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UFGS for Cold Recycled Asphalt: A Specification Framework Informed by Practice

Mark E. Jacobson[1], James O. Toyin[1], Anoop Sattineni[1]
[1]Auburn University, McWhorter School of Building Science

In the United States, approximately 400 million tons of asphalt are replaced annually, Evidence shows that the Cold Recycled Asphalt (CRA), delivered as Cold In-Place Recycling (CIR) or Cold Central Plant Recycling (CCPR), remains underutilized on federal projects. Moreover, studies reveal that contracting guidance is fragmented and difficult to enforce specification. To address this gap, this study develops an evidence-informed Unified Facilities Guide Specifications (UFGS)-style specification framework that consolidates requirements for materials, mix design, production control, and field acceptance for CRA. The research adopts a qualitative, specification-development approach, combining a comparative review of federal, state, and industry specifications with semi-structured interviews of agency engineers, contractors, and researchers to adjudicate inconsistencies and refine enforceable thresholds. Key outcomes include (i) harmonized mix-design procedures that mirror field conditions; (ii) a lab-to-field acceptance ladder sets 100% at a test-section break-over density and calibrates nuclear gauge readings to laboratory bulk specific gravity, (iii) standardized gradation treated as a production consistency metric, and (iv) a contract-ready quality control checklist with designer guidance for CIR versus CCPR selection, curing expectations and rejuvenator use. The proposed framework improves enforceability, reduces quality variability, and supports cost and carbon reduction objectives while recovering high-quality aggregates on federal rehabilitation projects.

Keywords: Asphalt, Specification, Emulsion, Foamed, CCPR

Introduction

Nearly 400 million tons of asphalt are replaced across the United States each year, an amount sufficient to pave a four-inch, two-lane public road around the world six times. With an average roadway life of approximately15 years, this turnover implies nearly 6 billion tons of replaced asphalt within a single life cycle (Sounart, 2025). Such volumes emphasize the opportunity for cold recycling-Cold In-Place Recycling (CIR) and Cold Central Plant Recycling (CCPR) to recover value, reduce hauling and energy use, and deliver consistent performance when supported by a modern, enforceable specification.

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Cold recycled asphalt (CRA), produced through CIR or CCPR, has matured into a viable pavement rehabilitation strategy that reuses reclaimed asphalt pavement (RAP) with emulsified or foamed asphalt binders to restore structural capacity at lower cost and reduced carbon intensity (Gu et al., 2019; Lin et al., 2017). Prior studies demonstrate that CRA can achieve performance comparable to hot-mix asphalt (HMA) while substantially reducing environmental impacts (Liu & Sun, 2023). Successful field implementation, however, depends heavily on clear and enforceable quality control (QC) and acceptance specifications. Although asphalt cold recycling has been documented since at least the early 1980s with early validation sponsored by the U.S. Army (Scholz, Todd V et al., 1991), adoption remains limited. Industry survey data indicate that of approximately 407.8 million tons of asphalt used in the United States in 2020, only about 0.4 million tons (<0.1%) were produced as cold-mix asphalt (NAPA, 2021).

It is important to distinguish between short-term maintenance cold mixes and CRA used for structural rehabilitation. While “cold mix asphalt” is often perceived as temporary when applied for pothole patching or emergency repairs, CRA implemented through CIR and CCPR is designed to rehabilitate existing pavement layers by reprocessing in-place materials under controlled conditions using emulsified or foamed binders and, where appropriate, additives (FHWA-HIF, 2018). When properly selected and specified, CIR and CCPR can reduce virgin material demand and hauling, lower energy use and emissions by eliminating high-temperature production, and improve constructability by correcting surface distress and profile irregularities (FHWA-HIF, 2023). Federal Highway Administration (FHWA) guidance further emphasizes that cold recycling technologies have matured substantially and provides project selection criteria that support reliable application where pavement condition, foundation integrity, and traffic demands are appropriate.

