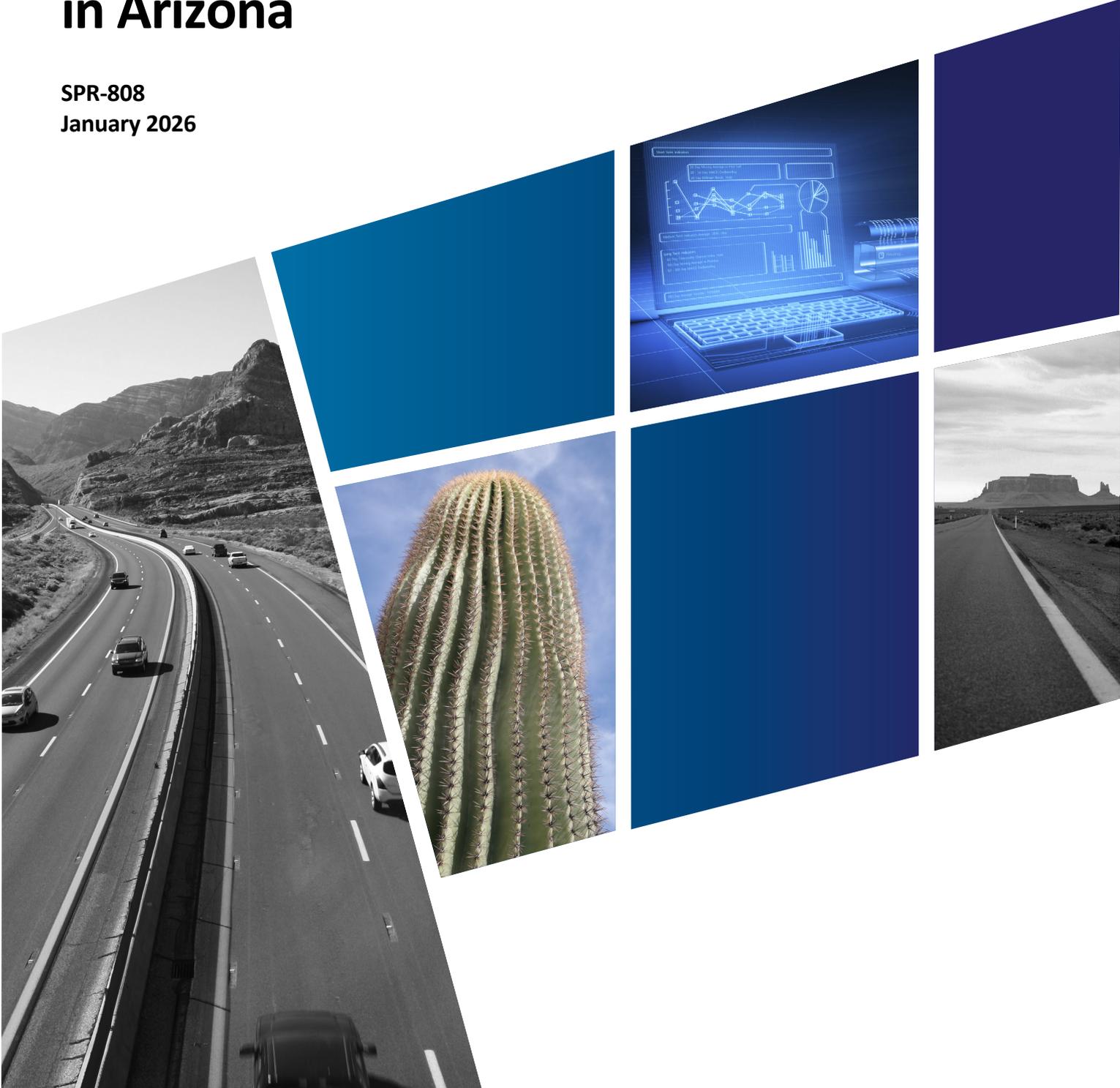


# Cold In-Place Recycle (CIR) and Full-Depth Reclamation (FDR) in Arizona

SPR-808  
January 2026





# Final Project Summary

**SPR-808**

**Cold In-Place Recycle (CIR) and Full-Depth Reclamation (FDR) in Arizona**

**Task # 3**

**Task/Subtask Title: Final Project Summary**

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**Prepared for the ADOT Research Center, Arizona Department of Transportation**

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# Table of Contents

|  |           |
|--|-----------|
| <b>Introduction .....</b>                          | <b>1</b>  |
| <b>Project Objectives .....</b>                    | <b>2</b>  |
| <b>Current State of Knowledge .....</b>            | <b>3</b>  |
| Material Behavior .....                            | 3         |
| Mix Design .....                                   | 3         |
| Structural Design.....                             | 4         |
| Construction .....                                 | 4         |
| <b>Project Selection .....</b>                     | <b>5</b>  |
| Guidelines for Project Selection .....             | 5         |
| Preliminary Selection of Projects .....            | 7         |
| <b>FDR Specifications and Training .....</b>       | <b>9</b>  |
| FDR Preliminary Specifications.....                | 9         |
| Training Materials .....                           | 9         |
| <b>Roadmap for Implementation .....</b>            | <b>10</b> |
| Strategic Intent and Vision.....                   | 10        |
| Key Domains .....                                  | 10        |
| Phased Implementation Plan .....                   | 11        |
| <b>Conclusions .....</b>                           | <b>14</b> |
| <b>References .....</b>                            | <b>15</b> |
| <b>Appendix A. Mix Design .....</b>                | <b>16</b> |
| <b>Appendix B. Project Selection Guidance.....</b> | <b>19</b> |
| CR Versus FDR.....                                 | 19        |
| CIR Versus CCPR.....                               | 20        |
| Recycling Agent Selection for FDR .....            | 21        |

## List of Figures

|  |    |
|--|----|
| Figure 1. Cold In-Place Recycling.....   | 1  |
| Figure 2. Full-Depth Reclamation.....  | 2  |
| Figure 3. Map of the Candidate Recycling Sites. ....   | 7  |
| Figure 4. CR Mix Design. ....  | 17 |
| Figure 5. FDR Mix Design. ....   | 18 |
| Figure 6. Decision Tree Showing Conditions Under Which CR and FDR Can Be Used Efficiently. ....  | 19 |
| Figure 7. Decision Tree Showing Conditions under which CCPR and CIR Can Be Used Efficiently..... | 20 |
| Figure 8. Decision Tree Showing FDR Recycling Agent Selection for Different Soil Classes. ....   | 21 |

