Update on TERRA Survey & ARRA Activities

19th Annual TERRA Pavement Conference

February 12, 2015

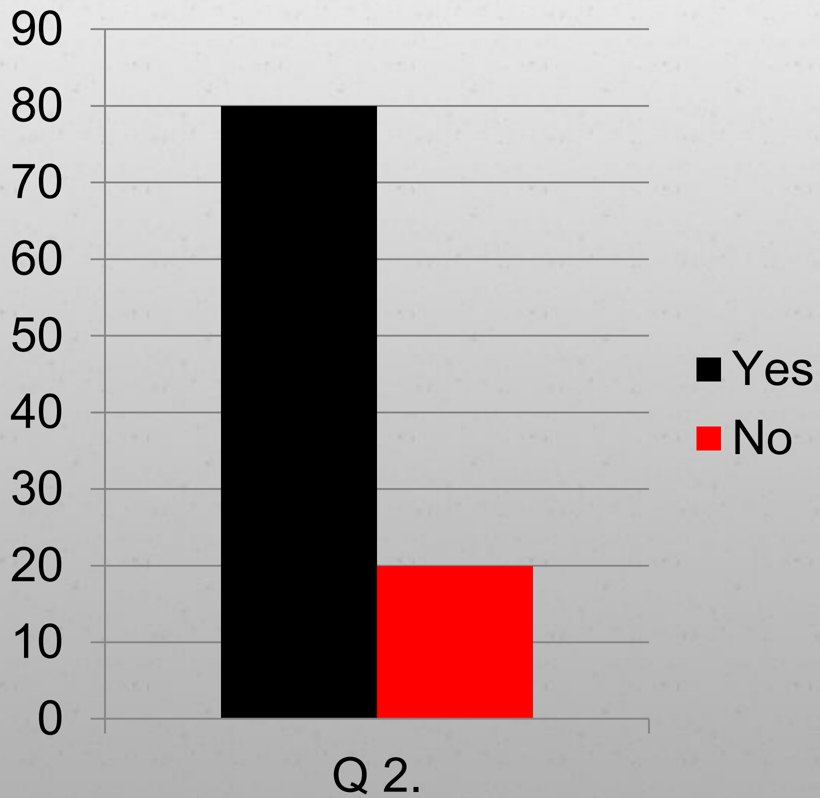
Stephen A (Steve) Cross, PhD, PE
Technical Director
Asphalt Recycling & Reclaiming Association

TERRA Survey

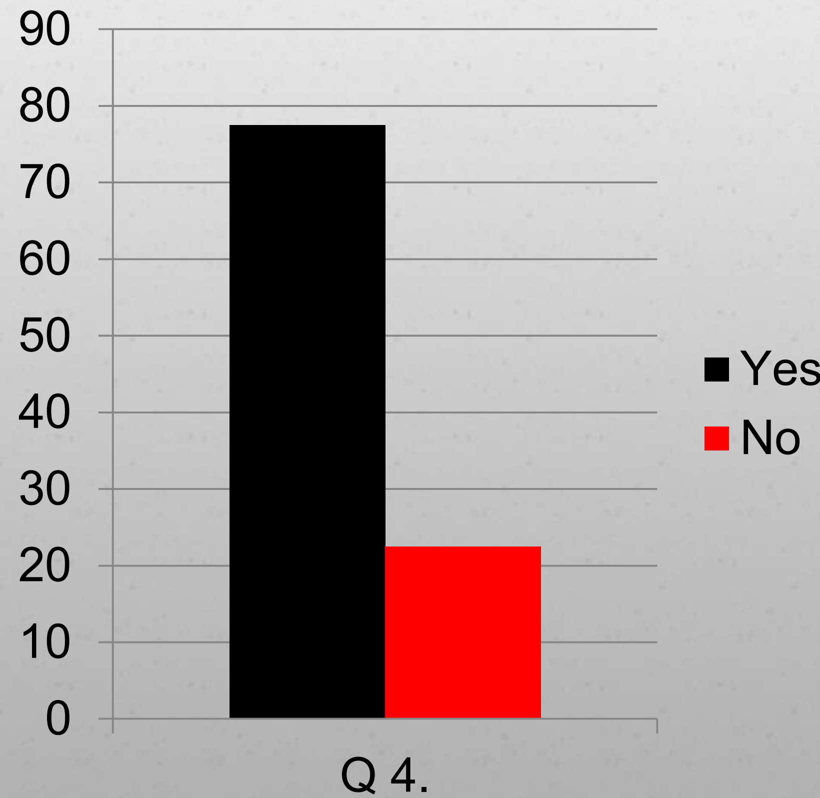
- **Surveyed agencies, suppliers and contractors to determine what methods/procedures they use to determine when a CR and FDR mixture has cured sufficiently to allow placement of a surface course.**
- **48 Respondents to survey**

Survey Results

Q 2. Does your agency have program or use CIR or FDR?

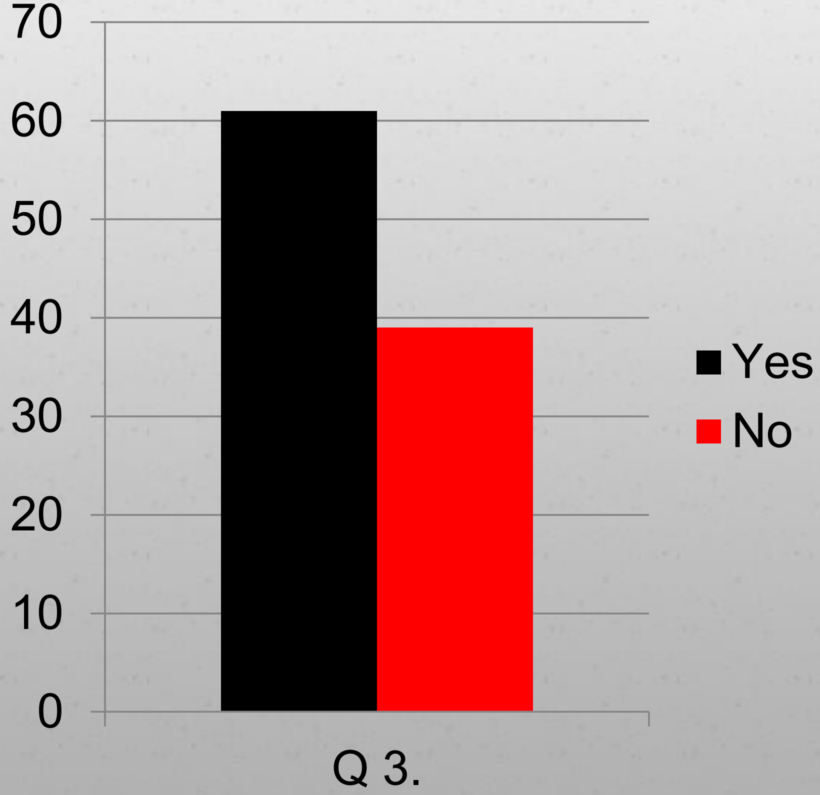


Q 4. Do you have a criteria for when safe place surface course?

