CHAPTER 14 PARTIAL DEPTH RECYCLING

14.1 OVERVIEW

This chapter covers Partial Depth Recycling (PDR), which is a process that recycles the existing (visually distressed) asphalt pavement and transforms it into a new base layer that is less susceptible to reflective cracking. PDR is considered a green technology because it recycles the existing HMA in place, requiring no added heat, and emitting no fumes. PDR offers both materials and energy savings. PDR reuses the aggregates from the existing HMA and minimizes or saves the need for virgin aggregates. PDR can reduce the environmental impact of a project.

The specific goal of this chapter is to provide information on the materials, design, and construction of PDR. The major topics include:

- Project Selection Considerations
- Materials
- Design and Specifications
- Construction
- Troubleshooting Guide
- References

Partial Depth Recycling (PDR), formerly known as Cold-in-Place Recycling (CIR), is increasingly becoming a preferred choice for maintenance projects. It is a pavement preservation or corrective maintenance technique that when combined with an asphalt overlay can significantly improve the structural integrity of the roadway. PDR typically recycles the top 3-4.8 inches (0.25 to 0.4 foot) of the existing hot mix asphalt wearing course, but the recycling depth can be increased to 6 inches (0.5 foot) on roadways that have good underlying support. In the HM-1 workplan, the PDR recycle depth is typically 3-4 inches (0.25 to 0.33 foot).

PDR corrects such deficiencies as thermal and reflective cracking, meanwhile improving the ride quality as well. PDR is generally not recommended when the underlying structural layers are structurally deficient or when poor drainage is an issue. PDR is designed to economically correct defects in the HMA wearing surface and correct cross-slope deficiencies as well as minor profile issues. There are two different types of PDR, one type uses

emulsion with the Reclaimed Asphalt Pavement (RAP), and the other type uses foamed asphalt. Both types of PDR have the following advantages listed by Caltrans.

- Conservation of non-renewable resources
- Energy conservation compared to other maintenance/rehabilitation methods
- Surface irregularities are corrected
- A portion of existing cracks are removed, and reflective cracking mitigated
- Base and subgrade materials are not disturbed with PDR during the construction process
- Pavement cross-slope and profile are improved
- Problems with existing aggregate gradation and/or asphalt binder can be corrected
- Reduced traffic disruptions and user inconvenience
- Reduced or no edge drop offs with PDR
- Cost savings compared to other maintenance strategies
- PDR should get first consideration in material selection for maintenance projects

This chapter on PDR is condensed to provide a quick general understanding of the concept, with enough detail so that the designer may develop a successful project. The PDR process removes a portion of an existing asphalt pavement by cold planning and then treats it with recycling agent (emulsion or foamed asphalt) and other additives then relays it. Typically, the steps include:

- Cold planing the existing asphalt layers a partial depth of three to four inches.
- Size the reclaimed asphalt pavement (RAP)
- Blend the recycling agent and other additives (cement and supplemental aggregate, if specified) with the RAP
- Place and compact the blended recycled mixture
- Asphaltic emulsion and sand cover
- Allow material to cure
- Place tack coat and overlay with a new HMA or RHMA surface over the cured PDR

Cold Central Plant Recycling (CCPR) is a maintenance or rehabilitation process that can be used as an alternative to PDR and Full Depth Recycling (FDR), but the recycling operation occurs at a mobile or central plant location rather than in-situ. The asphalt materials are milled, processed, and treated at a nearby cold central plant, and then returned to the project and placed with a paver. CCPR is a proven solution for projects where in-place recycling isn't feasible due to traffic constraints, tight urban geometries, or operational limitations. Although CCPR construction processes will not be covered in this chapter, the project selection considerations, materials, and mix design are similar to PDR.

Caltrans currently classifies FDR as a rehabilitation strategy rather than a maintenance strategy FDR will not be covered in this Chapter. Additional information may be found in Caltrans references as well as several UCPRC publications. Figure 14-1 shows the different types of pavement recycling.

