maximum size. The properly sized RAP shall then be blended with a bituminous recycling agent (emulsified or foamed asphalt) water and other additives (cement, lime or corrective aggregate) as necessary and as required by the mix design to produce a recycled asphalt mixture. The recycled asphalt mixture shall be placed and compacted in accordance with the plans and specifications.

2. Treatment Thickness

The depth of CCPR shall be _____ inches (mm) or as indicated on the plans.

User Note: CCPR single lift thickness should be a minimum compacted depth of 3 inches (75 mm) and not exceed a maximum compacted depth of 5 inches (125 mm). It may be possible to construct as thin as a 2 inch (50 mm) thick compacted CCPR lift, provided sufficient underlying support exists and the maximum top size of the RAP is reduced to 1 inch (25 mm). If greater than 5 inches (125 mm) of CCPR is required, multiple thinner lifts should be placed. Before placing any additional lifts, the recycled surface should be allowed to cure as required. A tack coat may also be necessary. Treatment thicknesses should be dependent on structural capacity requirements and project-specific criteria such as original asphalt thickness and expected design life. Milling depth does not necessarily have to be the same as placement thickness.

3. Preconstruction Personnel Training

Personnel involved with the construction of CCPR from both the Contractor and Owner Agency shall have successfully completed Preconstruction Personnel Training (PPT) to ensure that proper procedures are followed to construct a high quality CCPR pavement. The PPT shall be conducted at a location convenient for both the Contractor and the Owner Agency. The PPT shall be completed not more than ___ days, not including Saturdays, Sundays or holidays, prior to the start of CCPR operations. The training shall be held during normal working hours. In lieu of this training, proof may be provided showing successful experience has been obtained by the individuals performing the work for the materials and construction techniques to be used in the CCPR construction.

The PPT trainer shall be provided by the _____ *(Contractor **or** Owner Agency).* The PPT trainer shall be experienced in construction methods, materials, and test methods associated with construction of CCPR projects. The Contractor and Owner Agency shall mutually agree to the course instructor, course content and training site.

User Note: Typically, PPT is held less than 5 days before the start of the CCPR. PPT should be close enough to the start of construction so that it is fresh but also allow some time to address any issues that may be raised during the training.

4. Materials

CCPR shall consist of a homogeneous blend of RAP, bituminous recycling agent (either foamed asphalt or emulsified asphalt), water and other additives, if required. The actual materials used and their respective usage rates are dependent on the mix design and project requirements.

4.1 Reclaimed Asphalt Pavement

Reclaimed Asphalt Pavement (RAP) shall consist of asphalt coated material only. The RAP shall be free of

contamination of dirt, base, concrete or other deleterious materials such as silt and clay. The RAP shall be reclaimed from the roadways and sized to meet specific contract requirements. The gradation of the RAP shall have 100% passing the 1.25 inch (31.5 mm) sieve.

Rubberized crack filler, pavement markers, loop wires, thermoplastic markers, paving fabric and other similar materials shall be removed as observed. Residual materials that cannot be completely removed from the processed RAP may be incorporated into the recycled mix if the Contractor can demonstrate that those added materials will not adversely affect performance. Any such materials retained in the mix shall be appropriately sized and blended so as not to adversely affect the appearance or strength of the recycled pavement.

Sized RAP shall not be stockpiled for longer than ___ days or in stockpiles greater than ___ feet (m) in height that may, through the weight of the stockpile, reconsolidate the sized RAP. Water shall be added to the RAP as it is sized to abate dust and mitigate reconsolidation. The moisture content of the RAP shall be verified immediately before recycling to determine the amount of water needed to conform to the mix design requirements.

User Note: Typical maximum values are not longer than 10 days in the stockpile and not greater than 15 feet (4.5 m) in height.

4.2 Bituminous Recycling Agent

Bituminous recycling agent shall consist of either foamed asphalt or emulsified asphalt. Unless indicated elsewhere within the plans, project specifications, or an Owner Agency supplied mix design, the Contractor shall select the type and grade of recycling agent used.