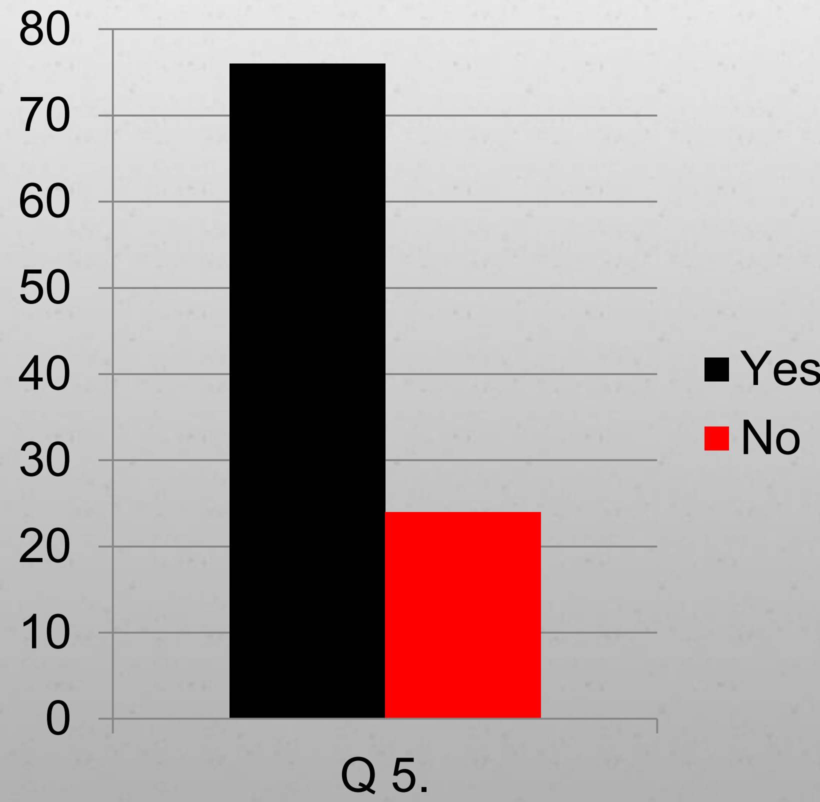


Survey Results

Q 3. Is time/criteria when place overlay an issue or concern?



Q 5. Are you satisfied with your criteria?



Questions 6 & 7

- **Only 23% were aware of any research in the area (U of Iowa/IDOT, Caltrans, Cal Davis, RMRC.**
- **Suggested test methods:**
  - **DCP, lightweight deflectometer, proof rolling, Geogauge, Clegg hammer, fracture energy**
- **Suggested procedures:**
  - **avoid/minimize curing issues by using additives (cement or lime) to improve curing and early strength gain, proper mix design, and secondary compaction prior to placing the surface course.**

ARRA's Recommended Curing Criteria for CIR

The recycled pavement layer should be allowed to cure for a minimum time (typically 3 days) and to a maximum moisture content (typically below 3 percent) before placing the surface course or applying secondary compaction. If the moisture content does not fall below the maximum limit and if the roadway has been free of rain for a specified amount of time (typically anywhere from 2 to 10 days), the contractor should be allowed to place the surface course or perform secondary compaction. Traffic is usually allowed on the mat during this time.

ARRA's Recommended Curing Criteria for FDR

The surface course may be placed after a minimum cure time (typically 3 days) and when the recycled layer can support the applied loads without deflection and/or the moisture content has dropped to less than 50% of the optimum moisture content determined from a modified Proctor of the recycled material. Traffic is usually allowed on the mat during this time.

ARRA's Concerns/Position

- **Development of test methods/QC procedures allowing evaluation of mix design/mix properties in the field**
- **Development of test procedure to determine when it is safe to allow traffic on the recycled mix**
- **Development of criteria when it is safe to place surface course**

ARRA Activities

- **Best Practice Guidelines**
- **Pavement Preservation Application Checklist Series**
- **Transportation Curriculum Coordination Council (TC3) web based courses**
- **New Basic Asphalt Recycling Manual**

ARRA Guidelines

- **100 Series - Recommended Construction Guidelines**
- **200 Series - Recommended Mix Design Guidelines**
- **300 Series - Recommended Quality Control Sampling and Testing Guidelines**
- **400 Series – Recommended Project Selection Guidelines**

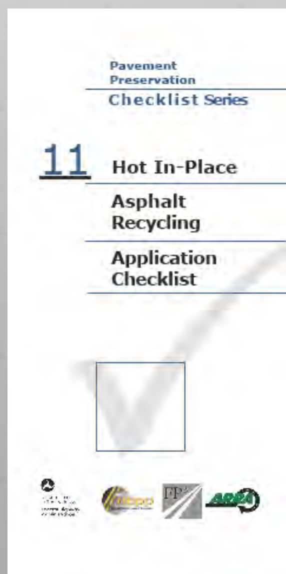
Status of ARRA Guidelines

		100 Series Const.	200 Series Mix Design	300 Series Quality Control	400 Series Project Selection
Cold Planing	Milling	X			
	Micro Milling	X			
Cold Recycling	Cold Central Plant	X	X	**X**	X
	Cold In-Place	**X**	X	**X**	X
Full Depth Reclamation	Bituminous	X	X	X	X
	Cementitious	**X**	X	X	X
	Lime	**X**	X	X	X

X Available X Under Development

Education Resources

- **Pavement Preservation Application Checklist Series**
- **www.fhwa.gov**
- **www.pavementpreservation.org**
- **www.arra.org &**



Inspection Training for Cold In-Place Recycling

Module 1: Introduction to Cold In-Place Recycling

The presentation is available as an attachment from the paperclip icon in the bottom right-hand part of the screen.