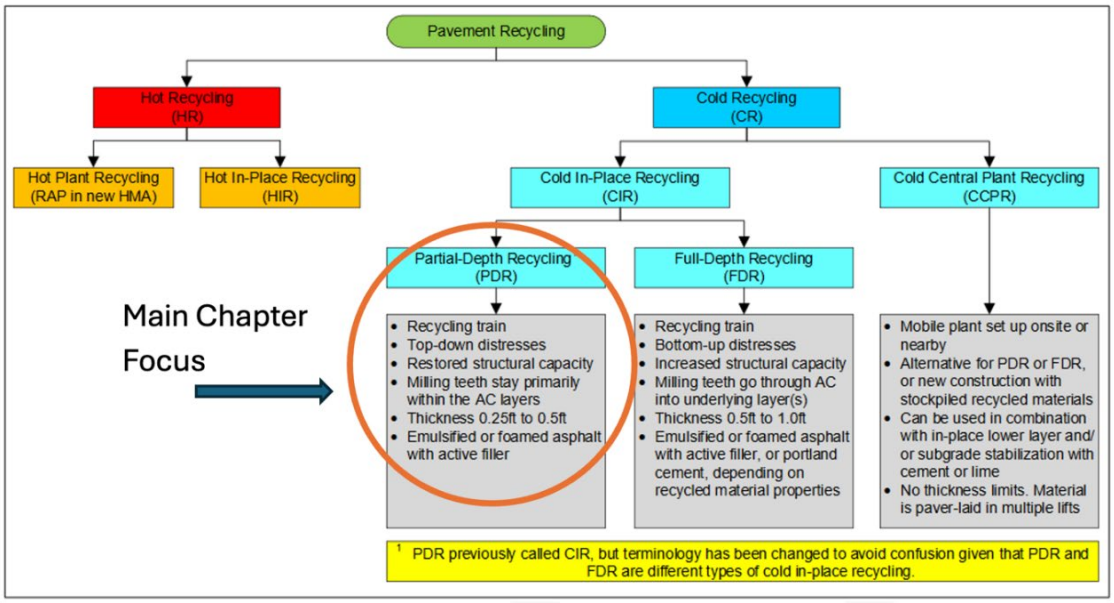

Figure 14-1 Different Types of Pavement Recycling and Terminology, (UCPRC, 2020)

14.2 PROJECT SELECTION CONSIDERATIONS

PDR is generally used on non-load associated distresses (thermal/reflective cracking). Cracked pavements that are structurally sound and have well drained bases are the best candidates. For PDR to be effective in mitigating cracking, the recycling depth should be sufficient enough to remove the distress, typically in the range of 3 to 4 inches. The greater the depth of the crack that is removed, the less impact the remaining crack will have on pavement performance, such as future reflective cracking.

The following are some general criteria used in selecting a PDR project:

- PDR construction on two-lane roadways with one-way traffic control is limited to roads with 12,000 ADT and 750 ADTT or less unless detours are available or if agreed to by the HQ Pavement Program. PDR operations typically occupy 1 ½ lanes within the construction zone with vehicles traveling on the PDR temporarily. For PDR projects on multilane roads with higher volumes, the same principles of safety and traffic handling during construction apply as to any other pavement project.
- PDR is generally used for correcting non-load-associated distresses.
- Do not use for base failures, and if pumping is present due to poor drainage.
- Existing RHMA sections need special evaluation by the District prior to PDR strategy selection to determine if the existing HMA thickness to be recycled is not more than 25% RHMA.
- Do not use on tight turns and steep grades (> 6%) for equipment limitations.
- PDR should be limited to the top 0.25-0.33 ft. of the existing pavement. Ensure that the remaining AC layer and base can support the PDR train. A minimum of 0.2 ft. of intact AC pavement or 0.5 ft. of intact, dry Class 2 aggregate base will typically support the recycling train.

The following are some guidelines in selection of a PDR project:

- Determine the cause of distress of the existing pavement.
- PDR as a single treatment will not restore base or sub-base failures (structurally deficient).
- Recycled pavement (under traffic) must be cured before placing an HMA overlay.

The presence of large or frequent surface patches increases the variability and decreases the homogeneity of existing materials and resulting PDR material. Excessive patches may be an indication of poor subgrade conditions, which may dictate the appropriate maintenance or rehabilitation technique. If patches are excessive, full-depth recycling (FDR) or reconstruction may be required. It is an economic decision.

14.3 MATERIALS

14.3.1 Reclaimed Asphalt Pavement

The PDR project shall have reclaimed asphalt pavement (RAP) consisting of asphalt coated material only. A special consideration for RAP is when the existing pavement has rubberized asphalt pavement. It is recommended that not more than 25% of the recycled section by length be rubberized asphalt pavement.

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 roadway and sized to meet specification requirements. RAP from an external location, such as a stockpile brought to a cold central plant, shall be free from dirt, base, concrete or other deleterious materials such as silt and clay. 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.