## List of Tables

|   |   |
|---|---|
| Table 1. Assessment of the Feasibility of CIR and FDR.....                                      | 6 |
| Table 2. Route Locations, Traffic, and Pavement Distresses in Recycling Candidate Sections..... | 8 |

## Acronyms and Abbreviations

|          |  |
|----------|--|
| AADT     | average annual daily traffic                                       |
| AASHTO   | American Association of State Highway and Transportation Officials |
| AC       | asphalt concrete   |
| ADOT     | Arizona Department of Transportation                               |
| ARRA     | Asphalt Recycling and Reclaiming Association                       |
| BMP      | beginning mile post  |
| CCPR     | cold central-plant recycling                                       |
| CIR      | cold in-place recycling  |
| CR       | cold recycling   |
| DCP      | dynamic cone penetrometer  |
| EMP      | end mile post  |
| FDR      | full-depth reclamation   |
| FDR-C    | full-depth reclamation with Portland cement                        |
| FDR-E    | full-depth reclamation with asphalt emulsion                       |
| FDR-F    | full-depth reclamation with foamed asphalt                         |
| FDR-FA   | full-depth reclamation with fly ash                                |
| FDR-L    | full-depth reclamation with lime                                   |
| FHWA     | Federal Highway Administration                                     |
| FWD      | falling weight deflectometer                                       |
| $G_{mm}$ | theoretical maximum specific gravity                               |
| HWTT     | Hamburg wheel tracking test  |
| IDT      | indirect tensile strength  |
| IRI      | international roughness index                                      |
| LCA      | life-cycle assessment  |
| LCCA     | life-cycle cost analysis   |
| LWD      | lightweight deflectometer  |
| M-E      | mechanistic-empirical pavement design                              |
| MDD      | maximum dry density  |
| OMC      | optimum moisture content   |
| P200     | passing sieve number 200   |
| PI       | plasticity index   |
| QA/QC    | quality assurance / quality control                                |
| RAP      | reclaimed asphalt pavement   |

|                |                                    |
|----------------|------------------------------------|
| SE             | sand equivalent                    |
| SGC            | Superpave™ gyratory compactor      |
| TSR            | tensile strength ratio             |
| UCS            | unconfined compressive strength    |
| USCS           | Unified Soil Classification System |
| V <sub>a</sub> | air voids                          |

## Introduction

Pavement recycling refers to the process of reclaiming materials from one or more layers of an existing pavement structure, processing them through mechanical or chemical stabilization, and then reusing them. Pavement recycling offers a range of advantages, such as efficient use of materials, cost savings, lowering environmental footprint, design flexibility, faster construction, street grade compatibility, and distress mitigation. Pavement recycling methods can be classified into several subcategories based on the location where the recycling will occur, the depth of required milling in the pavement under rehabilitation, and whether or not heating the reclaimed materials is required in the recycling process. Cold recycling (CR) technologies include cold in-place recycling (CIR) and cold central-plant recycling (CCPR). Full-depth reclamation (FDR) mixtures may be stabilized with emulsion (FDR-E), foamed asphalt (FDR-F), cement (FDR-C), fly ash (FDR-FA), or lime (FDR-L). Figure 1 and Figure 2 show typical CR and FDR operation and structures.



\* AC = asphalt concrete

**Figure 1. Cold In-Place Recycling.**



Figure 2. Full-Depth Reclamation.

## Project Objectives

The primary goal of this study was to develop guidance materials for the Arizona Department of Transportation's (ADOT's) consideration for the adoption and implementation of CIR and FDR technologies. The first objective in accomplishing this goal was to summarize the current state of the practice on the key engineering factors that could contribute to the successful implementation of CIR, CCPR, and FDR in Arizona. A second objective was to develop guidelines for project selection and help to identify some candidates for potential CIR and FDR projects in several ADOT districts. Preliminary FDR specifications and training materials were also developed to assist in training district engineers on CIR, CCPR, and FDR.

## Current State of Knowledge

### Material Behavior

Asphalt-stabilized cold-recycled materials exhibit unique behaviors that mimic a combination of behaviors from unbound aggregate layers as well as hot-mix asphalt. The early stages of a cold-recycled pavement's life are significantly influenced by the curing process. After the CIR, CCPR, or FDR layer is placed, the mixture experiences a considerable gain in strength and stiffness as it ages. Permanent deformation and deterioration due to repeated loading are thought to be some of the main causes of deterioration of asphalt-stabilized cold-recycled layers (Jones 2020; Sabita 2020). However, CR and FDR function as a base or subbase layer, and so cannot be passively observed, thus hindering the acquisition of accurate information regarding the layer's performance and its contribution to the pavement's overall responses unless specific on-site investigation is conducted, such as trenching, coring or boring, and/or other non-destructive tests.

FDR-C is unique in that its behavior blends the characteristics of unbound granular bases with those of traditional cement-treated bases. The dominant failure mechanisms for this material are associated with shrinkage cracking, fatigue under repeated loading, and moisture-related deterioration. While cement stabilization improves early strength and stiffness, excessive cement content or inadequate curing can lead to brittle behavior and shrinkage cracking that may reflect through the surface layer. Block cracking can happen due to cement hydration and thermal expansion/contraction. Fatigue cracking can occur due to weak zones or debonding at the cement-treated base and asphalt interface. Rutting can occur when water intrudes through cracks, which weakens the base (Louw 2015).

### Mix Design

The goal of mix design is to select the materials and ingredients that achieve good performance in real-world applications in the field. The materials used in the laboratory mix design for CIR, CCPR, or FDR should be representative of those anticipated during actual field construction. If and when the materials change significantly, then additional mix designs shall be performed to establish representative mixes for the entire job. Representative samples of the asphalt pavement are obtained from the roadway and delivered to an American Association of State Highway and Transportation Officials (AASHTO)-accredited or road-owner-agency-approved laboratory experienced in cold-recycled mix designs. The asphalt pavement samples are crushed, if required, and mixed with the stabilizer and additives, as necessary. Then, at a minimum, these samples are tested in accordance with the procedures and requirements specified by the agency (ARRA FDR201a, CR201, CR202, FDR202 (2021, 2023)).