Continue

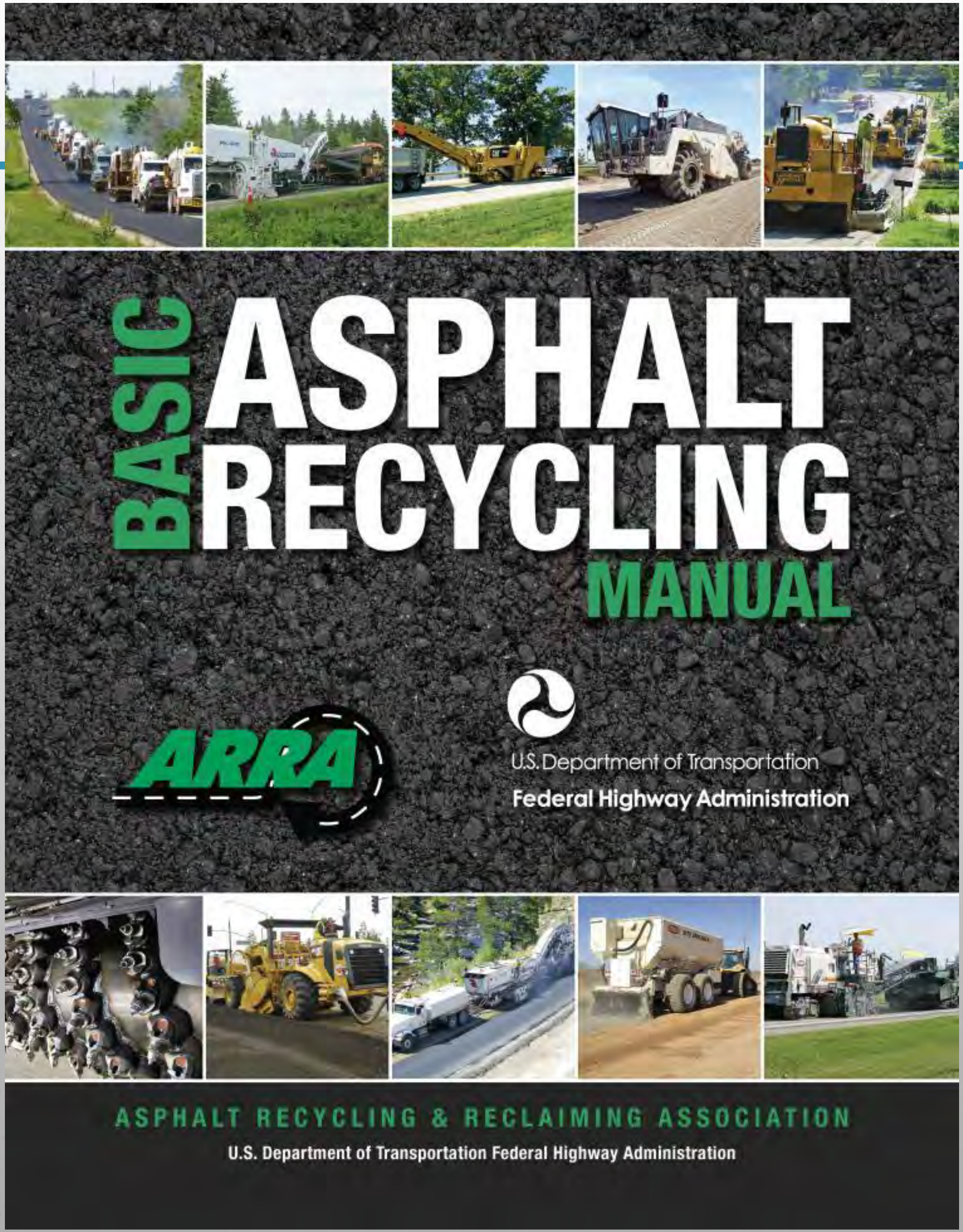
TC3 Training Resources

- ***TCCC Inspector Training for Cold In-Place Recycling (CIR) Web Based*** **FHWA-NHI-134114 – www.tccc.gov**
- **http://www.nhi.fhwa.dot.gov/training/course_search.aspx?tab=0&key=cold&typ=3&sf=0&course_no=134114**
- **HIR Class: 3-4 months out.**
- **FDR class: just started work.**

Training Overview

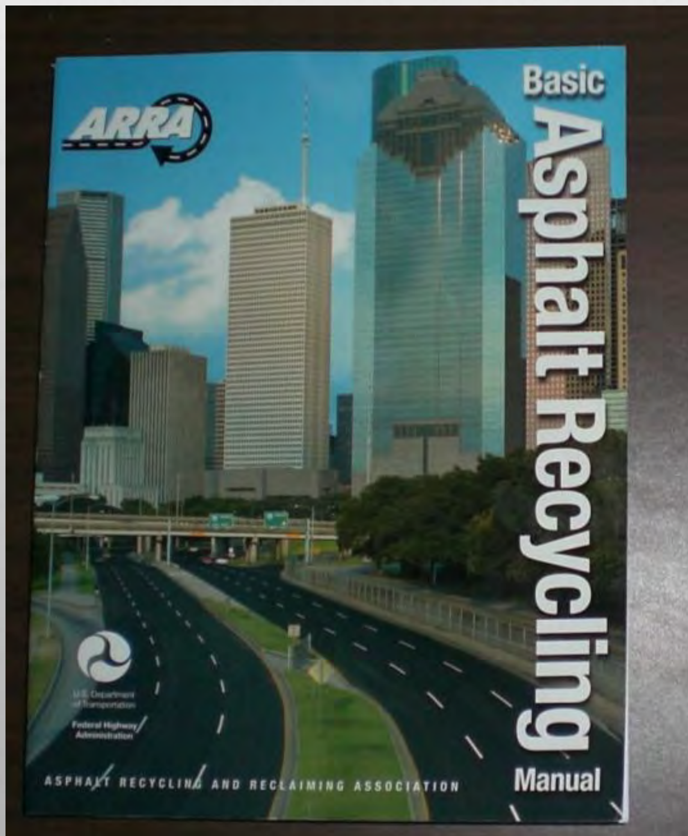
Intro	• Training Introduction
Module 1	• Introduction to Cold In-Place Recycling (CIR)
Module 2	• Cold In-Place Recycling Full Production
Module 4	• Cold In-Place Recycling Post Production Activities

BARM II will be sent to the printer in February



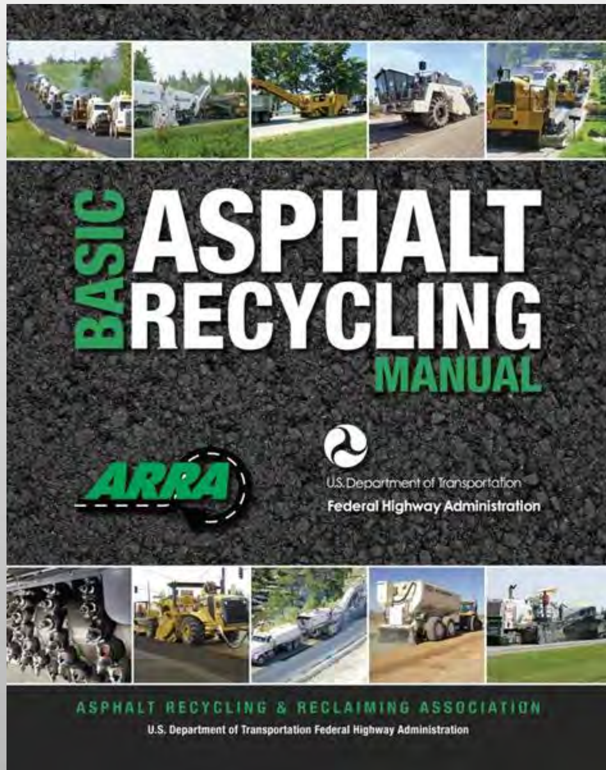
Basic Asphalt Recycling Manual

1st Edition



- Served industry well over past 13 years
- Numerous innovations and improvements in
  - Equipment
  - Materials
  - Methods
- Time for a complete rewrite of the original document

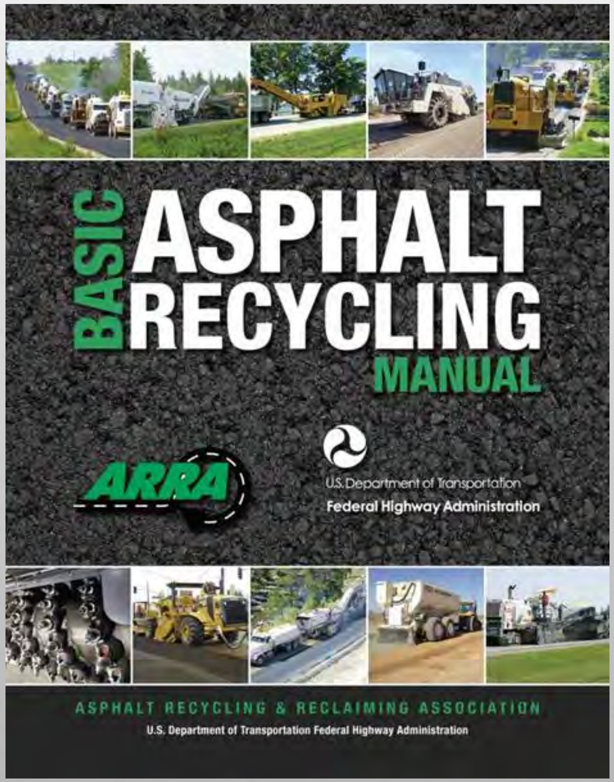
BARM II



FHWA –HIF-14-001

- True to the original concept of 1st edition
- Completely rewritten
- Same basic format
- Chapters reorganized
- All photos (117) updated (in color)

