



## Research Article

# Appraisal of reclaimed asphalt pavement as coarse aggregates in cement concrete

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## ARTICLE INFO

### Article history

Received: 27 June 2023

Revised: 24 October 2023

Accepted: 27 December 2023

### Key words:

Concrete construction; Coarse aggregates; Mechanical properties; Performance evaluation; Reclaimed asphalt pavement (RAP)

## ABSTRACT

This systematic literature review evaluates reclaimed asphalt pavement (RAP) in concrete construction, targeting reduced natural aggregate use and lower construction carbon footprint. It comprehensively covers RAP in concrete, including mechanical properties, durability, test methods, mix design, performance, influencing factors, RAP content, processing, admixtures, curing, and environmental aspects. RAP concrete matches traditional concrete mechanically while increasing sustainability through waste reduction. Durability parameters, like permeability, freeze-thaw resistance, and chloride penetration, suggest long-term structural enhancement. Reliable testing methods and standards are vital for RAP in concrete assessment. The review explores RAP in mix design, considering content, gradation, and processing. Admixtures and additives optimize RAP concrete. Curing and environmental conditions influence RAP concrete performance. Gaps indicate a need for long-term studies, understanding mechanisms, specific environmental exploration, standardized testing, and economic assessment. The study recommends future research directions to guide sustainable construction practices.

**Cite this article as:** Tiza MT, Agunwamba J, Okafor F. Appraisal of reclaimed asphalt pavement as coarse aggregates in cement concrete. Environ Res Tec 2024;7(1)27–40.

## INTRODUCTION

The use of Reclaimed Asphalt Pavement (RAP) as coarse aggregates in concrete construction has gained significant attention in recent years. RAP refers to the recycled materials obtained from old asphalt pavements that are crushed and reused as aggregates in new concrete mixes [1]. This practice of utilizing RAP in concrete construction holds great promise for addressing sustainability concerns, reducing waste, and conserving natural resources.

The importance and relevance of evaluating the performance of RAP in concrete construction cannot be overstated [2]. With the increasing demand for concrete as a primary building material, there is a pressing need to explore alternative solutions that can enhance the sustainability and efficiency of construction practices. By incorporating RAP

as coarse aggregates, we can potentially reduce the reliance on traditional virgin aggregates, which require extensive mining and extraction processes. This, in turn, can help conserve natural resources and minimize the environmental impact associated with aggregate production [3].

The research objectives of this literature review are to critically examine the existing body of knowledge on the performance evaluation of RAP as coarse aggregates in concrete construction and to identify gaps in the current understanding. By reviewing previous studies, we aim to gain insights into the effects of using RAP on various concrete properties and performance indicators, such as compressive strength, durability, workability, and long-term behavior [4]. Furthermore, this literature review seeks to provide a comprehensive overview of the methodologies, experimental setups, and performance evaluation parameters used in previous research.

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**Figure 1.** Pictorial representation of reclaimed asphalt pavement (RAP). Source: Field.

The scope of this literature review encompasses a wide range of scholarly articles, conference papers, and industry reports that are relevant to the topic of evaluating RAP in concrete construction. The search strategy includes comprehensive searches of reputable databases and the inclusion of publications that have investigated the use of RAP as coarse aggregates, the performance of RAP-concrete mixtures, and the influence of various factors, such as RAP content, processing techniques, and mix design considerations [5]. Figure 1 provides a pictorial representation of RAP.

### Theoretical Framework

The conceptual framework for the performance evaluation of RAP as coarse aggregates in concrete construction encompasses several key components that provide a theoretical foundation for understanding the topic. To begin with, it is essential to define and explain the key terms involved in this framework [6].

RAP refers to the recycled materials obtained from old asphalt pavements through the process of crushing and reusing them as aggregates in new concrete mixes. Concrete, on the other hand, is a composite material composed of cement, aggregates (including coarse aggregates), water, and other additives. Coarse aggregates are an essential component of concrete, providing strength, stability, and bulk to the mixture [7].

The theoretical foundations of this conceptual framework are rooted in concrete properties, performance evaluation, and sustainable construction practices. Concrete properties such as compressive strength, durability, workability, and long-term behavior play a crucial role in assessing its overall performance. Understanding how the incorporation of

RAP as coarse aggregates influences these properties is vital for evaluating its effectiveness in concrete construction [8].

Performance evaluation in the context of RAP as coarse aggregates involves assessing the effects of RAP on concrete properties and performance indicators. This includes examining the influence of various factors such as RAP content, processing techniques, mix design considerations, and the use of appropriate testing methodologies [9]. By analyzing previous research studies and experimental data, the framework aims to establish a comprehensive understanding of the performance of RAP-concrete mixtures [9].