14.3.2 Emulsions

Asphalt emulsions “glue” the RAP aggregates together. The emulsion and RAP mixture is mixed with cement that is placed on the existing pavement ahead of the equipment train. With engineered emulsions, it rarely takes more than a few days for the moisture content to drop below 3 percent except in wet, foggy, cool conditions or when the pavement has high in situ moisture content. In these conditions, it is recommended to have a maximum cure time of 10 days.

14.3.3 Foamed Asphalt

Besides emulsions, foamed asphalt can be used as an alternative with the RAP. The foaming occurs as the binder expands from the trapped water, changing from a liquid to a vapor, which reduces the viscosity of the binder, and the surface area that it can cover increases. The foamed asphalt and RAP mixture is usually mixed with cement that is placed on the existing pavement ahead of the equipment train. During the mix design, the foaming properties (expansion ratio and half-life) are determined visually to ensure good dispersion of the asphalt binder in the mix. In the field, the binder should be visually inspected for foaming to determine if any anti-foaming agents are present in the binder. Figure 14-2 shows foamed asphalt bonding with RAP and mineral filler.

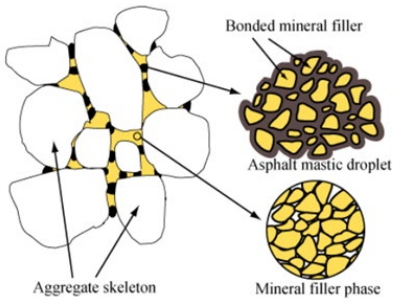

Figure 14-2 Foamed Asphalt Bonding with RAP and Mineral Filler
https://dot.ca.gov/programs/maintenance/pavement/cold-recycling-main/pdr

14.3.4 Supplemental Aggregate

Supplemental aggregate may be required to supplement the RAP gradation in the PDR to meet mix design requirements.

14.3.5 Sampling and Testing

PDR behavior will have a certain degree of variation. This will occur based on both the existing pavement to be recycled as well as the environmental and material conditions during construction. These conditions may include the following:

- Emulsion, type, and manufacturer
- Coating characteristics
- Emulsion break time and workability
- Temperature during PDR construction
- Variability in the existing structural section.

Prior to developing a mix design, core samples at a suggested minimum of 3 locations, or enough to generate 450 pounds of Reclaimed Asphalt Pavement (RAP). California Test (CT) 315 entitled “Method of Test for Mixture Design and Testing of Partial Depth Recycling of Asphalt Pavement Using Bituminous Recycling Agents and Additives”, is specified to be used in Section 30-5 for mix design development of PDR material.

14.3.6 Laboratory Testing

All required laboratory testing for the PDR mix design is completed by the contractor according to CT 315, which currently consists of:

- Optimal Water Content
- Maximum Bulk and Dry Density
- Ratio of recycling agent residual asphalt content to cement
- Dry indirect tensile test
- Wet indirect tensile test
- Raveling Test
- Rap Coating Test (for PDR-EA)

Caltrans reviews and approves the PDR Mix Design submitted by the contractor. If required, the mix design may be adjusted in the field with approval from the Office of Pavement Recycling and Job Order Contracting.

14.4 DESIGN AND SPECIFICATIONS

The contractor shall submit PDR mix designs for Caltrans' review. The contractor has the flexibility to choose recycling agents in the design.

Mix designs must follow the procedures detailed in the appropriate mix design method. For PDR, California Test 315, "Method of Test for Mixture Design and Testing of Partial Depth Recycling (PDR) of Asphalt Pavements Using Bituminous Recycling Agents and Additives" is used. For CCPR, California Test 316, "Method of Test for Mixture Design and Testing of Cold Central Plant Recycling (CCPR) of Asphalt Pavements Using Bituminous Recycling Agents and Additives" is used. These methods include recycling with either emulsified or foamed asphalt.

Determination of the load-carrying capacity of the existing pavement and underlying materials becomes more important for thinner pavement. Three useful methods of assessing the load carrying capacity of the pavement structure are Ground Penetrating Radar (GPR), Dynamic Cone Penetrometer (DCP), and Falling Weight Deflectometer (FWD) testing. GPR is an effective device to determine thickness and variability of the pavement structure and adequacy for PDR construction and may be verified through field sampling (coring) of the pavement at multiple locations throughout the project's length and width.