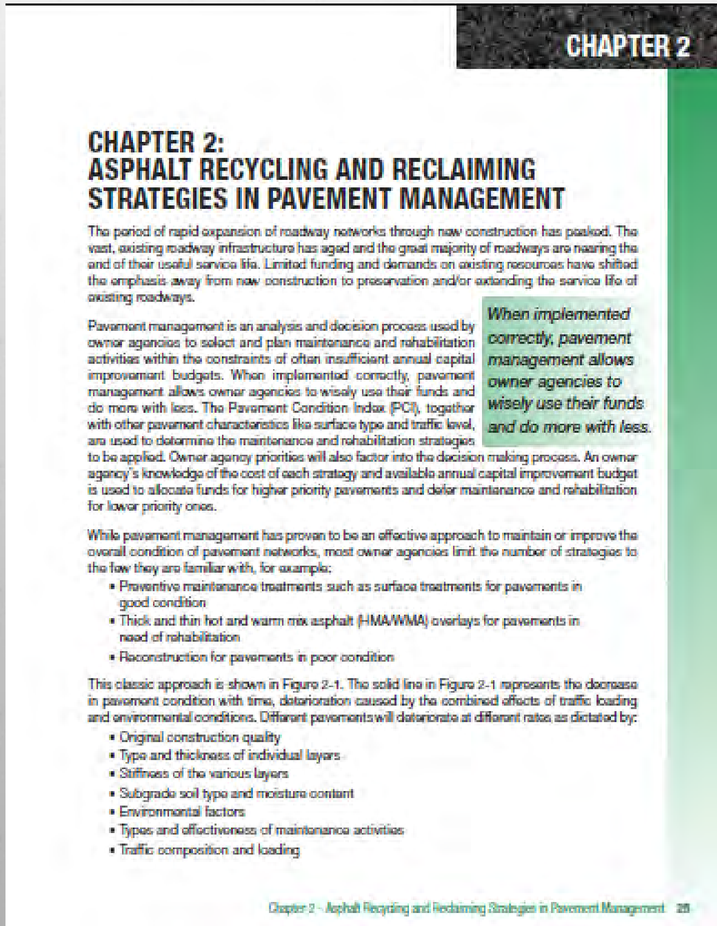
BARM II



FHWA –HIF-14-001

- **Divided 6 Parts**
  - **Introduction**
  - **Cold Planing**
  - **Hot In-place Recycling**
  - **Cold Recycling**
  - **Full Depth Reclamation**
  - **Appendix**
- **Each Part Color Coded**

BARM II


CHAPTER 2

CHAPTER 2:
ASPHALT RECYCLING AND RECLAIMING STRATEGIES IN PAVEMENT MANAGEMENT

The period of rapid expansion of roadway networks through new construction has peaked. The vast, existing roadway infrastructure has aged and the great majority of roadways are nearing the end of their useful service life. Limited funding and demands on existing resources have shifted the emphasis away from new construction to preservation and/or extending the service life of existing roadways.

Pavement management is an analysis and decision process used by owner agencies to select and plan maintenance and rehabilitation activities within the constraints of often insufficient annual capital improvement budgets. When implemented correctly, pavement management allows owner agencies to wisely use their funds and do more with less. The Pavement Condition Index (PCI), together with other pavement characteristics like surface type and traffic level, are used to determine the maintenance and rehabilitation strategies to be applied. Owner agency priorities will also factor into the decision making process. An owner agency's knowledge of the cost of each strategy and available annual capital improvement budget is used to allocate funds for higher priority pavements and defer maintenance and rehabilitation for lower priority ones.

When implemented correctly, pavement management allows owner agencies to wisely use their funds and do more with less.

While pavement management has proven to be an effective approach to maintain or improve the overall condition of pavement networks, most owner agencies limit the number of strategies to the few they are familiar with, for example:

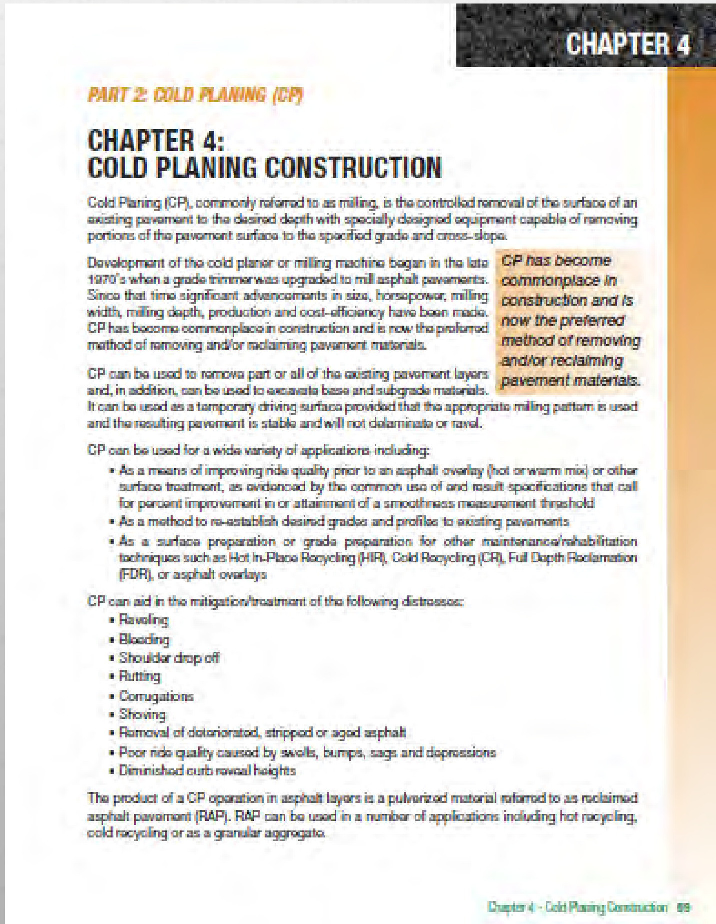
- Preventive maintenance treatments such as surface treatments for pavements in good condition
- Thick and thin hot and warm mix asphalt (HMA/WMA) overlays for pavements in need of rehabilitation
- Reconstruction for pavements in poor condition

This classic approach is shown in Figure 2-1. The solid line in Figure 2-1 represents the decrease in pavement condition with time, deterioration caused by the combined effects of traffic loading and environmental conditions. Different pavements will deteriorate at different rates as dictated by:

- Original construction quality
- Type and thickness of individual layers
- Stiffness of the various layers
- Subgrade soil type and moisture content
- Environmental factors
- Types and effectiveness of maintenance activities
- Traffic composition and loading

- Part 1: 3 Chapters
  - Introduction
  - Asphalt Recycling and Reclaiming Strategies in Pavement Management
  - Project Evaluation
- Part 6 – Appendix
  - Glossary Terms
  - List Acronyms

BARM II



CHAPTER 4

PART 2: COLD PLANING (CP)

CHAPTER 4: COLD PLANING CONSTRUCTION

Cold Planing (CP), commonly referred to as milling, is the controlled removal of the surface of an existing pavement to the desired depth with specially designed equipment capable of removing portions of the pavement surface to the specified grade and cross-slope.