4.2.1 Asphalt Binder for Foamed Asphalt

Asphalt binder used for foamed asphalt shall be selected to meet local temperature standards and specifications and to ensure that optimum foaming characteristics are met in the field. Polymer modified asphalt binders shall not be used. The asphalt binder shall be of sufficient temperature to meet the minimum expansion and half-life criteria but not be heated above 375 °F (190 °C). Asphalt binder provided to the job shall have no additives or properties which will inhibit the ability to produce asphalt foam with a minimum expansion ratio of ____, and a half-life of not less than ____ seconds. The application rate shall be determined by the mix design.

User Note: The expansion ratio is defined as the volume of foamed asphalt to residual unfoamed asphalt. The half-life is defined as the time for the foamed asphalt to lose half of its expanded volume. Typically, the asphalt binder must exceed 320 °F (160 °C) to achieve optimum foaming characteristics; however, this temperature may vary depending on the type of asphalt binder used. Typical expansion ratios should be a minimum of 8 and the half-life should be a minimum of 6 seconds.

4.2.2 Emulsified Asphalt

Emulsified asphalt shall be selected to meet local standards and specifications and to achieve appropriate mixing with the RAP. Polymer modification may be used. The actual emulsified asphalt type and applicable usage rate shall be determined by the mix design.

User Note: Typical emulsified asphalts used for CCPR include CSS-1h, HFE 150 or engineered emulsions.

4.3 Recycling Additives (Optional)

Cement, lime slurry and corrective aggregate may be used as recycling additives to improve CCPR mix properties. Cement or lime slurry may be utilized as a catalyst at a small dosage rate to increase mix cohesion, to aid in curing, to improve early strength gain, and/or to improve moisture susceptibility (stripping) properties of the CCPR material. Corrective aggregate may be required to supplement the RAP gradation to meet performance requirements of the mix design. The usage rate of all additives shall be determined by the mix design.

User Note: If other additives such as fly ash or lime kiln dust are desired, caution should be exercised as experience with use of these additives is limited. Cement or lime should not be used with anionic emulsions such as HFE 150.

4.3.1 Cement

Cement, in either dry or slurry form, may be added to the CCPR mixture as determined by the mix design. Slurry made from cement shall contain a minimum of 30% dry solids content. Cement shall comply with the latest specifications for Type I or Type II cement (AASHTO M 85, AASHTO M 240 or ASTM C150, ASTM C595). The ratio of residual asphalt in the bituminous recycling agent to dry cement shall be at least 2.5:1. In addition, the cement shall be limited to a maximum of 1.0 percent by dry weight of RAP. The Contractor shall submit to the Owner Agency the type of process for incorporating cement into the recycling process.

4.3.2 Lime Slurry

Lime slurry produced from high-calcium quicklime or hydrated lime may be added to the CCPR mixture as determined by the mix design. Lime slurry shall contain a minimum of 30% dry solids content. The dry solids shall be limited to 1.5 percent by dry weight of RAP. Quicklime or hydrated lime used shall meet requirements of AASHTO M 216 or ASTM C977. The Contractor shall submit to the Owner Agency the type of process for incorporating lime slurry into the recycling process.

4.3.3 Corrective Aggregate

Corrective aggregate may be required to supplement the RAP gradation in order to meet performance requirements of the mix. When required by the mix design, corrective aggregate shall meet the requirements of Table 1.

TABLE 1 – CORRECTIVE AGGREGATE

Tests	Method	Limit
Los Angeles Abrasion Value, % loss	AASHTO T 96 ASTM C131	40 max
Sand Equivalent, %	AASHTO T 176 ASTM D2419	60 minimum
Washed Gradation	AASHTO T 11 & T 27 ASTM C117 & C136	As required

User Note: Corrective aggregate gradation will vary according to size and distribution, depending on the desired effect to the resultant CCPR material.

4.4 Water

Water may be added to the RAP in the mixing apparatus to achieve uniform mixing and to lubricate the mix to facilitate compaction. Water added to the RAP shall be free from deleterious concentrations of

acids, alkalis, salts, sugars and other organics, chemical or deleterious substances. The water shall not cause an adverse effect on either the recycling agent or the recycled pavement mixture. If the water is of questionable quality it shall be tested in accordance with ASTM C1602 or according to local standards and procedures.

Water used specifically for foaming asphalt shall be filtered so that on evaporation no deposits or residue are left behind that might clog or impede water flow to the foaming nozzles of the recycling unit.