Surface treatments (chip seals, slurry seals, micro surfacing) tend to be high in asphalt binder and therefore, must be accounted for in the mix design process for PDR treatments. Specialty mixtures such as open-graded drainage layers, open-graded friction courses, etc., may influence mix design as well. Properly installed paving fabrics can be successfully recycled during the PDR operation, however poorly installed fabrics and geogrids may tear out and negatively affect the construction operation and recycled material. PDR treatment depths should extend through or stay above the paving fabric to prevent pulling of the fabric and delamination of the existing HMA mixture. The contractor should be informed of the

presence of paving fabrics and excessive crack seal, as additional personnel may be required to remove oversize pieces.

The Caltrans 2025 Standard Specifications or latest version, section 30-5 and 30-6, are entitled Partial Depth Recycling (PDR) and Cold Central Plant Recycling (CCPR). The Caltrans 2025 Standard Specifications Section 30-5 (PDR) and Section 30-6 (CCPR), includes definitions, submittals, required certificates, quality assurance plan, materials, equipment, PDR/CCPR activities, emulsion and sand cover, temporary structural section, supplemental compaction, and payment.

14.5 CONSTRUCTION

PDR construction typically begins with milling the existing pavement to the specified treatment depth, followed by adding and mixing the chosen stabilizing agent and spreading water to achieve proper moisture content. For areas with grade restrictions, the pavement is premilled prior to recycling to accommodate room for the new asphalt cap. The recycled material is then shaped and compacted to meet density and smoothness requirements, after which a curing period is applied. Once the PDR layer has sufficiently set, a new hot-mix asphalt overlay is placed to complete the structural section.

Figures 14-3, 14-4, and 14-5, show the PDR equipment trains, Figure 14-6 shows a PDR milling operation, Figure 14-7 shows a PDR windrow, Figure 14-8 is a picture of PDR being placed with a paver, and Figure 14-9 is a picture of completed PDR with thin RHMA overlay.

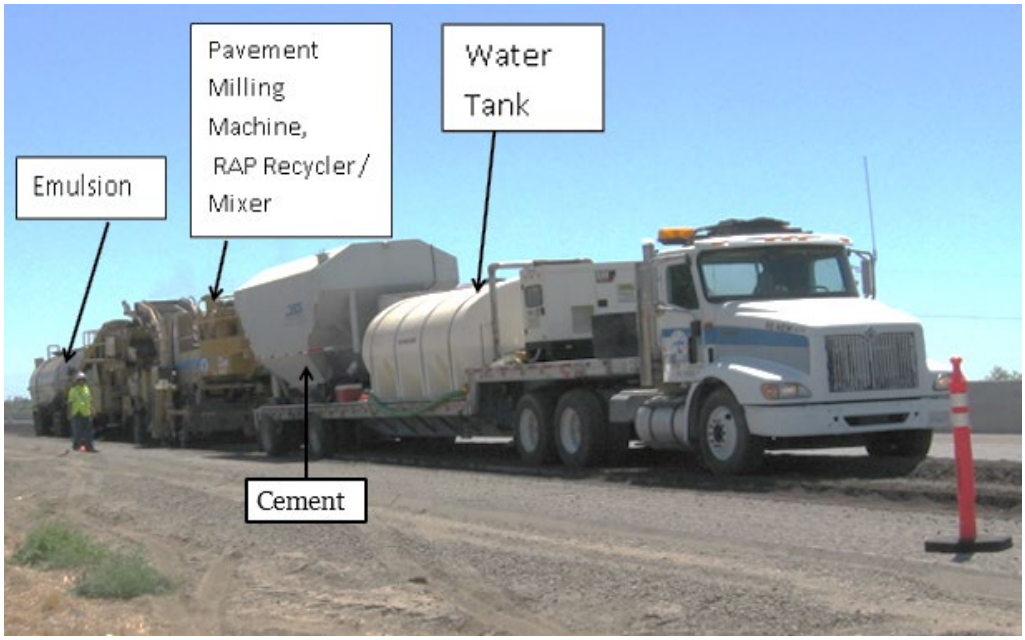

Figure 14-3 PDR Equipment Train (Courtesy CP2 Center)

Figure 14-4 PDR Equipment Train

Figure 14-5 PDR Full Equipment Train with Paver (Courtesy Mike Concannon, Pavement Recycling Systems, Inc.)

Figure 14-6 PDR Milling Operation (Courtesy Performance Equipment Service Inc.)

Figure 14-7 PDR in Windrow after Emulsion is Mixed

Figure 14-8 PDR Placed with Paver (Courtesy of CP2 Center)

Figure 14-9 Post Construction after RHMA Overlay (Courtesy of CP2 Center)

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.