Development of the cold planer or milling machine began in the late 1970's when a grade trimmer was upgraded to mill asphalt pavements. Since that time significant advancements in size, horsepower, milling width, milling depth, production and cost-efficiency have been made. CP has become commonplace in construction and is now the preferred method of removing and/or reclaiming pavement materials.

CP has become commonplace in construction and is now the preferred method of removing and/or reclaiming pavement materials.

CP can be used to remove part or all of the existing pavement layers and, in addition, can be used to excavate base and subgrade materials. It can be used as a temporary driving surface provided that the appropriate milling pattern is used and the resulting pavement is stable and will not delaminate or ravel.

CP can be used for a wide variety of applications including:

- As a means of improving ride quality prior to an asphalt overlay (hot or warm mix) or other surface treatment, as evidenced by the common use of end result specifications that call for percent improvement in or attainment of a smoothness measurement threshold
- As a method to re-establish desired grades and profiles to existing pavements
- As a surface preparation or grade preparation for other maintenance/rehabilitation techniques such as Hot In-Place Recycling (HIR), Cold Recycling (CR), Full Depth Reclamation (FDR), or asphalt overlays

CP can aid in the mitigation/treatment of the following distresses:

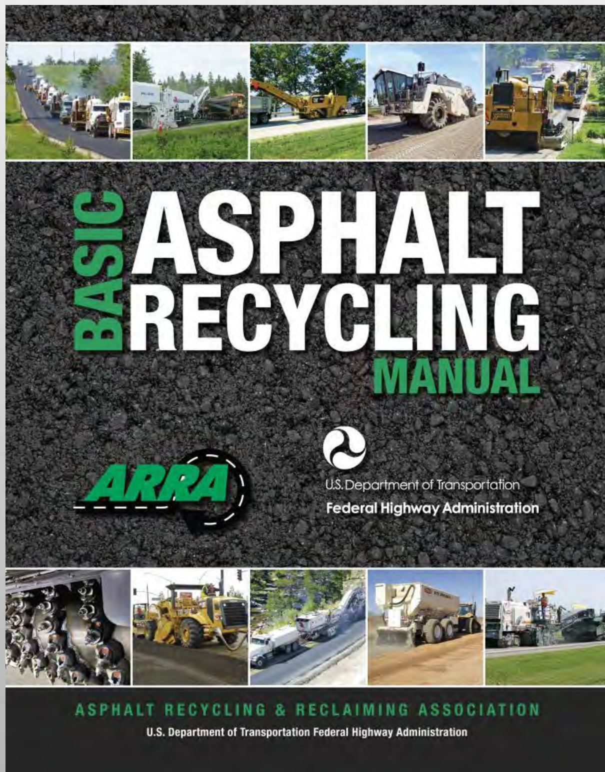
- Raveling
- Bleeding
- Shoulder drop off
- Rutting
- Corrugations
- Shoving
- Removal of deteriorated, stripped or aged asphalt
- Poor ride quality caused by swells, bumps, sags and depressions
- Diminished curb reveal heights

The product of a CP operation in asphalt layers is a pulverized material referred to as reclaimed asphalt pavement (RAP). RAP can be used in a number of applications including hot recycling, cold recycling or as a granular aggregate.

Chapter 4 - Cold Planing Construction 69

- ► **Part 2: Cold Planing**
- ► **2 Chapters**
  - **Cold Planing Construction**
  - **Cold Planing Specifications**

BARM II

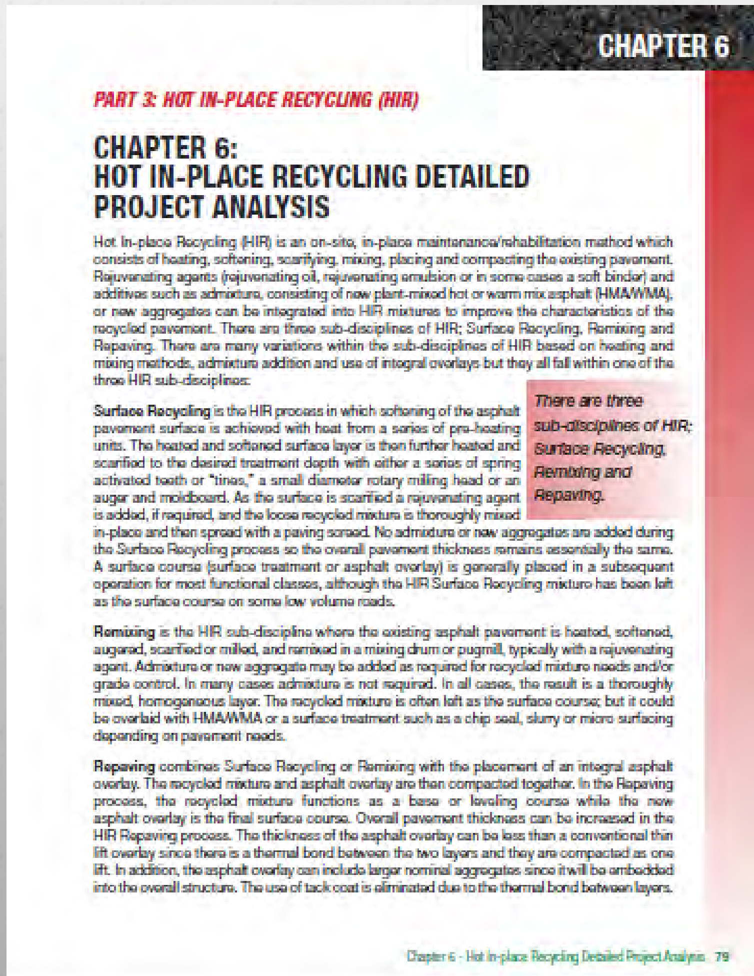


- **Parts 3-5**
- **Hot In-place Recycling**
- **Cold Recycling**
- **Full Depth Reclamation**
- **Four Chapters for Each Part (Discipline)**

BARM II

- For Each Part - Chapters on:
  - Detailed Project Analysis
  - Mix Design
  - Construction
  - Project Specifications and Inspection

Part 3: Hot In-place Recycling Chapters 6-9



CHAPTER 6

PART 3: HOT IN-PLACE RECYCLING (HIR)

CHAPTER 6: HOT IN-PLACE RECYCLING DETAILED PROJECT ANALYSIS

Hot In-place Recycling (HIR) is an on-site, in-place maintenance/rehabilitation method which consists of heating, softening, scarifying, mixing, placing and compacting the existing pavement. Rejuvenating agents (rejuvenating oil, rejuvenating emulsion or in some cases a soft binder) and additives such as admixture, consisting of new plant-mixed hot or warm mix asphalt (HMA/WMA), or new aggregates can be integrated into HIR mixtures to improve the characteristics of the recycled pavement. There are three sub-disciplines of HIR; Surface Recycling, Remixing and Repaving. There are many variations within the sub-disciplines of HIR based on heating and mixing methods, admixture addition and use of integral overlays but they all fall within one of the three HIR sub-disciplines:

There are three sub-disciplines of HIR: Surface Recycling, Remixing and Repaving.