Despite these documented advantages, widespread adoption of CRA in the United States remains constrained by several recurring impediments identified across practice guidance and the literature. These include: (i) fragmented and inconsistent specifications that create uncertainty in enforceability and risk allocation; (ii) variability in laboratory mix design procedures and curing or conditioning methods, which weakens the laboratory-to-field performance link; (iii) acceptance practices relying on inconsistent or non-traceable density references; and (iv) owner concerns regarding early-life performance when curing expectations and QC actions are not explicitly codified (Ma et al., 2015; Liu et al., 2022). Recent best-practice documents and peer-reviewed syntheses highlight the need for standardized procedures and contract-ready requirements to improve reliability and confidence in implementation(Liu et al., 2022), an exact gap this paper addresses through a UFGS-style framework

Within the Whole Building Design Guide (WBDG), two Unified Facilities Guide Specifications (UFGS) sections currently address cold asphalt mixtures: 32 01 16.70 *Cold-Mix Reused Asphalt Paving* and 32 12 16.19 *Cold-Mix Asphalt Paving*. Both sections were slated for review in 2023; however, prior assessments indicate that neither reflects current industry practice (Li et al., 2023). Identified deficiencies include outdated references to cutback asphalt with no provision for foamed asphalt, job mix formula language implying that the government performs the mix design, application of HMA compaction temperature requirements to cold mixes, attempts to control gradation during production rather than as a consistency metric, and acceptance criteria based on theoretical maximum density rather than project-specific test-section references (Kuchiishi et al., 2021). Given the extent of these misalignments, replacing both sections with a single, modern specification is warranted.

More broadly, fragmented guidance across federal agency manuals, state DOT specifications, industry bulletins, and vendor procedures complicates the development of consistent contract documents and the administration of construction with predictable quality outcomes. In practice, this fragmentation manifests as inconsistent laboratory protocols, uneven performance checks and thresholds, unclear field density targets, and variable QC/QA frequencies—each of which complicates enforcement and risk management.

To address these challenges, this paper develops an evidence-informed UFGS-style specification framework for Cold Recycled Asphalt that harmonizes requirements for materials, mix design, production control, and field acceptance without vendor bias. The framework synthesizes federal, state, and industry guidance; laboratory and field evidence; and targeted practitioner input from agencies, contractors, and researchers. Structured in accordance with UFGS conventions (General, Products, Execution), it includes non-contractual Designer Notes addressing CIR versus CCPR selection, curing windows, rejuvenator use, and day-to-day QC actions. The framework focuses on rehabilitation applications appropriate for CRA and on specification elements governing mix design, production, and acceptance; pavement structural design, network-level planning, and life-cycle economic modeling are outside the scope except where they inform specification thresholds.

This study is a qualitative, evidence-informed specification development effort rather than a traditional mixed-methods or statistically driven experimental investigation. The research integrates peer-reviewed literature, agency and industry specifications, and semi-structured practitioner interviews to develop a contract-ready UFGS framework. Quantitative values presented are used solely for descriptive comparison and benchmarking of current practice against proposed specification thresholds; no surveys, Likert-scale instruments, or inferential statistical analyses were employed.

Methodology

Research scope and design

This research is scoped to specification development for Cold In-Place Recycling (CIR) and Cold Central Plant Recycling (CCPR) on U.S. federal projects. The study focuses on materials requirements, mix-design procedures, production controls, and field acceptance criteria suitable for incorporation into Unified Facilities Guide Specifications (UFGS)-format contract documents. It does not involve controlled laboratory experimentation, statistical hypothesis testing, or long-term performance monitoring of constructed projects. Instead, the research emphasizes enforceability, usability, and alignment with current field practice. Accordingly, the study adopts a qualitative, evidence-informed specification synthesis approach, integrating documentary analysis and expert input to evaluate, reconcile, and formalize requirements found in existing guidance (Salman et al., 2025). Quantitative information from the literature and specifications is used descriptively to compare practices and benchmark proposed thresholds, rather than for inferential analysis.