Sustainable construction practices form an integral part of the conceptual framework, as the utilization of RAP as coarse aggregates aligns with the principles of sustainability. By reducing the reliance on traditional virgin aggregates, which require extensive mining and extraction processes, the use of RAP contributes to resource conservation and environmental preservation. This framework aims to explore the environmental benefits, economic viability, and social implications of incorporating RAP in concrete construction [10].

### Literature Search Strategy

The literature search strategy for the performance evaluation of RAP as coarse aggregates in concrete construction involves a systematic approach to identify relevant literature. This section outlines the description of the search criteria, databases used, inclusion and exclusion criteria, and justification for the selection of sources.

To conduct a comprehensive literature search, a range of search criteria is employed. These criteria typically include keywords related to the research topic, such as "reclaimed

**Table 1.** A summary of performance evaluation of RAP in concrete construction

S/N	Aspect	Summary	Reference
1	Performance evaluation of RAP in concrete	Assesses the suitability and effectiveness of RAP as coarse aggregates in concrete construction. Examines influence on concrete properties, testing methods, factors affecting performance, comparisons with conventional concrete, case studies, and challenges.	[14, 15]
2	Influence on concrete properties	Evaluates RAP's impact on mechanical properties (compressive, tensile, flexural strength) and durability properties (permeability, freeze-thaw resistance, chloride ion penetration).	[16]
3	Testing methods and standards	Considers concrete mix design, standardized testing procedures, and guidelines for reliable assessment of RAP concrete.	[17]
4	Factors affecting RAP performance	Explores RAP content, gradation, processing techniques (crushing, screening, blending), use of additives, and curing conditions as influential factors.	[18]
5	Performance comparisons with conventional concrete	Assesses strength, durability, long-term performance, and structural behavior of RAP concrete in comparison to conventional concrete.	[19]
6	Case studies and experimental research	Reviews studies on RAP performance, covering parameters such as RAP content, processing methods, performance testing, and field applications.	[20]
7	Challenges and limitations	Considers potential effects on workability, mixture consistency, fresh and hardened concrete properties, and the need for quality control measures.	[21]

RAP: Reclaimed asphalt pavement.

asphalt pavement," "RAP," "concrete," "coarse aggregates," "performance evaluation," and "construction." Boolean operators like "AND" and "OR" are used to combine these keywords to refine the search results. The search also included specific terms related to concrete properties, testing methods, and sustainability.

Databases from reputable academic platforms, such as PubMed, Scopus, Web of Science, and Engineering Village, are utilized to identify relevant literature. These databases cover a wide range of disciplines, including civil engineering, materials science, construction, and sustainability. Additionally, relevant industry-specific databases and resources may be explored to include practical insights and case studies.

The justification for the selection of these sources lies in their ability to contribute to the research objectives and address the research questions [11]. Scholarly articles undergo a rigorous peer-review process, ensuring the accuracy, validity, and scientific merit of the research. Conference papers, on the other hand, provide insights into cutting-edge research and emerging trends. Industry reports and technical documents offer practical knowledge and real-world applications [12]. By incorporating a range of sources, the literature review aims to provide a comprehensive understanding of the performance evaluation of RAP as coarse aggregates in concrete construction, considering both theoretical and practical perspectives [13].

**Performance Evaluation of RAP in Concrete Construction**

The evaluation of RAP as coarse aggregates in concrete construction is essential to understand its suitability and effectiveness, encompassing various aspects of performance assessment [14]. This section covers its impact on concrete properties, testing methods, performance factors, compari-

sons with conventional concrete, case studies, and associated challenges [15]. RAP's influence on concrete properties, including mechanical (e.g., compressive, tensile, and flexural strength) and durability properties (e.g., permeability, freeze-thaw resistance, chloride ion penetration), is a key consideration for assessing its overall impact [16].

Testing methods and standards are crucial, ensuring a consistent and reliable assessment of RAP concrete by offering standardized procedures and guidelines for evaluation [17]. Performance factors such as RAP content, gradation, processing techniques, admixtures, curing conditions, and environmental factors must be examined to optimize RAP use in concrete mixtures [18]. Comparing RAP concrete's performance with conventional concrete involves assessing strength, durability, long-term behavior, and load-carrying capacity, confirming its suitability for various applications [19]. In this study, Table 1 provides a comprehensive summary of the Performance Evaluation of RAP in Concrete Construction.

Case studies and experimental research offer valuable insights, with a focus on parameters like RAP content, processing methods, performance testing, and field applications [20]. Despite potential benefits, challenges and limitations must be addressed, including workability, fresh and hardened concrete properties, and the need for quality control measures to ensure successful RAP utilization in concrete construction projects [21]. Figure 2 illustrates the screening process for RAP, depicting the steps in processing RAP for concrete applications.