Surface Recycling is the HIR process in which softening of the asphalt pavement surface is achieved with heat from a series of pre-heating units. The heated and softened surface layer is then further heated and scarified to the desired treatment depth with either a series of spring activated teeth or "tines," a small diameter rotary milling head or an auger and moldboard. As the surface is scarified a rejuvenating agent is added, if required, and the loose recycled mixture is thoroughly mixed in-place and then spread with a paving screed. No admixture or new aggregates are added during the Surface Recycling process so the overall pavement thickness remains essentially the same. A surface course (surface treatment or asphalt overlay) is generally placed in a subsequent operation for most functional classes, although the HIR Surface Recycling mixture has been left as the surface course on some low volume roads.

Remixing is the HIR sub-discipline where the existing asphalt pavement is heated, softened, augered, scarified or milled, and remixed in a mixing drum or pugmill, typically with a rejuvenating agent. Admixture or new aggregate may be added as required for recycled mixture needs and/or grade control. In many cases admixture is not required. In all cases, the result is a thoroughly mixed, homogeneous layer. The recycled mixture is often left as the surface course; but it could be overlaid with HMA/WMA or a surface treatment such as a chip seal, slurry or micro surfacing depending on pavement needs.

Repaving combines Surface Recycling or Remixing with the placement of an integral asphalt overlay. The recycled mixture and asphalt overlay are then compacted together. In the Repaving process, the recycled mixture functions as a base or leveling course while the new asphalt overlay is the final surface course. Overall pavement thickness can be increased in the HIR Repaving process. The thickness of the asphalt overlay can be less than a conventional thin lift overlay since there is a thermal bond between the two layers and they are compacted as one lift. In addition, the asphalt overlay can include larger nominal aggregates since it will be embedded into the overall structure. The use of tack coat is eliminated due to the thermal bond between layers.

Chapter 6 - Hot In-place Recycling Detailed Project Analysis 79

HIR Applicability

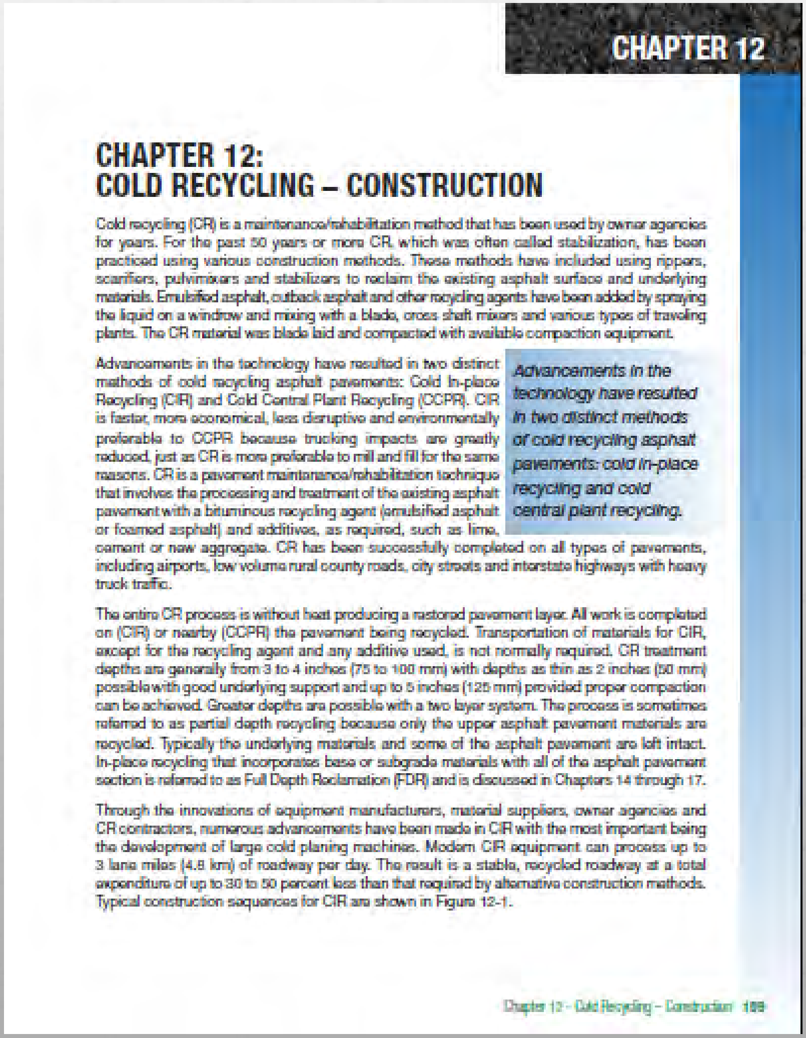
Table 6-1: HIR Applicability

Condition		Surface Recycling	Remixing	Repaving
Surface Defects	Raveling	Yes	Yes	Yes
	Pot Holes	Yes	Yes	Yes
	Bleeding	No	Possible, see note a	Possible, see note b
	Skid Resistance	No	Possible, see note a	Yes
Deformations	Shoulder Drop Off	No	No	No
	Rutting - Wear	Yes	Yes	Yes
	Rutting - Mix Instability	No	Possible, see note a & c	Possible, see note d
	Rutting - Deep Structural	No	No	No
	Corrugations	Yes	Yes	Yes
	Shoving	No	Possible, see note a & c	Possible, see note d
Load Associated Cracking	Fatigue - Bottom Up	No	No	No
	Fatigue - Top Down	Possible, see note e	Possible, see note e	Possible, see note e
	Edge	Possible, see note b & f	Possible, see note b & f	Possible, see note b & f
	Slippage	Possible, see note g	Possible, see note g	Possible, see note g
Non-load Associated Cracking	Block	Yes	Yes	Yes
	Longitudinal	Yes	Yes	Yes
	Transverse	Yes, see note d	Yes, see note d	Yes, see note d
	Reflective	Yes, see note d	Yes, see note d	Yes, see note d
Combined Cracking	Joint Reflection	Possible, see note b	Possible, see note b	Possible, see note b
	Discontinuity	Possible, see note b	Possible, see note b	Possible, see note b
Base/Subgrade Deficiencies	Swells, Bumps, Sags Depressions	Unlikely, see note b	Unlikely, see note b	Unlikely, see note b
Roughness	Ride Quality	Yes	Yes	Yes
Other Criteria	All Levels of Traffic	Yes, see note h	Yes, see note h	Yes, see note h
	Rural	Yes	Yes	Yes
	Urban	Yes, see note i	Yes, see note i	Yes, see note i
	Stripping	Possible, see note c & d	Possible, see note c & d	Possible, see note c & d
	Poor Drainage	No, see note j	No, see note j	No, see note j

Notes: a) Can be corrected with additives such as admixture or new aggregate. b) May not correct but will mitigate. c) Needs to be verified by a mix design. d) Determine severity and depth of existing layers that are affected. May not correct but will mitigate. e) Ensure that structural requirements can be met. An asphalt overlay may be needed. f) Need to provide shoulder confinement after HIR. g) Treatment depth should exceed slippage plane. h) As long as proper pavement structural design is undertaken as part of the process to ensure that the effects of future traffic are taken into account. i) Geometric constraints may influence the type of recycling units used. j) Poor drainage must be improved for HIR, or any other pavement treatment, to ensure adequate performance.