The mix design is used to establish the job mix formula to ensure the components of the mixture meet a standard or a set of standards that ensure the mixture meets optimal or desired performance. CIR and CCPR mix design require the selection and optimization of all the components that make up the mixtures, the considerations related to those components, and the construction conditions that affect its performance. A brief overview of the mix-design process is available in Appendix A.

## Structural Design

The AASHTO 1993 Structural Design method is commonly used by many state and local transportation agencies to design CR and FDR layers. Typical structural layer coefficients have been recommended by different states, ranging from 0.2 to 0.4. ADOT has been using a coefficient value of 0.28 for CIR design.

At this time, a mechanistic-empirical (M-E) design method for CR and FDR in the United States is merely conceptual. While significant work has been done to characterize the key engineering properties of these layers, limited information is available on the field performance of CR and FDR and their representative laboratory characteristics, which limits the ability to develop the mechanistic-empirical models necessary for layer design.

## Construction

Cold in-place construction begins with preparing the pavement by marking utilities and cleaning the surface, followed by setting the recycling depth based on existing layer thicknesses. Equipment for water and recycling agent delivery is calibrated, and a control strip is constructed to verify depth, gradation, moisture, coating, and density before production. The pavement is milled to the specified depth, moisture is adjusted to the target range, and the asphalt recycling agent is injected, with active fillers or corrective aggregate added if needed. The mixed material is laid down and shaped to grade and cross-slope, then compacted using the established rolling pattern. After curing, secondary compaction is performed. The layer is then cleaned and prepared for the required surface treatment or asphalt overlay.

FDR construction begins by locating and lowering utilities, clearing the work area, and setting the treatment depth based on the asphalt, base, and subgrade layers. Weather and moisture conditions are checked to ensure the pavement and underlying layers are neither frozen nor saturated. After calibrating the equipment, a control strip is created to verify gradation, moisture, density, and strength, with adjustments made before full production begins. The asphalt and base layers are pulverized to the specified depth, moisture is adjusted to the optimum range, and corrective aggregate is added if required. The stabilizing agent is applied and mixed uniformly through the full depth, followed by shaping, compaction, and finish grading. The layer then cures under appropriate moisture or break-time conditions. If specified, microcracking is performed on the cement-treated sections, and the reclaimed layer is finally prepared for the selected surface treatment or asphalt overlay.

Several problems could occur during or after CIR or FDR construction. Possible problems include rutting or shoving, uneven surface, mix segregation, varying dry and wet spots, uncoated materials in the reclaimed asphalt pavement (RAP), excessive emulsion or moisture content, raveling or scuffing, dimpling due to parked vehicles or equipment, oversized chunks of material, or the mat stays spongy and/or will not densify. Depending on the type of problem, adjustments need to be made during construction, such as adjusting the mix design, ensuring equipment works properly, or using proper compaction equipment and compaction effort. If problems exist after construction, repair would be required as needed.

# Project Selection

## Guidelines for Project Selection

Site investigation for recycling begins with establishing the existing pavement structure, typically through coring or test pits, to determine the thickness and composition of the asphalt, base, and subbase layers. Subgrade and base support are then evaluated using a dynamic cone penetrometer (DCP) or a falling weight deflectometer (FWD) to locate weak areas and confirm that the pavement can support recycling equipment. Material samples are then collected for the mix design, which helps determine whether the existing materials are suitable for in-place recycling and what type of stabilizer may be required. Table 1 summarizes the conditions under which neither CIR nor FDR is feasible (ARRA 2016; Jones 2020; Reeder 2016; Wegman 2017). Recommendations for selecting appropriate recycling techniques and recycling agents, when none of the conditions in Table 1 preclude recycling, are provided in Figure 6, Figure 7, and Figure 8 in Appendix B.

**Table 1. Assessment of the Feasibility of CIR and FDR.**

| When CIR or FDR Is Not Feasible   | Reason   |
|---|--|
| Pavement thickness < 10 inches or AC < 2.5 inches                         | Not enough reclaimable materials for CIR/FDR to generate a uniform, stable recycled layer.   |
| Distresses do not extend beyond the top 2 inches of AC                    | Recycling adds cost with no structural benefit. A surface treatment or thin overlay may be more appropriate.   |
| Utilities located within 6 inches of the required recycling depth         | High risk of utility damage due to deep rotors. Therefore, it would require excavating or relocating the utilities. CCPR could be possible.                                |
| Concrete or cement-treated layers occur in the recycling segment          | CIR recycler cannot cut or mix rigid layers, and FDR produces oversized particles.   |
| Unresolved drainage issues  | Moisture prevents compaction, reduces subgrade bearing capacity, and causes early failure.   |
| Subgrade stiffness < 6,500 psi ( $\approx 45$ MPa) in >10% of the project | Weak subgrade cannot support recycling equipment or the recycled base. This leads to excessive rutting.  |
| Stability/geotechnical issues present                                     | Underlying problems are reflected in the recycled layer.   |
| Repeated failing patches or shoulder drop-offs                            | Indicates deep structural/subgrade failure that recycling cannot correct without prior removal.  |
| Frequent abrupt changes in layer thickness or material type               | Produces non-uniform gradation and inconsistent demand content for recycling agents. If the number of changes is reasonable, then several mix designs can solve the issue. |
| Traffic cannot be managed by detour or one-lane control                   | Continuous train operations and curing periods are required; without traffic control, recycling cannot be performed safely or reliably.                                    |
| Insufficient space for recycling equipment access                         | Reclaimers, tankers, and rollers require significant working room; constrained geometry prevents in-place recycling operations.  |

### Preliminary Selection of Projects

Fourteen CIR and FDR candidate pilot pavement sites have been provided by ADOT district engineers. These sites were selected primarily based on preliminary screening criteria. The locations, traffic data, and pavement distress of these sites were extracted from the ADOT database, as shown in Figure 3 and Table 2. Distress data were calculated by taking the average of values provided in each segment within the beginning and ending milepost provided and the two directions. The data in Table 2 are from 2024.