14.6 ECONOMIC ASSESSMENT

The limiting factor for service life of PDR treated pavements is typically the service life of the surface course and not the recycled material itself. The effectiveness and performance are dependent on the costs associated with:

- Local conditions
- Climate
- Traffic
- Existing materials to be recycled
- Adequacy of structural design
- Type and availability of HIR technique
- Quality of materials used
- Quality of workmanship
- Specifications used for the work
- Economy of scale of the project.

14.7 TROUBLESHOOTING GUIDE

There is ample opportunity for achieving excellent results when constructing PDR projects. However, one must be diligent and follow a well thought out QC plan in order reach the intended final goal. Conditions may change, and then the uniformity and balance of the various components of the process may need to be adjusted during construction. For example, a change in the weather, materials encountered, or construction equipment calibration may contribute to the need for continuous fine tuning of the construction process. Because of these factors, it is important to be able to quickly pinpoint what is wrong and to find a solution. A guide to this process of troubleshooting is provided in the table entitled “Troubleshooting Guide for Partial Depth Recycling using Emulsion” which identifies some of the more common problems that the contractor or QC inspector may encounter during a project. This table is shown on the following pages.

Table 14-1 Troubleshooting Guide for Partial Depth Recycling using Emulsion

Problem	Typical Cause(s)	Solution(s)
Flushing of RAP after laydown (uncompacted)	Excessive mix water Excessive emulsion or recycling additive	Reduce water content in mix
	Excessive emulsion or recycling additive	Reduce emulsion content
	Inadequate mixing of RAP and emulsion	Increase mixing time
Mix segregation	Inadequate emulsion coating of the aggregate	Increase water content in mix or use softer grade asphalt binder in emulsion
	Variation of existing RAP	Add new graded base rock material
	Mechanical problem with Paver	Fix and verify mechanical paver issue
Surface raveling after compaction	Too little emulsion or recycling additive in the mix	Increase the amount of emulsion or recycling additive in the mix and, Reprocessing the problem areas
Shiny black surface after compaction	Too much emulsion or recycling additive in the RAP	Reduce the amount of emulsion or recycling additive in the mix Reprocess the problem area and add more RAP or virgin material
Poorly graded RAP behind recycling unit	Variation in depth of existing road structural section	Add new graded base rock to maintain constant depth
	Milling machine worn, or broken teeth	Change milling head
	Speed of operation too fast	Slow operation speed
Varying dry and wet spots in RAP	Poor water and/or recycling agent control. Varying HMA pavement depth and/or gradation change in existing HMA	Check and calibrate pulverizing and mixing operations. Make sure equipment has been calibrated and flow meters are verified working.

Table 14-1 Troubleshooting Guide for Partial Depth Recycling using Emulsion (Continued)

Problem	Typical Cause(s)	Solution(s)
Appearance of fines in RAP material	Speeds of milling equipment may be too slow Milling too deep into base layer	Increase speed of milling operation. Confirm thickness of existing HMA layer
Oversized RAP in the mix	Screen or breaker bar not functioning properly Recycling train moving too fast	Repair the screen or the breaker bar Reduce recycling train speed
New surface staying spongy and not curing	Steel wheel rollers sealing the surface too tight Excessive moisture in mix	Change to pneumatic tire rollers Confirm water content in emulsion. Revise target value of water as necessary

14.8 SUMMARY

The cold recycling techniques of PDR and CCPR are best suited for roadways where the pavement surface is worn and cracked but the subgrade is still firm and in good condition. When applied to the right road at the right time, the following benefits have been realized:

- Reduction in project time, which reduces delays and inconvenience to road users
- Reduction in the need for material hauling, significantly reducing trucking costs
- Reduction in the need for purchase of new materials, reducing material costs
- Lower initial cost compared to traditional methods with the same performance.
- Reduction in reflective cracking compared similarly performing mill and overlay treatments

14.9 REFERENCES

Annapolis, MD (2015). Basic Asphalt Recycling Manual. Asphalt Recycling and Reclaiming Association. https://www.arra.org/store/ViewProduct.aspx?id=9384006

California Department of Transportation (Caltrans), Standard Specifications 2025. https://dot.ca.gov/-/media/dot-media/programs/design/documents/2025_stdspecs.pdf

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Note: Caltrans manuals referenced above may have later editions than those cited. Refer to the latest editions of these references for the most current information.