5. Mix Design

If not provided by the Owner Agency, a mix design shall be submitted by the Contractor for approval by the Owner Agency. The mix design shall be performed with representative materials to be used during construction of the CCPR mix. When the materials to be recycled change significantly, additional mix designs shall be performed to establish representative mixes for the entire job. Representative samples of the asphalt pavement shall be obtained directly from the project site by sampling in accordance with *ARRA CR201 - Mix Design Guidelines For Cold Recycling Using Emulsified Asphalt Recycling Agent* or *ARRA CR202 - Mix Design Guidelines For Cold Recycling Using Foamed (Expanded) Asphalt Recycling Agent* and delivered to an AASHTO or Owner Agency approved laboratory experienced in cold recycled mix designs where the asphalt pavement samples shall be sized and mixed with the recycling agent, water and any additives, if required. The mixture shall then be tested in accordance with the mix design guidelines outlined in *ARRA CR201 or ARRA CR202* as applicable. The mix design shall be the baseline measure for the rate of recycling agent application, water and other additives blended with the RAP to construct the recycled pavement mixture. The mix design shall indicate allowable tolerances for the bituminous recycling agent and any additives so as to not jeopardize the performance of the mix but allow the Contractor to adjust the mix so that it may be placed and performs successfully.

6. Equipment

The equipment required to perform cold central plant recycling generally includes a milling machine, portable sizing unit, mixing and proportioning equipment and conventional paving equipment. The sizing, mixing and proportioning equipment shall be capable of producing a homogeneous recycled pavement mixture by mixing the RAP with the recycling agent, water and any other additives. The equipment used for placement of the recycled pavement mixture shall be capable of placement to the guidelines provided herein and to the lines and grades shown on the plans. The recycling equipment shall consist of the following major components:

6.1 Pavement Cold Planer (Milling Machine)

The pavement cold planer shall be self-propelled. The cold planing equipment shall have a cutter capable of removing the existing pavement to the depths shown in the plans. Milling equipment shall be equipped with depth controls capable of maintaining the cutting depth to within 1/4 inch (6 mm) of the desired depth, and shall have an effective means for controlling cross-slope. The milling operation shall not disturb or damage the underlying material. Use of a heating device to soften the pavement shall not be permitted.

6.2 Sizing Equipment

The recycled material shall be processed through a material sizing unit having a scalping screen and /or crushing capabilities to reduce the RAP to the maximum size of 1.25 inches (31.5 mm) prior to mixing with the bituminous asphalt recycling agent.

6.3 Mixing and Proportioning Equipment

The sized recycled material shall be processed in a mixing apparatus capable of processing the sized RAP, bituminous recycling agent, water and any additives to a homogeneous mixture to produce a recycled asphalt mixture. The bituminous recycling agent, water and additives shall be incorporated into the graded RAP at the initial rate determined by the mix design and approved by the Engineer. The total water content shall include that amount present in the stockpile and additional water added if necessary. Mixing shall continue until a thoroughly and uniformly coated recycled pavement mixture of unchanging appearance is produced at discharge from the mixing apparatus. Adjustments in the rate of bituminous recycling agent, water and any additives shall be made as necessary based on field observed changes in the RAP and/or condition of the recycled mat.

The mixing apparatus shall have cold feed hopper equipped with vibrators on the hopper's walls to assist the free flow of materials to a variable speed belt conveyor. Control of the RAP shall be by mechanically adjustable gate valves at the point of discharge or a RAP belt scale for the continuous weighing of the RAP. The variable speed belt conveyor and/or RAP belt scale shall be coupled/interlocked to the recycling agent metering device.

The recycling agent metering device shall be capable of automatically adjusting the flow of recycling agent to compensate for any variation in the amount of RAP introduced into the mixing apparatus. Recycling agent shall be metered by weight of RAP using a calibrated meter that will accurately measure the amount of recycling agent to within a tolerance of ± 2.0% of the specified rate. The mixing apparatus shall have an independent source of water to properly disperse the recycling agent. Calibration of the water meter is not necessary. Automatic digital readings shall be displayed for flow rate of both the RAP and recycling agent in appropriate units of weight and time.