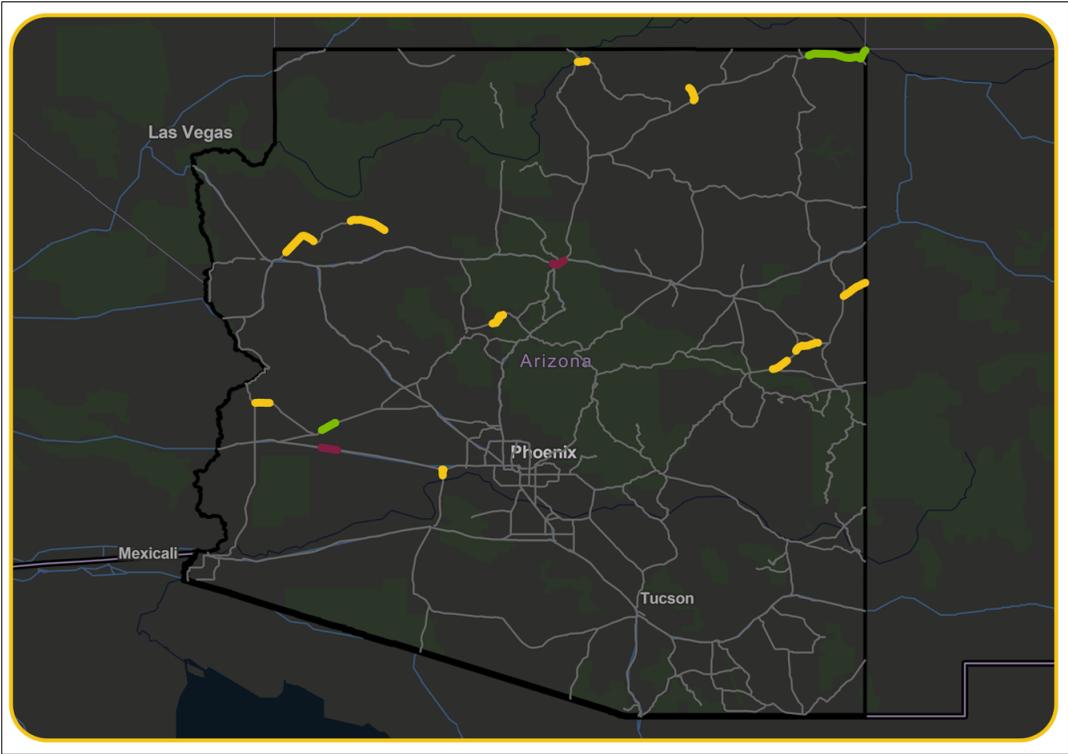


Figure 3. Map of the Candidate Recycling Sites.

**Table 2. Route Locations, Traffic, and Pavement Distresses in Recycling Candidate Sections.**

| Route               | BMP <sup>1</sup> | EMP <sup>2</sup> | 2024 AADT <sup>3</sup><br>(Truck %) | 7-Day Max Pavement<br>Temperature (°F) | 7-Day Min Pavement<br>Temperature (°F) | Alligator<br>Cracking(%) | Rutting<br>(inch) | IRI <sup>4</sup> |
|---------------------|------------------|------------------|-------------------------------------|--|--|--------------------------|-------------------|------------------|
| SR <sup>5</sup> 98  | 294.70           | 299.50           | 3,855 (15)                          | 147                                    | 23                                     | 13                       | 0.20              | 154              |
| US <sup>6</sup> 160 | 440.00           | 471.00           | 2,561 (18)                          | 147                                    | 19                                     | 8                        | 0.15              | 94               |
| SR 564              | 374.31           | 383.46           | 226 (15)                            | 142                                    | 19                                     | 63                       | 0.20              | 245              |
| SR 61               | 369.20           | 384.50           | 1,893 (10)                          | 145                                    | 21                                     | 40                       | 0.17              | 124              |
| SR 61               | 416.49           | 430.26           | 160 (47)                            | 145                                    | 21                                     | 68                       | 0.10              | 195              |
| SR 61               | 353.00           | 362.00           | 1,939 (12)                          | 146                                    | 21                                     | 17                       | 0.16              | 145              |
| I <sup>7</sup> -40  | 193.30           | 199.97           | 39,830 (26)                         | 150                                    | 23                                     | 0                        | 0.06              | 62               |
| SR 72               | 13.10            | 20.50            | 3,314 (26)                          | 155                                    | 40                                     | 1                        | 0.10              | 158              |
| I-10                | 52.00            | 60.00            | 26,068 (38)                         | 153                                    | 38                                     | 17                       | 0.10              | 106              |
| SR 85               | 151.00           | 155.10           | 18,658 (26)                         | 153                                    | 38                                     | 2                        | 0.10              | 107              |
| US 60               | 54.00            | 62.00            | 2243 (16)                           | 152                                    | 37                                     | 19                       | 0.28              | 121              |
| SR 89               | 331.40           | 343.90           | 2308 (7)                            | 150                                    | 27                                     | 25                       | 0.10              | 180              |
| SR 66               | 62.00            | 81.00            | 4450 (11)                           | 146                                    | 30                                     | 21                       | 0.18              | 120              |
| SR 66               | 105.00           | 123.17           | 1252 (17)                           | 144                                    | 26                                     | 8                        | 0.16              | 92               |

1. BMP = beginning mile post

2. EMP = end mile post

3. ARA = average annual daily traffic

4. IRI = international roughness index

5. SR = state route

6. US = United States route

7. I = interstate (highway)

## **FDR Specifications and Training**

### **FDR Preliminary Specifications**

Preliminary FDR specifications were developed as a part of this project, which ADOT may consider. The specifications cover typical topics including description, materials, mix design, equipment, construction requirements, quality assurance and quality control (QA/QC), acceptance, method of measurement, and basis of contractor payment.

### **Training Materials**

Training materials were developed as a training resource and technical guidance to support the broader adoption of CIR and FDR practices at ADOT. This material was developed to inform agency staff, designers, contractors, and decision-makers about the essential components of recycling projects, including appropriate recycling strategy selection, design procedures, and construction quality control.