Data extraction and coding

A structured review of peer-reviewed literature, federal agency manuals, state department of transportation (DOT) specifications, and industry guidance documents was conducted to identify prevailing requirements and areas of divergence. The purpose of this review was to assess the validity, applicability, and consistency of specification elements currently governing CIR and CCPR practice. A standardized data extraction sheet was used to capture: (i) material requirements, (ii) mix-design inputs and procedures, (iii) production controls, and (iv) field acceptance criteria. Extracted content was coded into thematic categories: Materials, Mix Design, Performance Testing, Production Control, Field Acceptance, and Designer Notes. Conflicting or inconsistent requirements were explicitly flagged for further evaluation and adjudication.

Practitioner interviews

To complement the documentary synthesis and resolve apparent conflicts among specifications, semi-structured interviews were conducted with ten subject-matter experts using purposive sampling. Participants included federal agency engineers, contractors operating CIR/CCPR crews, and researchers with documented field pilots or peer-reviewed publications. All participants possessed substantial professional experience and advanced graduate-level training. The interview protocol explored: (a) laboratory procedures most predictive of field performance; (b) practical density references and calibration practices; (c) curing management and opening-to-traffic considerations; (d) QC/QA frequencies and realistic tolerances; (e) CIR versus CCPR selection criteria; and (f) common failure modes and mitigation strategies. Interview notes were anonymized and coded using the same thematic framework as the documentary review to surface areas of consensus and practice-tested thresholds.

Specification writing

Findings from the documentary review and practitioner interviews were synthesized into a draft UFGS-style specification structured in accordance with UFC 1-300-02, comprising General, Products, and Execution sections. The General section addresses submittals, quality control requirements, and administrative provisions; the Products section defines material and performance requirements; and the Execution section outlines construction procedures, tolerances, and acceptance. Because cold recycled asphalt is a field-manufactured material, primary emphasis was placed on developing a clear and enforceable Products section addressing emulsified and foamed asphalt options, additives, mix-design procedures, and acceptance properties. Execution requirements for CIR and CCPR were aligned with prevailing field practice and adapted, where appropriate, from UFGS 32 12 16.16 (Hot-Mix Asphalt). Non-contractual Designer Notes were incorporated to guide option selection, provide adjustable ranges for nationwide applicability, and support day-to-day decision-making. The draft framework was refined through expert review, with the intent that future pilot deployments inform iterative updates based on bid clarity and observed construction outcomes.

Results and Discussion

Technical Synthesis Incorporated into the Draft UFGS

The synthesis of literature evidence and practitioner input indicates that cold recycled asphalt (CRA) can be produced with process controls that deliver consistent, large-scale quality approaching that of hot-mix asphalt (HMA) when appropriate quality control and acceptance practices are applied (Ma et al., 2015). In many existing pavements, the coarse aggregate remains structurally sound at the time of rehabilitation; common distresses such as weathering, raveling, rutting, and surface cracking are typically binder- or surface-driven rather than the result of aggregate degradation. Consequently, CRA enables recovery of high-quality aggregate within a bound pavement layer instead of downgrading it to base material (Asphalt, 2025; Recycling, 2012).

From a sustainability perspective, an illustrative comparison shows that a 6-inch CIR layer plus 2-inch HMA (20% RAP) can reduce materials-phase CO_2 by ≈26% and save ≈3,000 lb. of aggregate per cubic yard versus virgin HMA; additional benefits from reduced hauling and no hot plant heating would further lower impacts. Consistent with Federal Highway Administration (FHWA) /Asphalt Recycling and Reclaiming Association (ARRA) guidance, CIR is best within defined PCI ranges and not recommended where subgrade failure exists or traffic has markedly increased; CCPR may still be appropriate in some of those cases (NAPA, 2021). Curing expectations should be explicit: emulsion-based CRA typically requires ≥16 hours; if rapid opening is critical, foamed asphalt is preferable (Ferrotti et al., 2020). Where the recovered binder is active, a rejuvenator ≈0.4% of RAP mass is a suitable starting point (Sorociak & Grzesik, 2019). Table 1 summarizes the key findings and thresholds synthesized for CRA applications using CIR and CCPR