If a foamed asphalt recycling agent is used, the system shall be equipped with a heating and/or thermal insulating system capable of maintaining the temperature of asphalt flow components to maintain the required expansion ratio and half-life. The binder injection system shall contain two independent pumping systems and spray bars to regulate the application of foamed asphalt separate from the water used to increase the moisture content for compaction. The additive system shall be computer controlled and the rate of addition of water into the hot asphalt binder shall be automatically kept at a constant percent by mass of asphalt binder. An inspection or test nozzle shall be fitted at one end of the spray bar to produce a representative sample of foamed asphalt binder.

User Note: During calibration of the meter, if 3.0% recycling agent is required, based on the allowable tolerance, the meter must deliver the recycling agent between 2.94% to 3.06%. For example, if 8,000 pounds of recycling agent is used, then the tolerance is ± 160 pounds.

The application rate of bituminous recycling agent should be checked during production by evaluating the weight of recycled material against the volume of recycling agent used for a single tanker, as indicated in *CR301 Recommended Quality Control Sampling and Testing Guidelines For Cold Recycling Using Bituminous Recycling Agents*.

6.4 Cement or Lime Storage and Supply Equipment

Cement or lime slurry storage and supply equipment shall have agitators or similar equipment to keep the cement or lime slurry in suspension when held in the slurry feed tank. Cement or lime slurry shall be kept in suspension during transport using agitator equipment. The meter system controlling application of slurry shall apply the additive within a tolerance of ± 10% of the specified rate.

Dry cement shall be stored in water tight containers and shall be transferred directly to the mixing apparatus via silo augers or separate transfer devices. The meter system controlling application of dry cement shall apply the additive within a tolerance of ± 10% of the specified rate.

6.5 Corrective Aggregate Equipment

Corrective aggregate shall be added by a separate cold feed bin. The feed shall be controlled by mechanically adjustable gate openings or by a belt scale. The equipment shall apply the corrective aggregate within a tolerance of ± 10% of the specified rate.

6.6 Transportation

Trucks with smooth clean beds shall be used to haul the recycled asphalt mixture to the placement area. The loaded trucks shall deliver the blended CCPR material into the paver within___ hours of mixing or before an emulsified recycling agent begins to break and set, whichever time is earlier.

User Note: Depending on the recycling agent, the workability of the mix will dictate the permissible maximum haul time.

6.7 Paving Equipment

The processed recycled mixture shall be spread uniformly across the recycling width utilizing a self-propelled paver. The screed shall be controlled by electronic grade and cross-slope control. The equipment shall be of sufficient size and power to spread the recycled material in one continuous pass, without segregation, to the lines and grades established by the Owner Agency and according to the plans and specifications. Heating of the screed shall not be permitted. CCPR material shall either be loaded directly into the paver hopper from transport trucks or loaded by a pickup device. If utilizing a pickup device, it shall be capable of removing and transferring the entire windrow of recycled mix in a single pass.

User Note: If a pick up device is used, a track paver with a minimum power of 170 hp should be used.

6.8 Compaction Equipment

Compaction of the recycled mix shall be completed using self-propelled rollers complete with properly operating scrapers and water spray systems. The number, weight, and types of rollers shall be as necessary to obtain the required compaction. At a minimum, the following rollers shall be used:

- At least one pneumatic-tired roller with a minimum weight of not less than 22 tons (19.9 metric tons).
- At least one double drum vibratory steel-wheeled roller with a minimum weight of not less than 10 tons (9.1 metric tons).

The combined weight of the two required rollers shall be not less than 34 tons (30.9 metric tons). Rollers shall have a width of not less than 65 inches (1.65 m). Tires on pneumatic rollers shall be evenly inflated and matched in size and profile so as to maximize compactive effort.

6.9 Fog Sealing and Sand Spreading Equipment

Fog sealing, if required, shall be applied using a distributor truck, or equivalent, specifically manufactured for the purpose of sealing/spreading emulsified asphalt at a uniform rate over the full width of a traffic lane in a single application. Sand blotter, if required, shall be spread with a self-propelled screenings or salt spreader equipped with a mechanical device that spreads the sand at a uniform rate over the full width of a traffic lane in a single application.

7. Construction

Prior to the start of construction employees representing both the Contractor and Owner Agency shall submit certification of PPT to ensure the CCPR is constructed properly.

Throughout the mixing, placement, and compaction of the recycled mixture adjustments may be made to the recycling agent, water and any additives so as to provide an optimum product. All adjustments shall be recorded by the Contractor and submitted to the Owner Agency.