# Roadmap for Implementation

## Strategic Intent and Vision

CR and FDR can serve as a cost-effective and a sustainable rehabilitation alternative that can produce durable pavement structures meeting target design life, as demonstrated by the collective evidence from supporting research studies as well as states that have deployed them at scale. However, the margin between strong performance and premature failure is primarily governed by the selection of appropriate projects, sound design, high-quality construction, effective drainage, proper selection of the recycling agent, control of recycling agent and moisture contents, and adequate curing.

For ADOT's consideration, a roadmap for implementation was developed with a focus on delivering measurable cost savings and expanding pavement design flexibility by enabling a broader range of effective recycling treatments and lowering life-cycle expenditures across Arizona's state highway system. The roadmap aims to establish a unified, evidence-driven recycling framework with the following goals:

- Develop a scalable recycling methodology that both aligns with and advances current national best practices.
- Improve mix-design practices and establish appropriate structural design methods.
- Improve construction reliability through standardized, performance-linked QA/QC measures.
- Enhance the quality and consistency of recycling projects' selection and investigation.
- Document and optimize long-term sustainability benefits through integrated life-cycle assessment (LCA) and life-cycle cost analysis (LCCA).

## Key Domains

The key domains define the primary areas requiring development, monitoring, and continuous improvement to ensure reliable and consistent CR and FDR implementation in Arizona. While presented as separate domains, these domains function as an integrated system that supports performance-informed improvements under local conditions, accommodates future research and technological advancements, and ensures ADOT's performance and design-life objectives are met.

### *Domain 1 – Standards and Governance*

- Implementing a structured specifications- and guidelines-revision cycle that incorporates validated field performance through continuous feedback loops.
- Standardizing data and documentation protocols for mix design, investigation, and construction.
- Establishing a clear, streamlined process that assigns the appropriate authority for approving changes, resolving testing issues, and authorizing corrective actions during construction.
- Establishing multi-stakeholder engagement (departments of transportation, industry, academia) to guide specification revisions and maintain consistency across districts.

### *Domain 2 – Mix Design, Structural Design, and Material Characterization*

- Refining mix-design practices by defining application-appropriate strength, performance, and moisture criteria (e.g., traffic, climate), refining compaction methods to align with field densities, and standardizing in-place gradation adjustments and CCPR stockpile proportioning.
- Defining a structured laboratory characterization plan, including modulus characterization, repeated-load permanent deformation, and complementary performance tests that provide reliable mechanistic inputs for structural design and field performance prediction.
- Establishing an M-E structural design framework to succeed an interim empirical method by using field-based performance data and curing-dependent mechanistic models.

### *Domain 3 – Construction Quality, Field Implementation, and Operational Controls*

- Strengthening construction quality control, including field density targets; ensuring gradation uniformity requirements; and verifying stabilizer and moisture application.
- Developing a coordinated in-situ evaluation framework including compaction curve checks, moisture/density measurements, and early-age behavior assessments.
- Refining curing thresholds and associated measurement procedures, defining consistent rules for traffic return, and authorizing the placement of subsequent layers or overlays.

### *Domain 4 – Data Collection, Structural Performance, and Network Integration*

- Collecting integrated data across all phases, including pre-construction site investigation, mix and structural design outputs, QA/QC results from both control strips and production sections, and economic data.
- Monitoring structural performance continuously, including both early-life and long-term performance. The data should include strains, stresses, deflection behavior, and distress development under real operating conditions.
- Develop performance models by linking site performance data to curing behavior, load response, and environmental factors.

### *Domain 5 – Decision Framework, LCA, and LCCA*

- Developing a unified decision framework that embeds long-term performance into treatment selection for all recycling strategies.
- Integrating LCA and LCCA into project evaluation and selection.

## **Phased Implementation Plan**

The phased implementation plan provides a structured pathway for advancing CR and FDR in Arizona from nationally adopted baseline practices to a performance- and evidence-based program that relies on field outcomes and local operating conditions. Each phase enhances technical expertise and

organizational capability by progressively strengthening field records, mechanistic and performance-based design methods, and standardized QA/QC and decision-making processes to ensure that the statewide expansion is driven by validated outcomes rather than isolated successes.

### *Phase 1 – Capability Building and Pilot Deployment*

- Deploy two pilot projects per engineering district, ensuring meaningful variation in recycling methods, stabilizer types, climate zones, traffic classes, and in-place material conditions to capture a representative range of performance behaviors.
- Apply the interim empirical structural design approach and the latest specification's mix-design procedures to establish baseline practice.
- Conduct focused laboratory studies that characterize modulus, repeated-load deformation behavior, moisture sensitivity, and other engineering and performance tests.
- Instrument segments of the selected pilot projects by installing strain gauges, pressure cells, and temperature and moisture sensors.
- Establish the initial LCA/LCCA framework and develop initial models based on pilot project assumptions.
- Train all stakeholder groups, including agency personnel and contractor QA/QC teams, on updated field QA/QC procedures, including stabilizer verification, moisture and gradation control, compaction timing protocols, and curing validation, supported by alignment workshops across districts.

### *Phase 2 – Data Collection, Characterization, and Benchmarking*

- Conduct comprehensive pre-recycling site characterization across all projects utilizing multiple methods, including pavement thickness mapping (e.g., ground-penetrating radar, cores), subgrade strength measurements (e.g., DCP, FWD, or lightweight deflectometer [LWD]), moisture and drainage assessment, gradation variability mapping, and full reclaimed-material characterization.
- Collect construction QA/QC data across full-scale project sections, including density development over time, stabilizer application accuracy, moisture and gradation uniformity, and adherence to compaction targets and curing protocols.
- Perform short-term structural performance measurements with the target of capturing stiffness gain, early-age deflection trends, moisture loss, and the distribution of stress and strain through scheduled FWD testing (including during construction as each layer is compacted), sensors data, and targeted sampling.
- Utilize LWD during construction to monitor stiffness gain and develop a correlation analysis to the results of the nuclear density testing.
- Develop benchmarking datasets that compare laboratory design data against field observations and identify sources of variability for different stabilizers, climates, and traffic contexts.