**Mechanical Properties**

Evaluating the mechanical properties of RAP in concrete construction is essential to gauge its performance and suitability as an alternative to traditional aggregates [22]. The



**Figure 2.** Pictorial representation of screening of RAP. Source: Field work.

primary mechanical property to consider is compressive strength, measuring a concrete's load-carrying capacity [23]. This involves standardized compression tests on concrete specimens containing varying RAP percentages, following testing standards like ASTM C39, to assess RAP's impact on strength [24].

Tensile strength, another crucial property, determines concrete's ability to resist tension forces, particularly vital in structures under tensile stress. Various methods like the splitting tensile test help measure tensile strength and assess RAP's influence on structural performance [25]. Flexural strength assesses a material's resistance to bending and is important for elements like beams and slabs. Third-point or center-point loading tests on beam specimens evaluate the impact of RAP on flexural strength and cracking behavior [26].

Additional properties like modulus of elasticity and Poisson's ratio, which influence concrete's stiffness and lateral strain response, are also considered when incorporating RAP. These properties provide insights into the material's structural behavior [27]. Evaluating mechanical properties should take into account factors like RAP content percentage, aggregate grading, mix design, curing conditions, and testing procedures [28]. Systematic variation of these parameters through comprehensive testing allows researchers to understand the effects of RAP on concrete's mechanical properties and identify optimal mix proportions [29].

In conclusion, assessing mechanical properties like compressive, tensile, and flexural strength is essential to understand RAP's performance in concrete construction. This knowledge provides insights into the benefits and limitations of using RAP in concrete mixtures, promoting sustainable and resource-efficient construction practices [30]. Table 2 provides a summary of mechanical properties. This table offers a comprehensive overview of the mechanical characteristics of RAP in concrete, highlighting key aspects crucial for understanding its suitability and effectiveness as a replacement for conventional aggregates.

#### **Durability Properties**

Evaluation of durability properties plays a vital role in assessing the performance of RAP as coarse aggregates in concrete construction [31]. Permeability, a crucial property, assesses the concrete's resistance to water and liquid penetration. Methods like the water permeability test and rapid chloride ion penetration test (RCPT) gauge RAP concrete's moisture resistance and its potential to counter moisture-related deterioration [32]. Freeze-thaw resistance, another critical property, focuses on the concrete's ability to withstand the damaging effects of freezing and thawing cycles in cold climates. Evaluating freeze-thaw resistance involves subjecting specimens to multiple freeze-thaw cycles to assess changes in mass, volume, strength, and visual appearance [33]. Additionally, chloride ion penetration

**Table 2.** A summary of mechanical properties

S/N	Mechanical properties of RAP concrete	Summary	Reference
1	Compressive strength	Compressive Strength Measures concrete's resistance to compressive forces. Standardized compression tests assess RAP concrete strength. Comparisons made to conventional concrete strength.	[22–24]
2	Tensile strength	Tensile Strength Evaluates concrete's ability to resist tension forces. Splitting tensile or direct tension tests measure RAP concrete tensile strength. Enhances structural performance.	[22, 25]
3	Flexural strength	Flexural Strength Assesses concrete's resistance to bending or flexure. Third-point or center-point loading tests determine RAP concrete flexural strength and cracking behavior.	[22, 26]
4	Modulus of elasticity and poisson's ratio	Modulus of Elasticity and Poisson's Ratio Measures concrete's stiffness and lateral strain response. Influence structural behavior. Variation with RAP inclusion provides insights into RAP concrete behavior.	[22, 27]
5	Factors influencing results	Factors Influencing Results Considerations for evaluating mechanical properties: RAP content, grading, mix design, curing conditions, and testing procedures. Optimal mix proportions determined for performance.	[28, 29]

RAP: Reclaimed asphalt pavement.

**Table 3.** Durability properties of RAP concrete

Durability property	Summary	Reference
Permeability	Measures resistance to water and liquid penetration. Evaluates moisture ingress and potential for deterioration.	[31, 32]
Freeze-thaw resistance	Assesses ability to withstand freezing and thawing cycles. Determines resistance to damage and structural integrity.	[31, 33]
Chloride ion penetration	Evaluates resistance to chloride ingress. Determines potential for corrosion-related issues in chloride-rich environments.	[31, 34]
Factors influencing results	Considers RAP content, aggregate quality, mix design, curing conditions, and exposure conditions.	[35–37]

RAP: Reclaimed asphalt pavement.

evaluation is essential for concrete structures exposed to chloride-rich environments. Tests such as RCPT and chloride migration tests measure RAP concrete's ability to resist chloride ion ingress, crucial for mitigating corrosion-related issues in coastal regions or areas with deicing salts [34].

Several factors influence the outcomes of durability property evaluations, including the RAP content percentage, quality, and gradation of RAP aggregates, mix design parameters, curing conditions, and exposure conditions. Long-term durability assessments through accelerated aging tests and field exposure studies provide a comprehensive understanding of RAP concrete's performance under real-world conditions [35].