7.1 Roadway Preparation

Before any recycling work begins the Contractor shall:

1) Coordinate the identification and location of all utilities within the CCPR operations.
2) Remove from the roadway any dirt, vegetation, standing water, combustible materials, oils, raised roadway markings, and other objectionable materials by sweeping, blading, or other approved method.
3) Adjust identified affected utilities down or accommodate for utilities prior to recycling in some other means as indicated on the project plans and specifications.
4) Accurately reference the profile and cross-slope as shown on the plans for the finished surface of the recycled pavement material.
5) Correct all known areas of soft or yielding subgrade, as indicated on the project plans.
6) If the CCPR mix is to be placed on a prepared subgrade or aggregate base, ensure the subgrade soils/base have been properly prepared, moisture treated and compacted to the minimum density according to plans or specifications, immediately prior to placement of the CCPR mix, so as to create an evenly graded, unyielding surface.
7) If the CCPR is to be placed on an existing pavement, cement stabilized surface or between multiple CR lifts, verify that the existing surface is firm and unyielding and that there are no subgrade failure areas. Any areas that are not firm or unyielding shall be replaced. Prior to placing the CCPR, the existing surface shall be swept with a power broom to clean the surface and a tack coat of diluted emulsified asphalt shall be applied to provide good bonding.
8) Sweep surfaces of adjacent structures such as curbs, concrete gutters, swales, etc. of loose material to create a clean, dry surface.

User Note: An application of low viscosity liquid asphalt (prime coat) may be required over untreated aggregate base before placing the CCPR. A prime coat and its benefits differ with each application, and its use often can be eliminated. If a prime coat is used, asphalt emulsion prime should be specified as it is designed to penetrate the base material. The use of a tack coat is not recommended as a prime coat.

Tack coats between pavement lift and on cement stabilized surfaces should consist of CCS-1h or SS-1h emulsified asphalt, or equivalent, at a minimum of 0.05 gal/yd^2 (0.2 L/m^2) applied to all surface areas. A hot asphalt binder tack coat should not be used.

7.2 Weather Limitations

CCPR operations shall be performed when the RAP temperature is above 50 °F (10 °C) with overnight ambient temperatures above 35 °F (2 °C). Recycling may be performed during light precipitation so long as the Contractor can demonstrate that performance of the recycled asphalt pavement will not be adversely affected.

User Note: Some emulsified asphalt binders may require a higher operating ambient and/or RAP temperature, such as 60 °F (16 °C) and rising. Depending on the binders, and if additives are used, the minimum temperatures may need to be adjusted.

7.3 Control Strip

During the first day of production the Contractor shall construct a minimum 500 foot (150 m) long control strip to verify that the construction process meets specification requirements. The purpose of the control strip is to:

A. Demonstrate that the equipment, materials, and processes proposed can produce a recycled pavement material layer that conforms to specification requirements;
B. Determine the optimal rates for recycling agent, water and any additives recommended for the reclaimed asphalt pavement; and
C. Determine the sequence and manner of rolling necessary to obtain density requirements.

CCPR operations may continue through the first day unless the Contractor's equipment and process fails to meet the requirements for successful completion of CCPR operations. Recycling operations shall not continue beyond the first day unless a control strip has been approved by the Owner Agency. Control strips that do not meet specification requirements shall be reworked, recompacted, or removed and replaced at the Contractor's expense. On acceptance of the control strip by the Owner Agency the Contractor shall use the same equipment, materials, and construction methods for the remainder of recycling operations unless adjustments made by the Contractor are approved by the Owner Agency. If adjustments are made the Contractor shall produce a new control strip.

In lieu of a control strip the Owner Agency may allow the Contractor to provide proof, based on previous experience with the same equipment, personnel, and materials that the work will conform to specification requirements.

A rolling pattern shall be determined to achieve optimum field density either during the initial control strip or during start up, if the control strip has been waived by the Owner Agency. The Contractor shall determine a sequence and manner of rolling which will define maximum compaction by establishing a rolling versus density chart that shows the progress of densification from initial lay down through maximum obtainable density (target density) at the "break over point" using a properly calibrated nuclear density gauge per AASHTO T 355 (ASTM D2950) or other Owner Agency approved method. The Contractor shall determine relative compaction per AASHTO T 355 (ASTM D2950), or other Owner Agency approved method, on the quantity within the control strip or during start up. If the relative compaction within the control strip, or at start up, does not meet density requirements, the Contractor shall establish a new rolling pattern to determine the maximum density obtainable (new target density) for the recycled material being produced under current site conditions. The rolling pattern determined shall be strictly followed to ensure compaction is met for the entire CCPR surface area. Precautions shall be exercised to ensure that material is not picked up on the drums or tires of the compaction equipment.