### *Phase 3 – Continuous Monitoring and Full-Scale Integration*

- Transition from pilot projects to district-wide deployment, applying updated mix design, construction, and QA/QC practices developed during the pilot phase.
- Monitor structural performance across all deployed sites by collecting seasonal and long-term data under traffic loading while tracking the progression of distresses within the recycled layer and in overlying layers.
- Integrate recycling performance data into network-level planning tools, treatment-selection pathways, funding prioritization processes, and asset management systems.
- Expand LCA and LCCA assessments using field-verified project data, and update cost curves, emissions factors, and benefits to reflect regional conditions and observed performance trends.

### *Phase 4 – Validation and Framework Refinement*

- Validate the full recycling framework by comparing predicted performance with observed behavior across all monitored sites, ensuring that design assumptions and field outcomes are aligned.
- Calibrate and finalize the M-E structural design framework using multi-year field data; refine curing-sensitive models, modulus-development functions, and performance models for permanent deformation and other relevant failure modes.
- Institutionalize the recycling program through recurring training, annual performance reviews, and a long-term research roadmap that supports continuous improvement and responds to emerging technical needs.

## Conclusions

This study developed guidelines for ADOT's consideration of the adoption and implementation of CIR and FDR technologies. The study summarized the current state of the practice on the key engineering factors that could contribute to the successful implementation of CIR, CCPR, and FDR in Arizona. The study also developed guidelines for project selection and identified some candidates for potential CIR and FDR projects in several ADOT districts. Preliminary FDR specifications and training materials were developed to train district engineers on CIR, CCPR, and FDR. A roadmap for implementation and future research was recommended.

Cold recycling and full-depth reclamation can deliver durable, cost-effective, and sustainable pavement maintenance and rehabilitation when properly engineered and constructed. The evidence synthesized in this study indicates that, once appropriate projects are selected, performance depends less on the specific recycling method and more on design integrity and construction quality control. The successful long-term implementation of CR and FDR requires building the data records and supporting infrastructure necessary for performance modeling and network integration, as well as accounting for the life-cycle value in treatment selection.

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## Appendix A. Mix Design

The mix design addresses the selection and properties of the stabilizer or recycling agent—along with any required additives, such as active fillers or corrective aggregates—while also accounting for water quality and content during preparation. Mixing considerations include method, timing, sequence, and temperature, followed by compaction approaches typically performed using a Superpave™ gyratory compactor (SGC) or Proctor compaction, which target the appropriate maximum dry density (MDD) and optimum moisture content (OMC). RAP characteristics, including sampling, gradation, and morphology, are evaluated alongside curing time and temperature. The density and volumetric properties are verified through measures such as maximum theoretical specific gravity ( $G_{mm}$ ) and air voids ( $V_a$ ). Performance confirmation encompasses standard indicators, including unconfined compressive strength (UCS), indirect tensile strength (IDT), tensile strength ratio (TSR), freeze-thaw response, and Hamburg wheel tracking test behavior (HWTT). Schematics for the flow of the mix design for both CR and FDR processes are presented in Figure 4 and Figure 5, respectively.

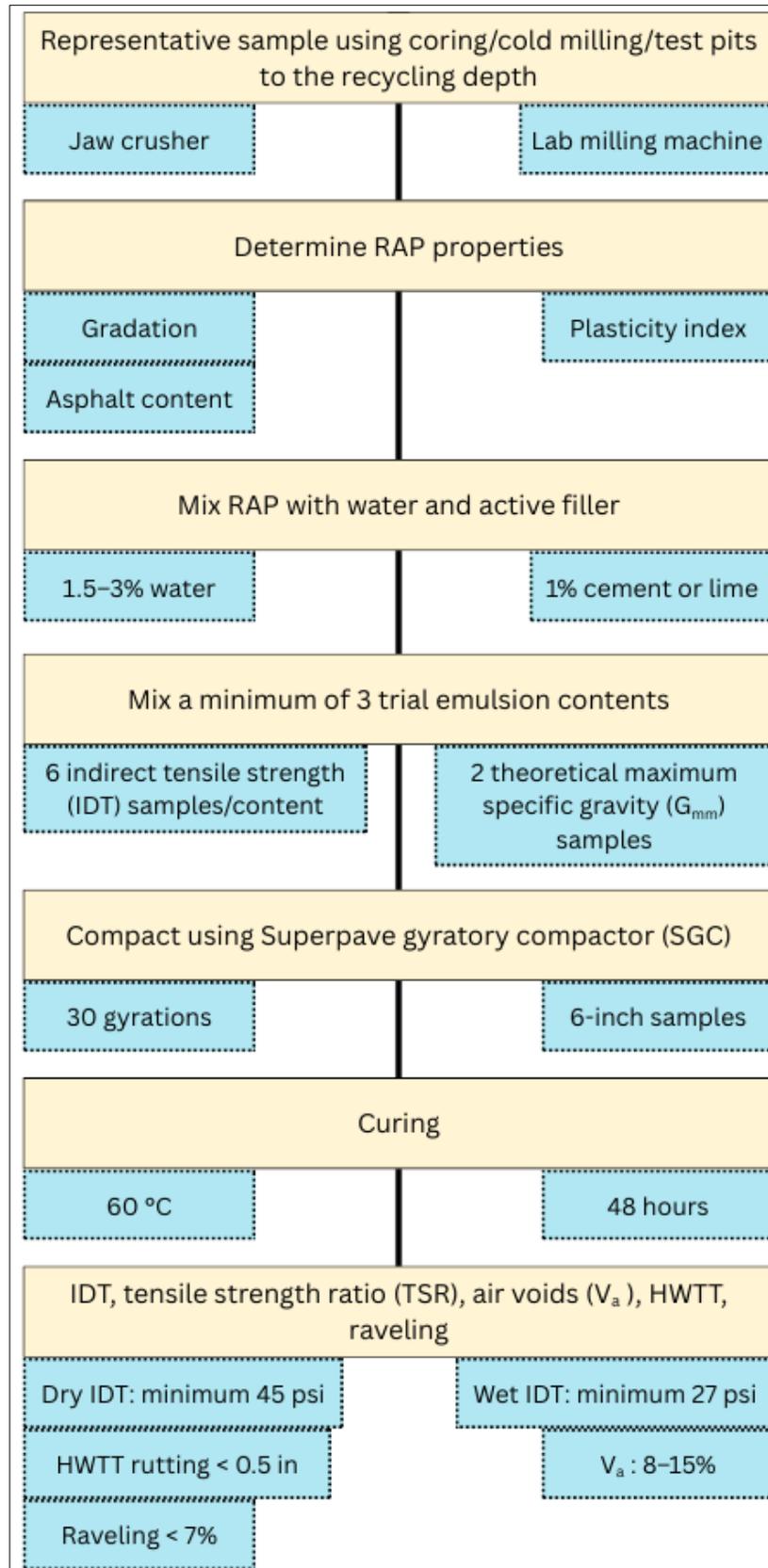


Figure 4. CR Mix Design.