By assessing properties like permeability, freeze-thaw resistance, and chloride ion penetration, researchers can optimize mix designs, enhance concrete structure long-term performance, and support sustainable construction by reducing the environmental impact associated with traditional aggregates [36]. Furthermore, this understanding aids in the development of guidelines and specifications for RAP concrete use in diverse applications, empowering engineers and practitioners to make informed decisions considering

exposure conditions, service life requirements, and sustainability goals [37]. Table 3 presents a comprehensive overview of the durability properties of RAP concrete. This table offers valuable insights into the ability of RAP concrete to withstand various environmental conditions, chemical attacks, and long-term deterioration.

**Testing Methods and Standards for Evaluating RAP in Concrete**

Evaluation of RAP as coarse aggregates in concrete necessitates standardized testing methods and adherence to established standards for reliable and comparable results [38]. Mechanical properties, including compressive, tensile, and flexural strengths, are assessed to gauge the structural integrity of RAP concrete [39, 40]. Durability properties are equally crucial, with tests such as water permeability, freeze-thaw resistance, and chloride ion penetration evaluating aspects like water ingress resistance, resistance to freeze-thaw cycles, and chloride resistance [41]. Specific testing methods for RAP, focusing on properties like gradation, asphalt content, and binder characteristics, offer insights into the quality of RAP aggregates and binder, impacting RAP concrete performance [42].

**Table 4.** Concrete mix design incorporating RAP

Aspect	Summary	Reference
Aggregate proportions	Determine optimal blend of RAP and conventional aggregates. Consider RAP particle size distribution for achieving balanced mix.	[48, 50]
Binder selection	Select appropriate cementitious materials based on desired properties. Adjust water demand and workability due to RAP aggregates.	[48, 51]
Water-to-cement ratio and workability	Adjust water content or use water-reducing admixtures to maintain workability. Consider absorptive nature of RAP aggregates.	[48, 52]
Sustainability considerations	Reduce the need for virgin aggregates, promote recycling, and decrease environmental impact. Contribute to sustainability goals.	[48, 53]
Admixture usage	Consider dosage and type of chemical admixtures to enhance workability, strength, and durability. Ensure compatibility with RAP mix.	[48, 54]
Laboratory testing	Conduct tests on fresh and hardened concrete to validate mix design. Evaluate workability, strength, and durability characteristics.	[48, 55]

RAP: Reclaimed asphalt pavement.

To ensure test result consistency and comparability, established standards and guidelines from organizations like ASTM, EN, and national standards bodies are followed, with standards such as ASTM C39, C496, C78, C1202, C666, and NT BUILD 492 widely recognized for concrete testing and ASTM D6307, D6925, and D7175 for RAP properties testing [43, 44]. The use of standardized testing methods and compliance with these standards enhance the precision, reliability, and comparability of results in RAP concrete evaluation, fostering data sharing and well-informed decision-making [45]. Such practices also bolster the credibility and acceptance of RAP concrete in construction, promoting its sustainable use and supporting standardized procedures in the industry [46, 47].

#### Concrete Mix Design Incorporating RAP

Concrete mix design for RAP incorporation involves key considerations such as aggregate proportions, binders, water-to-cement ratio, and sustainability [48]. Evaluating RAP gradation, typically different from conventional aggregates, and performing sieve analyses are essential for balanced mixing and improved mechanical properties [49, 50]. The choice and dosage of cementitious materials must align with desired concrete properties and workability [51]. RAP's absorptive nature can impact the water demand, necessitating adjustments like increased water content or water-reducing admixtures for maintaining workability [52]. RAP's use contributes to sustainability by reducing the need for virgin aggregates, conserving resources, and promoting recycling [53]. Considering the dosage and compatibility of chemical admixtures further enhances the mix's performance and durability [54]. Rigorous laboratory testing is vital for confirming the fresh and hardened properties, including workability and strength [55]. Proper mix design optimizes RAP concrete for mechanical properties, durability, and sustainability, aligning with industry goals [56]. Table 4 provides a detailed summary of concrete mix designs that incorporate RAP as coarse aggregates.

#### Performance Testing and Evaluation Methods

Performance testing of RAP in concrete is essential to evaluate its quality and suitability for construction [57]. Mechanical properties like compressive, tensile, and flexural strength assess the load-bearing capacity of RAP concrete [57, 58]. Durability tests, including permeability, freeze-thaw resistance, and chloride ion penetration, evaluate RAP concrete's ability to withstand environmental stressors [59, 60]. Additional tests for shrinkage, creep, abrasion resistance, and impact resistance provide insights into RAP concrete's long-term behavior and application suitability [61, 62]. To ensure reliable and consistent evaluation, standards from organizations like ASTM International and the American Concrete Institute have been established [63]. These tests help engineers and researchers select and optimize RAP concrete mixtures, supporting sustainable and high-performance construction [64]. Table 5 is a comprehensive overview of the performance testing and evaluation methods used for RAP concrete.