Table 1. CRA Key Findings and Thresholds

Task	**Practical metric / threshold**	**Notes / source cue**	**Key takeaway**
Quality & process control	Accept density as % of test-section break-over density; calibrate nuclear gauge to lab bulk SG.	Practice/evidence synthesis.	CRA can deliver consistent, large-scale quality with proper QC/QA; acceptance should be field-anchored.
Aggregate recovery	Reuse RAP as bound layer via CIR/CCPR rather than downgrading to base.	(Wirtgen 2012; Asphalt Institute 2023).	Existing pavements often contain high-quality coarse aggregate; most failures are binder/surface driven, not aggregate breakdown.
Materials-phase impacts	≈26% lower CO_2 (materials only) and ≈3,000 lb aggregate saved per cubic yard.	Additional savings from shorter hauls / no hot-plant heat.	CIR 6" + HMA 2" (20% RAP) vs virgin HMA shows meaningful footprint reduction.
Applicability & selection	CIR: within defined PCI ranges; not where subgrade failure exists or traffic has markedly increased. CCPR may still fit.	(FHWA/ARRA guidance; NAPA 2021).	Choose process by condition and logistics; avoid CIR in poor foundations or big traffic jumps.
Curing & opening to traffic	Emulsion CRA ≥16 h typical before surfacing;	(Ferrotti et al., 2020).	Set expectations in the spec and schedule.

	need rapid opening → prefer foamed asphalt.		
Rejuvenator use	Start at ≈0.4% of RAP mass; confirm in mix design.	(Sorociak & Grzesik, 2019).	Use when recovered binder is "active."

Mix Design Analysis

The analysis shows that CRA mix design is most reliable when laboratory procedures intentionally mirror field conditions: determine OMC and MDD with all constituents present except added asphalt (including cement/lime and corrective fines), perform these tests immediately after mixing, and adjust compaction temperatures to ambient (per AASHTO PP 86, CT-315, ARRA CR201/CR202). Several ASTM methods require adaptation: compact D4867 specimens by defined effort or target ~8–16% air voids for cold mixes; allow D5361 sampling by milling; and for D6925/D6926 use ambient aggregate/molds with binder heated only as required by the supplier. A simplified four-step process (CT-315 aligned) was validated: (1) Characterize materials (RAP gradation, binder activity; pick emulsion vs foam and document foam properties when used); (2) Produce specimens across 3 - 4 binder contents at ambient conditions, with paired dry and moisture-conditioned sets, and record curing time; (3) Select optimum using Marshall stability or ITS and (4) Confirm and tune with a raveling test at the selected proportions and add project-specific tests as needed. Crucially, the mix design should output field-ready adjustment ranges (binder/water) so engineers and crews can make controlled, on-site corrections. Figure 1 presents the key steps involved in the CRA mix-design method.

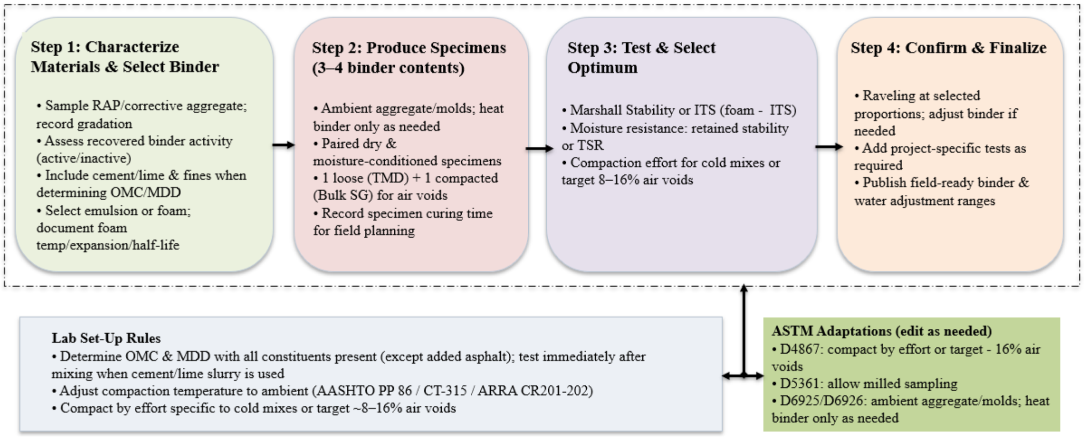

Figure 1. CRA Mix-design methodology (CIR/CCPR)