User Note: Many owner agencies have developed their own test methods for determining density of bituminous mixtures using nuclear methods and these procedures are acceptable substitutions. It has not been determined at this time if electromagnetic gauges are suitable for use on cold recycled mixtures; therefore, they are not recommended for use.

7.4 Processing and Placement of Recycled Mix

The existing asphalt pavement shall be milled to the length, depth and width as shown on the plans or specifications. The RAP shall be further sized to the maximum particle size specified, blended with the desired rate of recycling agent, water and additives (if required) as dictated by the mix design, or as adjusted in the field so as to produce a homogeneous recycled mixture. The recycled pavement mixture shall be delivered to the paver in a manner that prevents particle segregation. The recycled mixture shall be spread using a screed to the design elevations. Care shall be exercised while spreading to avoid segregation, tearing, or scarring of the final compacted surface. Handwork of CCPR pavement shall be minimized and care shall be taken to prevent segregation. The paver shall be operated with the wings up or the paver wings regularly emptied to prevent buildup and minimize segregation. The buildup of material on the edges of the screed shall not be allowed.

If a paving fabric is encountered during the cold milling operation, the CCPR Contractor shall make the necessary changes in equipment or operations so that incorporation of the shredded fabric in the recycled material does not affect the performance parameters of the recycled material does not affect the performance parameters of the recycled pavement or inhibit placing and compaction of the CCPR pavement. No fabric piece incorporated into the recycled section shall have any dimension exceeding a length of 2 inches (50 mm). The Contractor shall be required to remove and properly dispose of oversized pieces of paving fabric as indicated by the plans and specifications.

Loop wires, pavement markers, rubberized crack fill materials, thermoplastic marking materials, milled concrete, and other materials that may be incorporated into the RAP through the milling process shall be removed from the recycled material unless the Contractor can demonstrate that minor amounts of residual materials that remain will not compromise the integrity of the recycled mixture.

7.5 Compaction

The Contractor shall determine the time from which the treated material is placed until compaction can commence. Rolling patterns shall be established and the mixture compacted using the procedures established in section 7.3. Compaction shall be monitored using nuclear density testing in accordance with AASHTO T 355 (ASTM D2950), or Owner Agency approved method, throughout the time compaction is being completed to continuously verify the compaction is within ± 5% of the target density established in section 7.3.

The selected rolling pattern shall be followed unless changes in the recycled mix or placement conditions occur and a new rolling pattern is established at that time. Any type of rolling that causes cracking, major displacement, and/or any other type of pavement distress shall be discontinued until such time as the problem can be resolved. Discontinuation and commencement of rolling operations shall be at the discretion of the Owner Agency.

The recycled mat shall be continuously observed during compaction efforts. If moisture cracking occurs under vibratory compaction mode, the vibrators shall be turned off and static rolling only applied. If moisture cracking of the mat continues under static steel rolling, steel drum compaction shall cease, the mat shall be allowed to cure for a time in order for moisture to escape, and pneumatic rolling commenced, followed by steel rolling to correct irregularities from the pneumatic-tired roller(s). This procedure shall be followed until there is no longer any displacement of the mat observed from roller action on the recycled surface.

Care shall be taken to ensure that aggregate from the recycled mixture does not stick to the drums or wheels of rollers. Water shall be uniformly applied to the wheels and drums, along with mechanical

means, if necessary, so as to keep aggregate from sticking. Sufficient water shall be applied to keep rollers and tires clean, but not to the extent that water pools or ponds on the recycled surface.

Rollers shall not be started or stopped on uncompacted recycled material. Rolling patterns shall be established so that starting and stopping shall be on previously compacted material or the adjacent, existing surfacing.

User Note: The time to begin compaction operations is dependent on the recycling agent used, foamed asphalt or emulsified asphalt, the type of emulsified recycling agent, additives (lime or cement), as well as climatic conditions.