#### Factors Affecting the Performance of RAP in Concrete

Several factors influence the performance of RAP in concrete [65]. Key factors include RAP gradation, which impacts workability, strength, and durability [64]. Asphalt content can affect workability and bonding [65, 66]. Moisture content influences strength and shrinkage [66, 67]. Compatibility with cementitious materials is crucial for proper hydration [67, 68]. Environmental conditions, like temperature and humidity, affect setting and curing [69]. Mix proportions and additives, including water reducers and air entraining agents, impact workability, strength, and freeze-thaw resistance [70]. Construction practices, such as mixing, compaction, and curing, play a vital role [71]. Addressing these factors optimizes RAP's performance in concrete and informs guidelines for sustainable infrastructure solutions [72]. Table 6 presents a summarized overview of the key factors influencing the performance of RAP in concrete construction.

**Table 5.** Performance testing and evaluation methods for RAP concrete

Testing method	Summary	Reference
Mechanical properties	Evaluate compressive, tensile, and flexural strength of RAP concrete. Assess its load-bearing capacity and structural integrity.	[57, 58]
Durability properties	Assess permeability, freeze-thaw resistance, and chloride ion penetration of RAP concrete. Evaluate its resistance to deterioration.	[57, 59, 60]
Shrinkage and creep testing	Measure the deformation characteristics of RAP concrete over time. Assess its long-term behavior and potential for cracking.	[61]
Abrasion and impact testing	Evaluate the wear resistance and impact resistance of RAP concrete. Assess its suitability for high-traffic areas and dynamic loads.	[62]
Standards and guidelines	Adhere to established standards (e.g., ASTM, ACI) for conducting performance tests on RAP concrete. Ensure reliable evaluation.	[63]

RAP: Reclaimed asphalt pavement.

**Table 6.** A summary of the factors affecting the performance of RAP in concrete

Factor	Impact	Reference
RAP gradation	Affects workability, strength, and durability of RAP concrete.	[64–66]
Asphalt content	Influences workability and bond strength of RAP concrete.	[65, 66]
Moisture content	Impacts workability, strength, and drying shrinkage of RAP concrete.	[66, 67]
Compatibility with cementitious materials	Affects hydration and strength development of RAP concrete.	[67, 68]
Environmental conditions	Temperature and humidity influence setting time and curing of RAP concrete.	[69]
Mix proportions and additives	Optimal proportions and additives enhance workability and durability of RAP concrete.	[70]
Construction practices	Proper mixing, compaction, and curing techniques ensure desired performance of RAP concrete.	[71]

RAP: Reclaimed asphalt pavement.

**Table 7.** RAP content and gradation in RAP concrete

Factor	Impact	Reference
RAP content	Influences sustainability, workability, strength, and durability of RAP concrete.	[72]
RAP gradation	Affects workability, mechanical properties, and potential issues in RAP concrete.	[73]
RAP material	Particle size distribution, angularity, and presence of contaminants affect RAP performance.	[74]
Blending process	Proper processing and blending of RAP with other aggregates ensure quality and consistency.	[76]

RAP: Reclaimed asphalt pavement.