Field Production and Acceptance

A test section establishes the "break-over density," defined as the plateau in density gain under incremental rolling effort. This value becomes the 100% reference for production. Nuclear density readings are calibrated to laboratory bulk specific gravity (ASTM D2726 or equivalent) with reported relation to theoretical maximum density (ASTM D2041). Acceptance is based on percentage of break-over density achieved, production tolerances for moisture and binder content, and quick checks before surfacing (e.g., residual moisture ≤2–3%). Figure 2 presents the main cold pavement options.

Cold In-Place Recycling (CIR)

- Indicative treatment thickness: 3 - 5 inch
- Stabilization: asphalt emulsion or foamed asphalt
- Typical agency use: alternative to deep mill-and-fill or partial-depth patching

Cold Central Plant Recycling (CCPR)

- Indicative treatment thickness: 3 - 6 inch
- Stabilization: asphalt emulsion or foamed asphalt
- Typical agency use: structural base rehabilitation; alternative to deep mill-and-fill

Figure 2. Cold pavement recycling options

Standardizing what matters (gradation, specs usability)

Existing CRA specs are either too thin to enforce or so prescriptive they're hard to use. A pragmatic middle ground emerges from ARRA, Caltrans CT-315, and Wirtgen: adopt common sieve analysis via ASTM D5444 and publish industry-standard gradation bands sized to milling capabilities treating gradation as a consistency check, not a recipe. Interviews further support designing with two lab bands (coarse/fine) so production can switch as milling varies without halting work.

More broadly, the field needs specs that are readable and updateable. The evidence supports writing an enforceable baseline in UFGS form and then refining through pilots. This raises confidence for owners/contractors and avoids the stagnation that undermined prior WBDG sections.

Lab–field alignment (density, mix design, and QC)

Density acceptance should be project-specific and traceable: set 100% at the test-section break-over density, calibrate nuclear readings to lab bulk SG (ASTM D2726), and acknowledge TMD (ASTM D2041) as a lab reference, not a field target. Practical cross-checks: 100% = break-over, 98% ±2% of D2726, 94% ±2% of D2041. Require a test section and early-day verification; keep QC frequencies high enough to steer production, not punish it.

Mix design should mirror field conditions: determine OMC/MDD with all constituents (except added asphalt), use ambient compaction (AASHTO PP 86 / CT-315 / ARRA), and adapt ASTM methods (e.g., D4867 by effort or ~8-16% AV; D6925/D6926 ambient aggregate/molds). Strength checks: ITS and/or Marshall, with realistic raveling 5-7%; foam mixes - ITS. Manage total fluid (water +

emulsion/foam + slurry + in-place moisture); allow dry cement/lime when dust and moisture are controlled. Encourage engineered emulsions using RAP binder characterization.

Proposed UFGS structure and designer notes

Part 1 - General: submittals (QC plan with test matrix, fluid balance, gauge-to-lab calibration), referenced standards, definitions (break-over density), and test sections.
Part 2 - Products: RAP/corrective aggregate; emulsion/foam properties; optional cement/lime; rejuvenators; standard gradation table (ASTM D5444); lab procedures that mirror field (ambient compaction; ASTM adaptations).
Part 3 - Execution: milling/plant operations; mixing/placement; compaction and acceptance as % of break-over with D2726/D2041 cross-checks; curing/moisture thresholds before surfacing; optional fog seal; production tolerances and test frequencies with corrective actions.