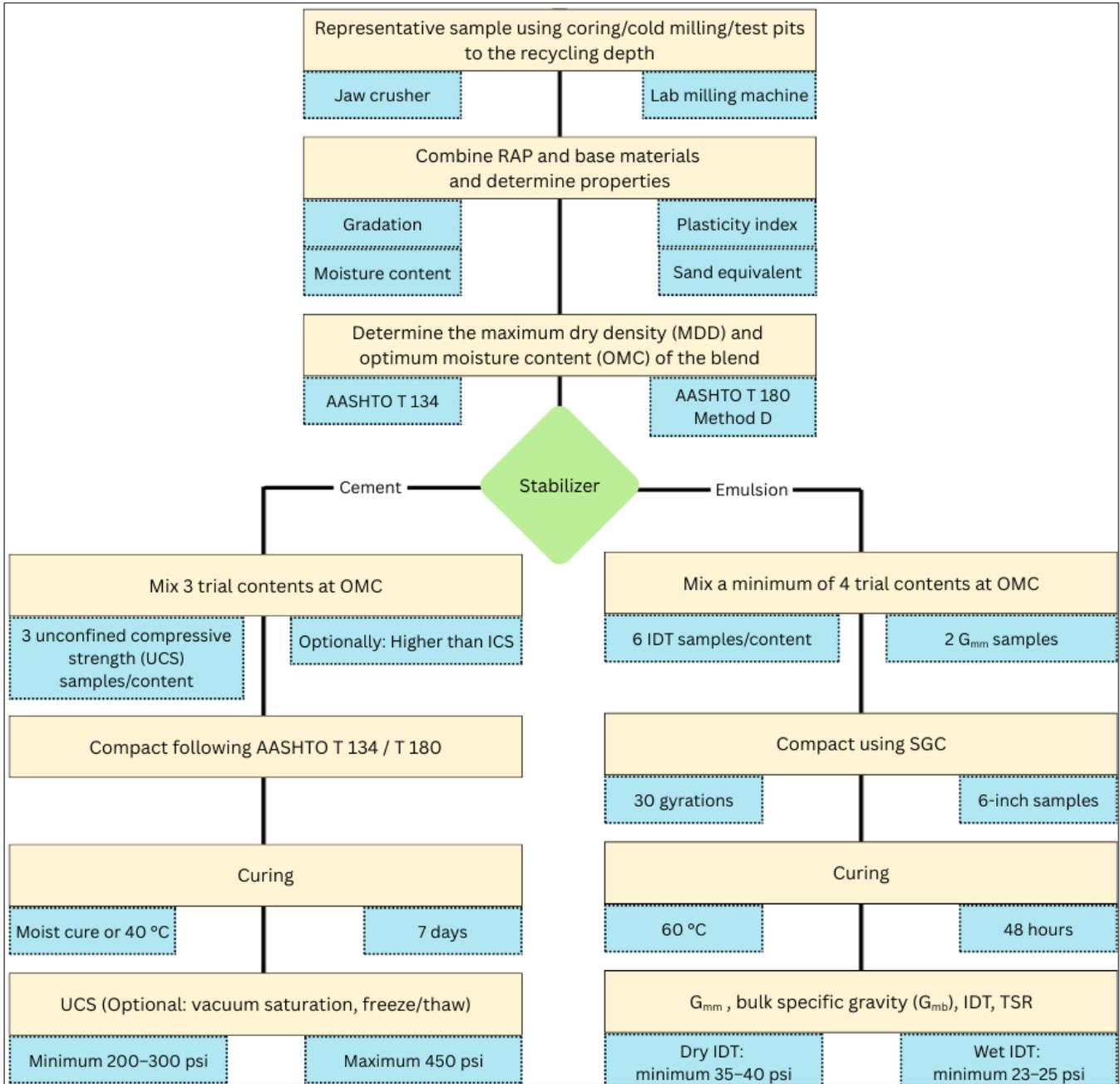


Figure 5. FDR Mix Design.

## Appendix B. Project Selection Guidance

The selection criteria define conditions under which recycling is suitable and identify the limitations or situations in which recycling may be undesirable. The criteria also assist in deciding which type of CR is appropriate for the existing pavement condition.

### CR Versus FDR

Figure 6 shows a decision tree indicating conditions under which CR and FDR can be used efficiently. Note that an LCCA needs to be conducted to obtain the most cost-effective recycling treatment.