- Table 6-1 describes which HIR sub-discipline addresses which pavement distresses
- Notes clarify if address, mitigate other actions required

Part 4: Cold Recycling Chapters 10-13


CHAPTER 12

CHAPTER 12: COLD RECYCLING – CONSTRUCTION

Cold recycling (CR) is a maintenance/rehabilitation method that has been used by owner agencies for years. For the past 50 years or more CR, which was often called stabilization, has been practiced using various construction methods. These methods have included using rippers, scarifiers, pulvimixers and stabilizers to reclaim the existing asphalt surface and underlying materials. Emulsified asphalt, cutback asphalt and other recycling agents have been added by spraying the liquid on a windrow and mixing with a blade, cross shaft mixers and various types of traveling plants. The CR material was blade laid and compacted with available compaction equipment.

Advancements in the technology have resulted in two distinct methods of cold recycling asphalt pavements: Cold In-place Recycling (CIR) and Cold Central Plant Recycling (CCPR). CIR is faster, more economical, less disruptive and environmentally preferable to CCPR because trucking impacts are greatly reduced, just as CR is more preferable to mill and fill for the same reasons. CR is a pavement maintenance/rehabilitation technique that involves the processing and treatment of the existing asphalt pavement with a bituminous recycling agent (emulsified asphalt or foamed asphalt) and additives, as required, such as lime, cement or new aggregate. CR has been successfully completed on all types of pavements, including airports, low volume rural county roads, city streets and interstate highways with heavy truck traffic.

Advancements in the technology have resulted in two distinct methods of cold recycling asphalt pavements: cold in-place recycling and cold central plant recycling.

The entire CR process is without heat producing a restored pavement layer. All work is completed on (CIR) or nearby (CCPR) the pavement being recycled. Transportation of materials for CIR, except for the recycling agent and any additive used, is not normally required. CR treatment depths are generally from 3 to 4 inches (75 to 100 mm) with depths as thin as 2 inches (50 mm) possible with good underlying support and up to 5 inches (125 mm) provided proper compaction can be achieved. Greater depths are possible with a two layer system. The process is sometimes referred to as partial depth recycling because only the upper asphalt pavement materials are recycled. Typically the underlying materials and some of the asphalt pavement are left intact. In-place recycling that incorporates base or subgrade materials with all of the asphalt pavement section is referred to as Full Depth Reclamation (FDR) and is discussed in Chapters 14 through 17.

Through the innovations of equipment manufacturers, material suppliers, owner agencies and CR contractors, numerous advancements have been made in CIR with the most important being the development of large cold planing machines. Modern CIR equipment can process up to 3 lane miles (4.8 km) of roadway per day. The result is a stable, recycled roadway at a total expenditure of up to 30 to 50 percent less than that required by alternative construction methods. Typical construction sequences for CIR are shown in Figure 12-1.

Chapter 12 - Cold Recycling – Construction 189

Cold Central Plant (CCPR)

Cold In-place (CIR)

CR Applicability

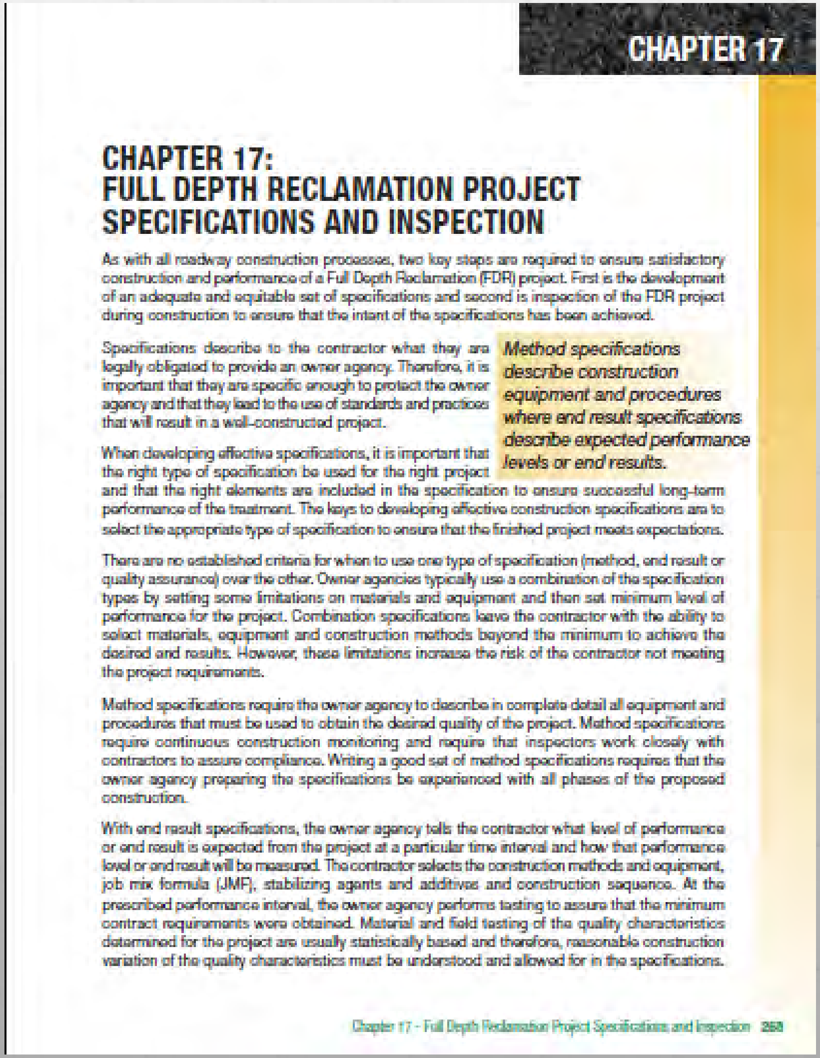
Table 10-1: CR Applicability

Condition		CR Applicability
Surface Defects	Raveling	Yes
	Pot Holes	Yes
	Bleeding	Yes
	Skid Resistance	Yes
Deformations	Shoulder Drop Off	No
	Rutting - Wear	Yes
	Rutting - Mix Instability	Possible, see note a
	Rutting - Deep Structural	Possible, see note b
	Corrugations	Yes
	Shoving	Possible, see note a
Load Associated Cracking	Fatigue - Bottom Up	Possible, see note c
	Fatigue - Top Down	Possible, see note c
	Edge	Possible, see note d
	Slippage	Possible, see note e
Non-load Associated Cracking	Block	Yes
	Longitudinal	Yes
	Transverse	Yes
	Reflective	Yes
Combined Cracking	Joint Reflective	Possible, see note f
	Discontinuity	Yes
Base/Subgrade Deficiencies	Swells, Bumps, Sags Depressions	Possible, see note g
Roughness	Ride Quality	Yes
Other Criteria	All Levels of Traffic	Yes, see note h
	Rural	Yes
	Urban	Yes, see note i
	Stripping	Possible, see note a
	Poor Drainage	No, see note j

Notes: a) Can be corrected with additives such as cement, lime and new aggregate. Needs to be verified by a mix design. b) Not with CIR but can be addressed with CCPR and correction of the underlying materials. c) Ensure that structural requirements can be met. CR in conjunction with an asphalt overlay may be needed. d) Need to provide shoulder confinement after CR. e) As long as treatment depth exceeds the slippage plane. f) May not correct but will mitigate. g) Can be addressed with CCPR and correction of the underlying materials. CIR may not correct but may mitigate. h) As long as proper pavement structural design is undertaken as part of the process to ensure that the effects of future traffic are taken into account and if the CR mixture is designed to have sufficient early and long term strength. Additives (cement or lime) may be necessary to improve early strength gain. i) Geometric constraints may influence the type of recycling units used or whether CIR or CCPR is used. j) Poor drainage must be improved for CR, or any other pavement treatment, to ensure adequate performance.