Non-contractual Designer Notes provide guidance on CIR versus CCPR selection, climate and scheduling considerations (e.g., emulsion curing ≥16 hours versus foamed asphalt for rapid opening), dual gradation strategies, cement or lime application methods, engagement with emulsion suppliers for engineered binders, and a compact acceptance ladder linking laboratory and field density references. Pilot deployment with structured feedback loops is recommended to refine thresholds and sustain specification relevance over time.

Conclusions and Recommendations

This research proposed an evidence-based, UFGS-style specification framework for Cold Recycled Asphalt (CRA) that accommodates both emulsified and foamed asphalt technologies and supports implementation through Cold In-Place Recycling (CIR) and Cold Central Plant Recycling (CCPR). By consolidating federal and state guidance, laboratory and field evidence, and targeted practitioner input, the framework addresses long-standing inconsistencies in gradation control, laboratory procedures, density acceptance criteria, and QC/QA frequency. Structured in the UFGS format (*General–Products–Execution*) and supported by non-contractual Designer Notes, the framework translates best practice into enforceable, vendor-neutral, and field-practical contract language.

Key outcomes: (1) A lab-to-field acceptance ladder that sets 100% density at the test-section break-over and calibrates nuclear gauge readings to lab bulk specific gravity, with D2041 used only as a reference; (2) a field-faithful mix-design process using ITS/Marshall and raveling checks at realistic thresholds; (3) standardized gradation treated as a consistency measure rather than a recipe, with a dual-band (coarse/fine) design option to accommodate milling variability; and (4) a contract-ready QC/acceptance checklist that pairs targets with methods, frequencies, and corrective actions. These elevate enforceability, reduce quality variability, and support cost and carbon objectives while recovering high-quality aggregates that would otherwise be downgraded.

Practical implications: The proposed framework clarifies risk allocation and day-to-day decision-making for contracting officers, inspectors, and contractors. It enables predictable field control through mandatory test sections and early density verification, transparent production adjustments via defined binder and moisture ranges, and safer opening-to-traffic strategies (e.g., emulsion curing ≥16 hours or use of foamed asphalt where rapid opening is required). The embedded Designer Notes further support process selection (CIR vs. CCPR), climate- and schedule-sensitive planning, cement or lime application strategies, and engagement with emulsion suppliers for engineered binder properties, enhancing usability across diverse project contexts.

Limitations and Delimitations:

This study is limited by its focus on specification synthesis and development rather than validation through full-scale field implementation. While grounded in published research and practitioner experience, the proposed UFGS framework has not yet been tested on an active construction project. The synthesis prioritizes implementable and enforceable requirements over exhaustive academic coverage, and certain niche tests were intentionally excluded where enforcement would be impractical. Practitioner interviews, while in-depth, were purposive and non-probabilistic.

Implementation roadmap: A staged implementation approach is recommended to transition the framework into practice:

1. Pilot deployment on selected DoD facilities, with a mandatory test section and gauge-to-lab calibration documented in submittals.
2. Data capture during production (density, moisture, binder/water feeds, curing time, spot raveling) using a standard template tied to lot/segment locations.
3. Post-construction review focused on bid clarity, achievement of acceptance targets, and early-life performance.
4. A scheduled update cadence (e.g., annually) to tune tolerances, cure expectations, and strength thresholds based on pilot evidence.

Research and refinement agenda: Future research should focus on: (i) refining ITS/Marshall/raveling thresholds by climate and traffic category; (ii) quantifying curing kinetics for emulsion vs. foam under representative weather; (iii) optimizing rejuvenator dosage when recovered binder is active; and (iv) improving the fluid-balance model (water + emulsion/foam + slurry + in-place moisture) to better predict compaction and early performance.

By standardizing what matters, the proposed UFGS draft framework provides a clear, enforceable path to scale CRA on federal projects. With disciplined piloting and feedback, agencies can convert today’s fragmented guidance into consistent outcomes in the field, accelerating adoption of CIR/CCPR while delivering measurable cost, carbon, and materials savings.

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