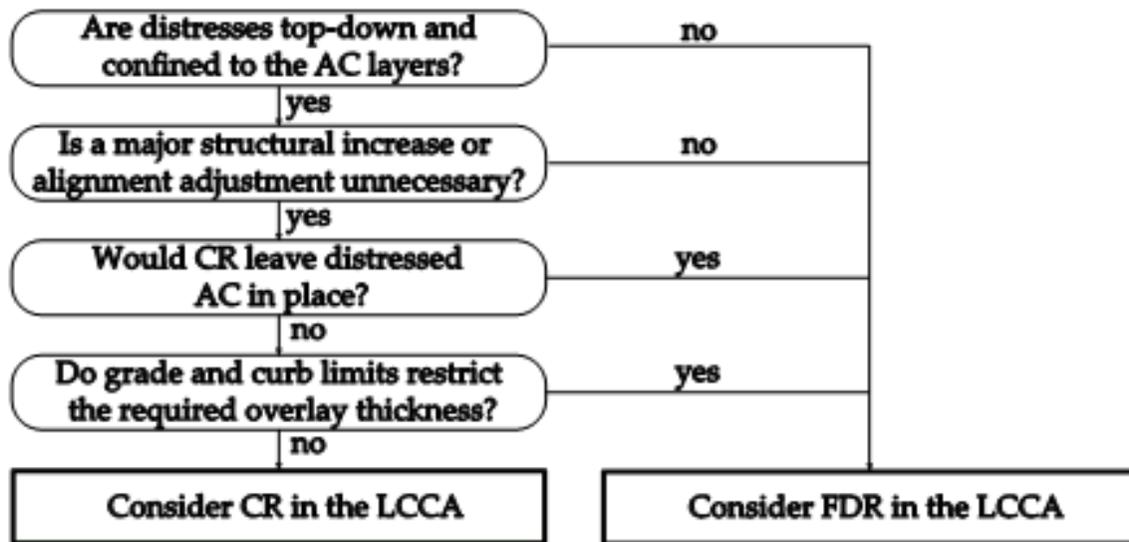


Figure 6. Decision Tree Showing Conditions Under Which CR and FDR Can Be Used Efficiently.

## CIR Versus CCPR

Figure 7 shows conditions under which CIR and CCPR can be used efficiently. Again, an LCCA needs to be conducted to obtain the most cost-effective recycling treatment.

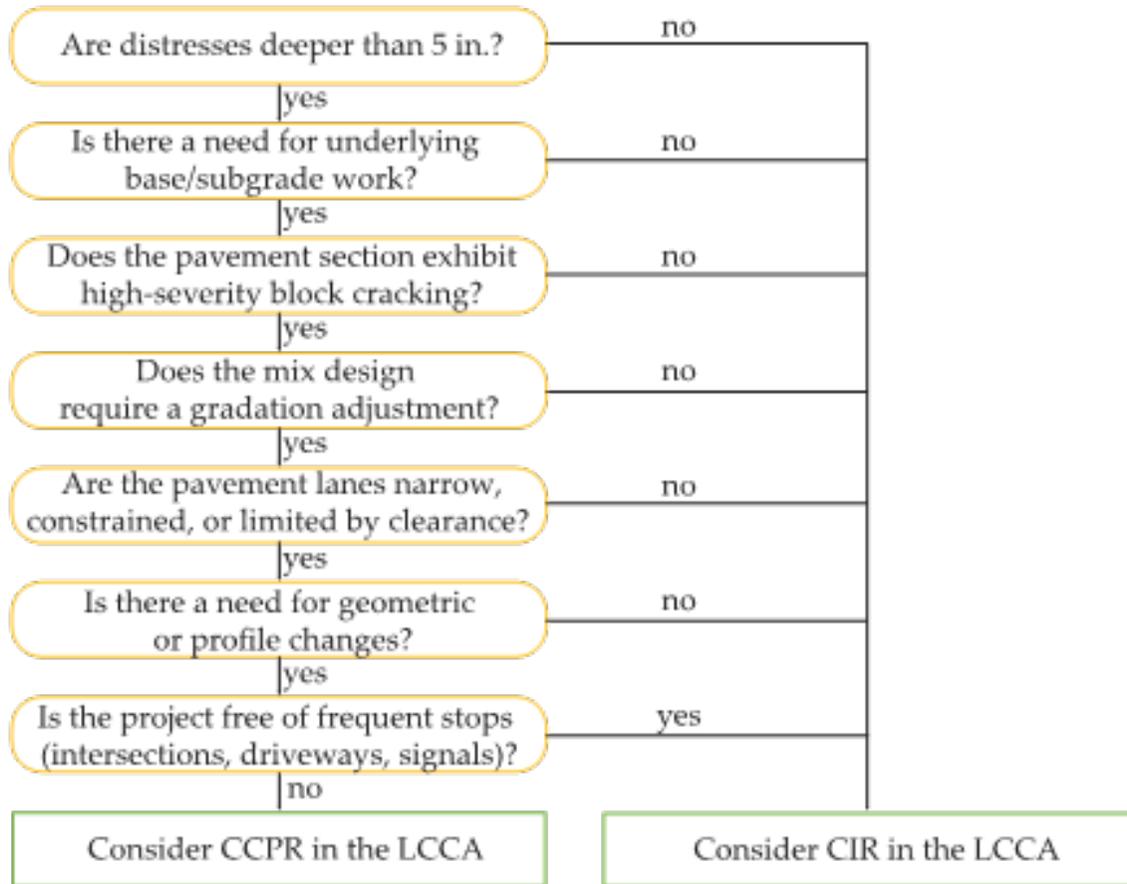


Figure 7. Decision Tree Showing Conditions under which CCPR and CIR Can Be Used Efficiently.

## Recycling Agent Selection for FDR

Figure 8 shows a decision tree for FDR recycling agent selection for different soil classes using the Unified Soil Classification System (USCS) and AASHTO's classification methods.

| Reclaimed Material Type                                    | Well-Graded Gravel | Poorly Graded Gravel | Silty Gravel | Clayey Gravel  | Well-Graded Sand | Poorly Graded Sand | Silty Sand     | Clayey Sand    |
|--|--------------------|----------------------|--------------|----------------|------------------|--------------------|----------------|----------------|
| USCS Classification  | GW                 | GP                   | GM           | GC             | SW               | SP                 | SM             | SC             |
| AASHTO Classification                                      | A-1-a              | A-1-a                | A-1-b        | A-1-b<br>A-2-6 | A-1-b            | A-3<br>A-1-b       | A-2-4<br>A-2-5 | A-2-6<br>A-2-7 |
| Asphalt Emulsion<br>SE>30<br>or PI<6<br>P200<20%           |                    |                      |              |                |                  |                    |                |                |
| Foamed Asphalt<br>PI<10<br>5%<P200<20%                     |                    |                      |              |                |                  |                    |                |                |
| Cement<br>PI<20  |                    |                      |              |                |                  |                    |                |                |
| Lime<br>PI>20<br>P200<25%                                  |                    |                      |              |                |                  |                    |                |                |
| Not recommended       Recommended       Highly Recommended |                    |                      |              |                |                  |                    |                |                |

\* SE = sand equivalent, PI = plasticity index, and P200 = passing sieve number 200

**Figure 8. Decision Tree Showing FDR Recycling Agent Selection for Different Soil Classes.**