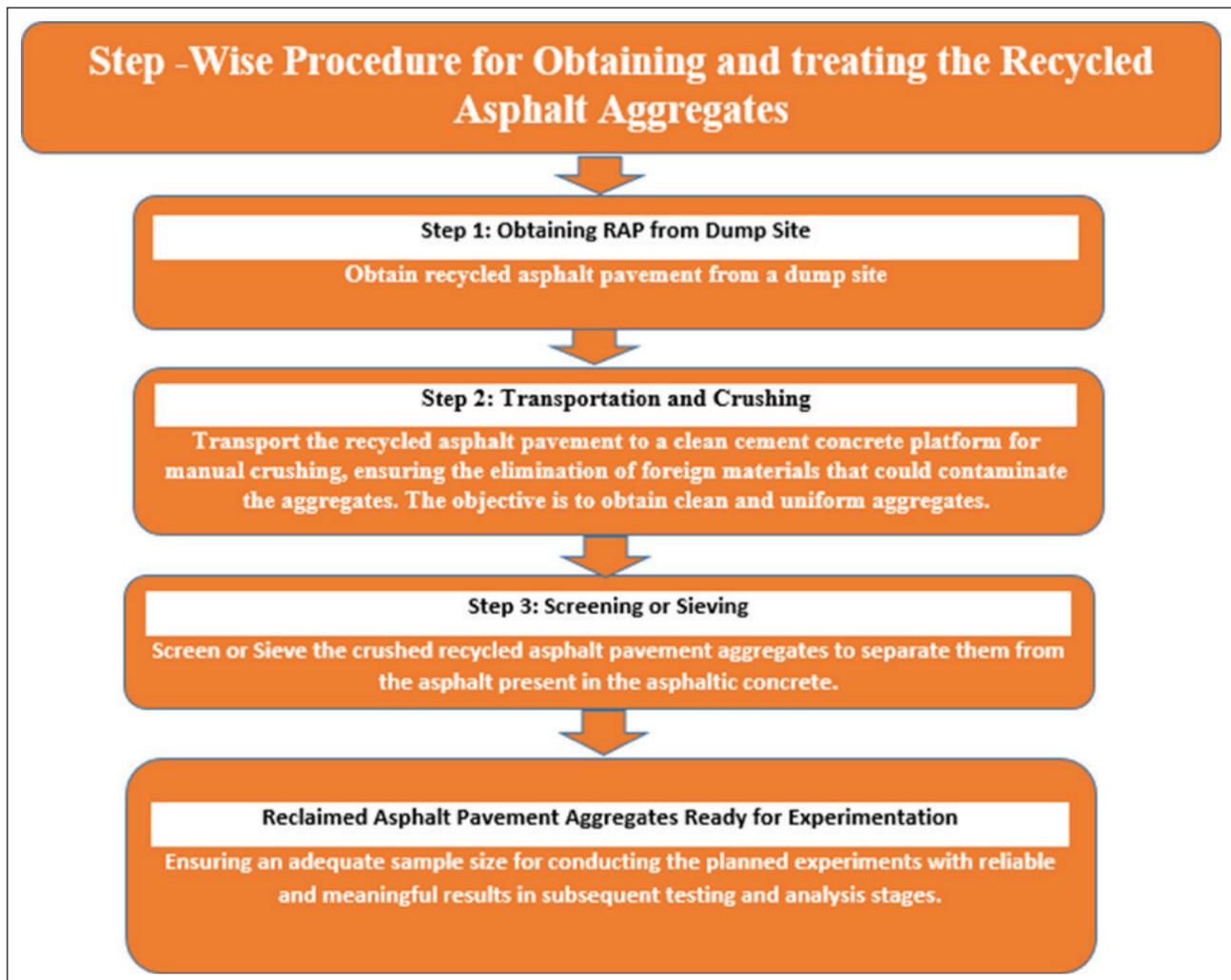
### 11.0 RAP Content and Gradation

In concrete construction using RAP as coarse aggregates, the RAP content and gradation are pivotal factors influencing RAP concrete's performance and properties. RAP content refers to the percentage of RAP used in the aggregate mix. While higher RAP content offers sustainability benefits by reducing environmental impact and conserving resources, it must be carefully balanced to avoid drawbacks like reduced workability, lower strength, and durability concerns. The optimum RAP content varies depending on RAP quality, desired concrete performance, and project specifics [72].

RAP's particle size distribution significantly impacts workability, mechanical properties, and overall performance of RAP concrete. Proper gradation ensures compatibility with other aggregates used in the mix. Well-graded RAP aggregates

optimize particle packing, improving mechanical properties and durability while mitigating issues like excessive voids, poor workability, and segregation or bleeding [73].

Balancing RAP content and gradation is crucial for a well-optimized concrete mix. Engineers should understand RAP characteristics and conduct thorough laboratory testing to determine the appropriate RAP content and adjust gradation for desired concrete performance [75]. The selection and blending of RAP with other aggregates must adhere to standards and guidelines for consistent concrete quality. This optimization, considering parameters like cement content, water-to-cement ratio, and supplementary materials, balances sustainability goals, concrete performance, and code compliance [77]. Table 7 provides a detailed summary of the RAP content and gradation in RAP concrete.



**Figure 3.** A typical procedure for processing RAP.

### Processing Techniques

Processing techniques are vital for preparing RAP for use in concrete construction, enhancing the quality and performance of RAP concrete. The first step is crushing, which reduces the asphalt material to the appropriate aggregate size. Primary and secondary crushers are utilized for this purpose. Proper crushing ensures the desired particle size distribution, a crucial factor for concrete performance [78].

Following crushing, the RAP material undergoes screening to separate aggregates into different size fractions. This step, done through vibrating screens or sieves, eliminates oversized particles and ensures compliance with gradation requirements. Screening also removes any remaining fine particles that could impact concrete workability and performance [80].

Blending is the next step, where RAP aggregates are mixed with other conventional aggregates to create a well-graded and homogeneous mixture. This process balances particle size distribution and enhances concrete quality and performance. It involves careful proportioning based on gradation, particle shape, and specific properties. Properly adhering to industry best practices, standards, and maintaining equipment ensures consistent and accurate processing [81].

Figure 3 illustrates a typical procedure for processing RAP. This procedure outlines the sequential steps involved in the processing of RAP materials, providing a visual guide to the key stages in the recycling process.