User Note: Many Owner Agencies have developed their own test methods for determining density of bituminous mixtures using nuclear methods and these procedures are acceptable substitutions. It has not been determined at this time if electromagnetic gauges are suitable for use on cold recycled mixtures; therefore, they are not recommended for use.

7.6 Curing

After compaction has been achieved and prior to opening the CCPR pavement layer to traffic, a fog seal, if required, shall be applied to the recycled pavement surface. The fog seal shall be composed of either CSS-1h or SS-1h emulsified asphalt diluted up to 50 percent by volume with water or an engineered emulsion diluted up to 60 percent by volume with water. Fog seal shall be applied at a rate of 0.05 to 0.15 gal/yd^2, (0.2 to 0.7 L/m^2). When a sand blotter is required, it shall be applied to the surface at approximately 2 to 3 lbs/yd^2 (1 to 5 kg/m^2). Sand shall be free from clay or organic material. The application rates of the fog seal and sand blotter shall be determined by the Contractor and shall be such that a stable and safe roadway surface can be maintained until the surface course is placed.

Prior to placing the final surfacing or any secondary compaction, if required, the CCPR shall meet the following criteria:

1. The completed CCPR shall cure for a minimum of 3 days.
2. The moisture content shall be less than 3.0 percent. If the moisture content does not fall below the maximum limit of 3.0 percent after 10 days and if the roadway has been free of rain for a minimum of 2 days, the Contractor shall be permitted to place the final surfacing or perform the secondary compaction, as required.

User Note: In some areas secondary compaction is not necessary. It is commonly completed with an emulsified recycling agent but rarely performed with foamed asphalt, particularly if cement is added.

7.7 Secondary Compaction

If the recycling agent is emulsified asphalt, secondary compaction, if required, shall be conducted with pneumatic-tired and steel-wheel rollers as per Section 6.8 after cure and before placing any final surfacing. Secondary compaction shall be completed after the morning sun has risen and when the pavement temperature is at least 80 °F (27 °C).

A new rolling pattern shall be established using the procedures of section 7.3 to determine the maximum density of secondary compaction. Density of the recycled pavement shall be verified behind the secondary compaction by nuclear density gauge in accordance with AASHTO T 355 (ASTM D2950) or Owner Agency equivalent procedure. Nuclear density testing shall be repeated throughout the time secondary compaction is being completed to continuously verify that the secondary compaction is

within ± 5% of the maximum density established. Care shall be taken not to over compact the mat. If cracking results secondary compaction shall be ceased.

User Note: Consider suspending any secondary compaction if the pavement temperature never reaches 80 °F (27 °C) prior to scheduled placement of the surface course. In addition, a minimum of four passes should be attempted during establishment of the rolling pattern for secondary compaction as the density may decrease during the initial roller pass. The roller pattern is the number of passes resulting in the peak increase in density. If no increase in density is noted, or if the mat exhibits cracking, secondary compaction should be suspended.

7.8 Surface Tolerance

The finished surface and grade of the recycled material shall be checked regularly during placement using a straight edge. The surface tolerance shall not vary more than 3/8 inch (10 mm) from a 10-foot (3.0-m) straight edge placed on the surface. The Contractor shall correct humps exceeding this tolerance by reworking, rerolling, trimming, milling or abrasive grinding. Depressions exceeding this depth shall have a tack coat applied of either CSS-1h or SS-1h emulsified asphalt, or equivalent, at a minimum of 0.05 gal/yd^2 (0.2 L/m^2) and filled with cold mix, recycled mix, warm mix asphalt (WMA) or hot mix asphalt (HMA) just prior to placement of the surface course.

7.9 Surfacing

Prior to placing the surface course, the recycled pavement shall be carefully swept of all loose material and any standing water. In the event that an HMA or WMA overlay is used as the surface course, a tack coat of either CSS-1h or SS-1h emulsified asphalt, or equivalent, at a minimum of 0.05 gal/yd^2 (0.2 L/m^2) shall be applied to all surface areas. A hot asphalt binder tack coat shall not be used.