- Same information for CR as HIR
- Notes clarify if address, mitigate other actions required

Part 5: Full Depth Reclamation Chapters 14-17



CHAPTER 17

CHAPTER 17: FULL DEPTH RECLAMATION PROJECT SPECIFICATIONS AND INSPECTION

As with all roadway construction processes, two key steps are required to ensure satisfactory construction and performance of a Full Depth Reclamation (FDR) project. First is the development of an adequate and equitable set of specifications and second is inspection of the FDR project during construction to ensure that the intent of the specifications has been achieved.

Specifications describe to the contractor what they are legally obligated to provide an owner agency. Therefore, it is important that they are specific enough to protect the owner agency and that they lead to the use of standards and practices that will result in a well-constructed project.

Method specifications describe construction equipment and procedures where end result specifications describe expected performance levels or end results.

When developing effective specifications, it is important that the right type of specification be used for the right project and that the right elements are included in the specification to ensure successful long-term performance of the treatment. The keys to developing effective construction specifications are to select the appropriate type of specification to ensure that the finished project meets expectations.

There are no established criteria for when to use one type of specification (method, end result or quality assurance) over the other. Owner agencies typically use a combination of the specification types by setting some limitations on materials and equipment and then set minimum level of performance for the project. Combination specifications leave the contractor with the ability to select materials, equipment and construction methods beyond the minimum to achieve the desired end results. However, these limitations increase the risk of the contractor not meeting the project requirements.

Method specifications require the owner agency to describe in complete detail all equipment and procedures that must be used to obtain the desired quality of the project. Method specifications require continuous construction monitoring and require that inspectors work closely with contractors to assure compliance. Writing a good set of method specifications requires that the owner agency preparing the specifications be experienced with all phases of the proposed construction.

With end result specifications, the owner agency tells the contractor what level of performance or end result is expected from the project at a particular time interval and how that performance level or end result will be measured. The contractor selects the construction methods and equipment, job mix formula (JMF), stabilizing agents and additives and construction sequence. At the prescribed performance interval, the owner agency performs testing to assure that the minimum contract requirements were obtained. Material and field testing of the quality characteristics determined for the project are usually statistically based and therefore, reasonable construction variation of the quality characteristics must be understood and allowed for in the specifications.

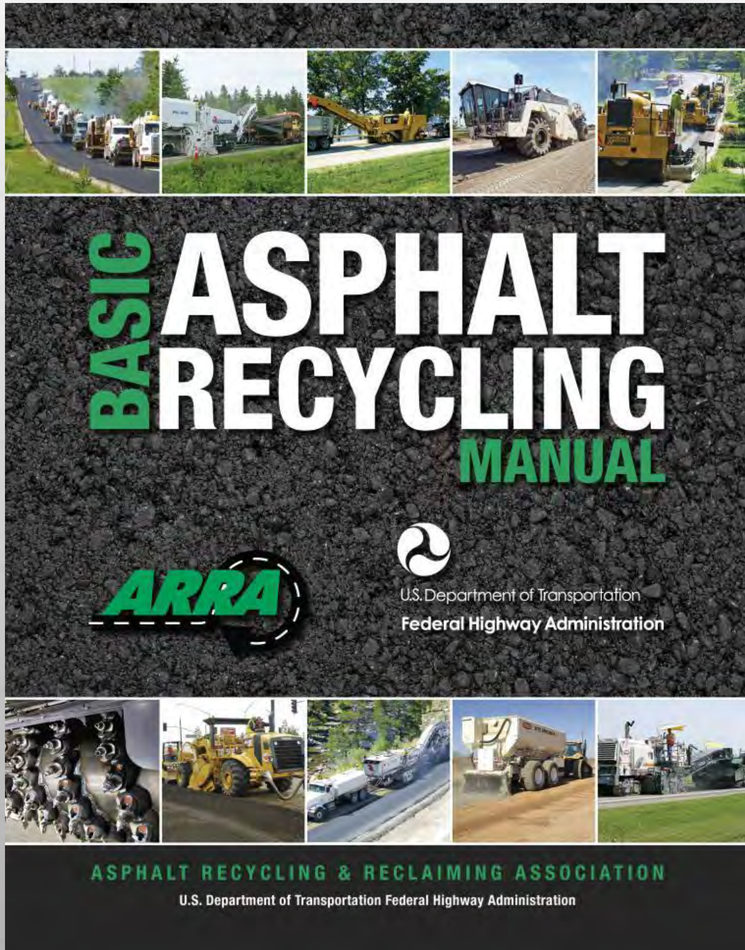
Chapter 17 - Full Depth Reclamation Project Specifications and Inspection 253

FDR Stabilizing Agent Selection Guide

Table 15-1: Stabilizing Agent[1] Selection Guide for FDR Mixtures Including RAP

Material Type - Including RAP	Well Graded Gravel	Poorly Graded Gravel	Silty Gravel	Clayey Gravel	Well Graded Sand	Poorly Graded Sand	Silty Sand	Clayey Sand	Silt, Silt with Sand	Lean Clay	Organic Silt/Organic Lean Clay	Elastic Silt	Fat Clay, Fat Clay with Sand
USCS[2]	GW	GP	GM	GC	SW	SP	SM	SC	ML	CL	OL	MH	CH
AASHTO[3]	A-1-a	A-1-a	A-1-b	A-1-b A-2-6	A-1-b	A-3 or A-1-b	A-2-4 or A-2-5	A-2-6 or A-2-7	A-4 or A-5	A-6	A-4	A-5 or A-7-5	A-7-6
Emulsified Asphalt SE > 30 or PI < 6 and P_{200} < 20%	X	X	X	X	X	X	X						
Foamed Asphalt PI < 10 and P_{200} 5 to 20%	X		X	X	X		X						
Cement, CKD or Self-Cementing Class C Fly Ash PI < 20 SO_4 < 3000 ppm	X	X	X	X	X	X	X	X	X	X			
Lime/LKD PI > 20 and P_{200} > 25% SO_4 < 3000 ppm								X		X		X	X

Availability



FHWA –HIF-14-001

BARM II will be available through ARRA members. Check with your local ARRA Contractor or Supplier Member for more information on how to receive a copy.

Thank You

Stephen A Cross, PhD, PE

Technical Director

ARRA

steve.cross@okstate.edu

405-744-7200