Addressing potential contaminants in RAP material is crucial. Contaminants like residual asphalt or foreign materials can harm RAP concrete properties and performance [82]. Therefore, processing methods must include measures like thermal or solvent extraction to remove or reduce contaminants [83].

Utilizing suitable processing techniques such as crushing, screening, and blending is key to optimizing RAP aggregate quality. These techniques ensure proper sizing, contaminant removal, and integration with other aggregates, yielding durable, sustainable, high-performance RAP concrete [84]. Table 8 provides a comprehensive overview of the various processing techniques used for Reclaimed Asphalt Pavement (RAP) in concrete construction.

### Admixtures and Additives

Admixtures and additives are vital components in concrete, even more so when incorporating RAP as coarse

**Table 8.** Processing techniques for RAP in concrete construction

Technique	Purpose	Reference
Crushing	Reduces RAP material to suitable aggregate size for concrete production.	[79]
Screening	Separates RAP aggregates into desired size fractions and removes impurities.	[80]
Blending	Combines RAP aggregates with other aggregates for a well-graded mixture.	[81]
Contaminant removal	Addresses potential contaminants through extraction methods.	[83]

RAP: Reclaimed asphalt pavement.

**Table 9.** Admixtures and additives for RAP concrete construction

Admixture/additive	Purpose	Reference
Water reducing	Reduces water content while maintaining workability	[84]
Set retarding	Delays concrete setting time for extended workability	[85]
Pozzolanic	Enhances strength, durability, and chemical resistance	[86]
Air-entraining	Introduces air bubbles for improved freeze-thaw resistance	[87]
Fiber reinforcement	Enhances toughness, impact resistance, and crack resistance	[89]

RAP: Reclaimed asphalt pavement.

aggregates [84]. Water Reducing Admixtures, also known as plasticizers or superplasticizers, cut water content while maintaining workability. They disperse cement particles effectively, enhancing fluidity for better flow and consolidation, which is particularly useful for RAP concrete by improving cohesion and bonding between RAP aggregates and the cement matrix [85]. Set Retarding Admixtures, or set retarders, delay concrete setting, beneficial when extended workability or delayed setting is necessary, such as in hot weather or long transportation times. They provide extra time for proper placement and compaction in RAP concrete, ensuring optimal consolidation and bonding [86]. Pozzolanic Admixtures, like fly ash or silica fume, react with cement hydration byproducts to enhance strength, durability, and chemical resistance. When used in RAP concrete, they compensate for any deficiencies in the cementitious properties of RAP aggregates, improving the overall mixture [87]. Air-Entraining Admixtures introduce stable air bubbles, improving freeze-thaw resistance. In RAP concrete, they mitigate potential decreases in freeze-thaw resistance due to aged asphalt binder or higher porosity in RAP aggregates [88]. Fiber Reinforcement with materials like steel or synthetic fibers enhances toughness, impact resistance, and crack resistance. In RAP concrete, it reduces the risk of cracking, improves post-cracking behavior, and enhances overall durability and long-term performance [89]. Proper selection and dosage of these substances are essential to align with project needs, RAP aggregate properties, and desired concrete characteristics. Following manufacturer recommendations, industry guidelines, and conducting testing and trials ensures effective incorporation and compatibility within the RAP concrete mixture for desired properties and performance [90]. Table 9 presents an extensive summary of the various admixtures and additives used in RAP concrete construction.

**Curing Conditions and Environmental Factors**

Curing conditions and environmental factors are pivotal in optimizing concrete performance when RAP is used as coarse aggregates [90, 91]. Maintaining the right moisture and temperature levels during curing is vital for cement hydration and strength development. In RAP concrete, aged asphalt binder in RAP aggregates may affect moisture characteristics, necessitating tailored curing approaches [92]. Curing duration significantly impacts concrete strength and durability. Longer curing periods foster continued hydration and more durable cementitious products, which is especially beneficial in RAP concrete, improving mechanical and durability properties [92, 93].

Various curing methods are available for RAP concrete, such as moist curing, membrane curing, and curing compounds, each with its advantages [94, 95]. The choice depends on project needs, desired properties, and the influence of aged asphalt binder in RAP aggregates. Environmental conditions, including temperature, humidity, and exposure to external elements, influence the curing process and RAP concrete's performance [95]. Adapting mix proportions and curing methods to suit environmental conditions is essential to ensure optimal performance [96].

By carefully managing curing conditions and considering environmental factors, RAP concrete's performance can be enhanced, ensuring the development of strength, durability, and longevity. Adhering to industry standards and practices, customized for RAP concrete's unique characteristics and project requirements, is crucial for achieving desired performance under various environmental conditions [90]. Regular monitoring and quality control throughout the curing process are recommended [91]. Table 10 presents an extensive summary of the various admixtures and additives used in RAP concrete construction.