7.10 Maintenance

After opening to traffic and prior to placing the surface course, the surface of the recycled pavement shall be maintained in a condition suitable for the safe movement of traffic. The Contractor shall protect and maintain the recycled surface from nuisance water, other deleterious substances, and/or any other damage. Any damage to the completed recycled material shall be repaired by the Contractor prior to placement of the surface course. Areas of the CCPR layer damaged as outlined in Table 2 shall be repaired in accordance with the procedures listed in Table 2. No direct payment will be made for repairs and costs shall be included elsewhere for protection and maintenance of the recycled asphalt pavement. Damage caused by poor subgrade support shall be repaired by the Contractor as directed by the Owner Agency. Costs to repair damaged CCPR due to the subgrade will be paid by the Owner Agency.

Table 2 – CCPR DAMAGE AND MITIGATION	
Damage	**Mitigation**
Isolated areas of minor raveling or scuffing.	Sweep and monitor. Determine if fog sealing or re-fog sealing is necessary to protect.
Isolated areas of major raveling, scuffing or tearing.	Maintain better traffic restrictions in areas that are not cured. Sweep and monitor. Determine if fog sealing or re-fog sealing is necessary to protect. Fill or remove, tack and replace deep damaged areas with asphalt mixture (cold mix, recycled mix, WMA, or HMA) prior to surface course.
Large scale areas of raveling, scuffing or tearing in straight traffic areas.	Re-recycle with CCPR or remove, tack and replace with asphalt mixture (cold mix, recycled mix, WMA, or HMA).
Dimpling due to parked vehicles or equipment.	Tack and fill with asphalt mixture (cold mix, recycled mix, WMA, or HMA) prior to surface course.
Permanent deformation within wheel path areas due to secondary compaction by traffic.	If pavement temperatures permit, apply secondary compaction. Tack and fill with asphalt mixture (cold mix, recycled mix, WMA, or HMA) or micro surfacing in the low areas or cold mill to provide a smooth surface.
Permanent deformation and shoving due to unstable mix.	Investigate pavement structure in conjunction with mix design lab. Depending on investigation, remove, tack and replace affected areas with asphalt mixture (cold mix, recycled mix, WMA, or HMA) or re-recycle supplementing with uncoated coarse aggregate, additives and/or recycling agent as necessary.

8. Quality Control

The Contractor shall perform process and quality control (QC) sampling and testing, and exercise management control to ensure that cold central plant recycling conforms to the project specifications. Sampling and testing shall be performed as outlined in *ARRA CR301 - Recommended Quality Control Guidelines For Cold Recycling Using a Bituminous Recycling Agent*. The Contractor shall provide a qualified technician, testing laboratory and personnel to perform process and quality control sampling and testing during the cold recycling, spreading, compaction, and finishing. The proficiency of testing laboratories and sampling and testing personnel shall be reviewed and approved by the Owner Agency prior to providing services to the project. The Owner Agency shall have unrestricted access to the laboratory, sampling, testing sites, and all information resulting from mix design and quality control activities. All quality control testing results shall be submitted to the Owner Agency.

9. Measurement and Payment

Quantities of the produced CCPR pavement shall be measured by the square yard (square meter) completed and accepted by the Owner Agency for the depths specified. Recycling agent and additive weight shall be based on certified delivery weigh tickets, less any unused portion. Water used in the CCPR operation will not be paid for directly and shall be considered subsidiary to the bid item.

Payment for CCPR shall be made at the contract unit price per square yard (square meter). The price shall be full compensation for all labor, materials, tools, equipment, and incidentals; for doing all the work involved in cold central plant recycling, completed in-place; for sizing, mixing, blending, transporting, placing and compacting the recycled pavement mixture; for protection and maintenance of the recycled layer, with the exception of poor subgrade areas; for performing all QC testing including mix design, if required to be provided by Contractor; for PPT training and instructor, if required to be

provided by Contractor; for fog sealing, sanding and sweeping if necessary; for obtaining measurements and recording results of all tests as shown on the plans and specifications.

Bituminous recycling agent will be paid for at the contract price per ton (metric ton).

Additives will be paid for by force account if determination is made during the mix design that additives are necessary.

Subgrade repair areas will be paid for by force account.

User Note: The costs associated with milling and hauling of the existing pavement to the CCPR stockpile area can be included in the price for CCPR or priced as a separate line item. If the milling and hauling of the existing pavement is to be included in the price of the CCPR, the words “milling” and “hauling” should be added in the paragraph for payment of CCPR. If milling and hauling are provided as a separate pay item, a paragraph describing measurement and payment should be added.