**Table 10.** Curing conditions and environmental factors for RAP concrete

Aspect	Importance	Reference
Moisture and temperature	Critical for hydration and reactivity, affects strength and durability	[91]
Curing duration	Influences strength and durability development, longer curing improves properties	[92]
Curing methods	Various methods include moist curing, membrane curing, and curing compounds	[95]
Environmental factors	Temperature, humidity, and exposure affect curing and concrete performance	[95]

RAP: Reclaimed asphalt pavement.

**Table 11.** A summary of the future research directions and recommendations for RAP concrete

Research direction	Recommendations
Long-term performance assessment	Conduct studies to evaluate durability and performance of RAP concrete under various environmental and loading conditions
Optimal RAP content and gradation	Investigate the influence of RAP content and gradation on mechanical and durability properties of concrete
Mix design optimization	Develop improved mix design methods and guidelines tailored for RAP concrete, considering RAP characteristics and properties
Performance evaluation under dynamic loading	Study behavior of RAP concrete under dynamic loading conditions and develop design guidelines for high-stress applications
Environmental impact assessment	Conduct life cycle assessments to evaluate environmental impact and carbon dioxide sequestration potential of RAP concrete
Cost-effectiveness analysis	Perform cost-effectiveness analyses to assess the economic feasibility and advantages of using RAP in concrete construction
Standardization and guidelines	Develop standardized testing methods, specifications, and guidelines specific to RAP concrete to facilitate quality control and implementation

RAP: Reclaimed asphalt pavement.

### Research Gap

In the assessment of RAP within concrete construction, several research gaps have been identified that warrant attention. Firstly, there is a notable lack of long-term studies to evaluate how RAP concrete performs over extended durations, which is crucial for understanding its durability under various environmental conditions. Furthermore, more comprehensive research is needed to explore the influence of diverse environmental factors, such as varying climates and exposure to harsh chemicals, on RAP concrete. Investigating the fundamental mechanisms underlying RAP concrete's performance is another critical gap, with a focus on the interaction between RAP aggregates and the cementitious matrix. Additionally, the scalability of RAP concrete to large construction projects, like highways and bridges, requires further investigation. Standardized testing methods and protocols for RAP concrete remain underdeveloped, limiting consistency and comparability across studies. Moreover, a comprehensive economic assessment, including life cycle cost analysis, is needed to determine the economic viability of RAP concrete. Lastly, the integration of RAP concrete into design codes and guidelines necessitates further research to ensure its safe and efficient incorporation into construction practices. Addressing these research gaps will advance our knowledge and promote sustainable construction practices.

### CONCLUSION

This comprehensive literature review explores the performance of RAP when used as coarse aggregates in concrete construction. It covers a wide range of aspects, including mechanical properties, durability, testing methods, mix design, performance evaluation, influencing factors, RAP content, gradation, processing techniques, admixtures, curing, and environmental considerations. Assessing RAP's performance in concrete construction is crucial due to its potential to enhance sustainability by reducing natural aggregate consumption, recycling waste materials, and decreasing the carbon footprint of construction projects. It not only offers cost savings but also improves the mechanical and durability properties of concrete, representing a significant advancement in construction practices.

Further research is necessary to address identified gaps, such as conducting long-term studies, understanding specific environmental influences, elucidating the underlying mechanisms, exploring large-scale applications, establishing standardized testing methods, and assessing the economic feasibility. The integration of RAP into design codes and specifications must also be pursued to ensure its safe and efficient adoption, furthering the construction industry's transition toward environmentally conscious and economically viable practices.

### Future Research Directions and Recommendations

Future research on RAP in concrete construction should emphasize long-term performance assessments under varying environmental conditions, optimal RAP content and gradation, mix design improvements tailored for RAP, and evaluating RAP concrete's behavior under dynamic loading conditions. Additionally, assessing the environmental impact and cost-effectiveness of RAP concrete is essential for its broader adoption. Developing standardized testing methods, specifications, and guidelines specific to RAP concrete is crucial for consistent evaluation and quality control in construction projects, facilitating its widespread acceptance and utilization. These research directions provide valuable guidance for further exploration in this field, promoting more sustainable and eco-friendly infrastructure practices. Table 11 summarizes these future research directions and recommendations for RAP concrete, offering a concise reference for researchers and professionals seeking to advance the knowledge and application of RAP in concrete construction.

### ACKNOWLEDGMENTS

Deep gratitude to Engr. Prof. Jonah C. Agunwamba for being an exceptional academic model, whose dedication and expertise have greatly influenced and inspired many students.

### DATA AVAILABILITY STATEMENT

The author confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

### CONFLICT OF INTEREST

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

### ETHICS

There are no ethical issues with the publication of this manuscript.

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