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Fabricating a Sustainable Roller Compacted Concrete Containing Recycled Waste Demolished Materials: A Literature Review

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ABSTRACT

The key benefits connected with Roller-Compacted Concrete Pavement (RCCP) technology are costs reduction of life-cycle, shrinkage decrease, opening to traffic at an earlier time, and a cooling of the city's core are. This technology received much consideration recently for applications in highway tenders. Several attempts worked on instill sustainable implementation in RCCP using alternate materials. This work presented a thorough review of the literature on alternative materials for RCCP published between 1997 and 2021. Recycled concrete and asphalt pavement aggregates are two examples of alternative materials to traditional quarry rock that have been studied. Critical evaluations of the mechanical properties of RCCP have been used to assess these alternative aggregates' potential. This article explains how the basic properties for the materials impact the RCCP's behavior. The results of a comprehensive study into utilizing the substitute aggregates in manufacturing RCCPs showed the best mix ratios for attaining long-term sustainability. Along with identifying potential future study topics. This research additionally indicates several knowledge gaps that can only be filled by further research and experimentation.

Keywords: Roller compacted concrete; Alternative aggregates; Recycled waste demolished materials

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تصنيع خرسانة مرصوصة بالحدل مستدامة تحتوي على مواد هدم المباني المعاد تدويرها: مراجعة ادبيات

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الخلاصة

أن تخفيض تكاليف دورة الحياة، وتقليل الانكماش ، وفتح حركة المرور في وقت مبكر، وتبريد قلب المدينة هي المزايا الرئيسية المرتبطة بتقنية الرصف الخرساني المضغوط اسطوانيا (RCCP) التي حظيت باهتمام كبير في العقود الاخيرة لاستخدامها في الطرق العامة. بذل الباحثون جهودًا في الماضي القريب لغرس الممارسات المستدامة في RCCP من خلال استخدام مواد بديلة. الدراسة الحالية هي مراجعة حديثة للدراسات المنشورة بين عامي 1997 و 2021 حول استخدام المواد البديلة لـ RCCP الركام البديل الذي تم استخدامه عبارة عن ركام خرساني معاد تدويره ، وركام رصف الأسفلت المعاد تدويره. تم تقييم إمكانات هذا الركام البديل بشكل نقدي بناءً على (محتوى الرطوبة الأمثل ، أقصى كثافة جافة) ، (قوة الانضغاط الميكانيكية ، قوة الانثناء ، قوة الشد الانقسام ، مقاومة التآكل) وخصائص المتانة (المسامية ، امتصاص الماء) ل RCCP وبالتالي ، تم أيضًا تلخيص الخصائص الأساسية لهذه المواد التي تؤثر على سلوك RCCP وطرق معالجتها. بناءً على المسح الشامل ، تم تحديد النسبة المثلى من هذه المواد البديلة لإنتاج RCCP المستدامة والإبلاغ عنها. يتم أيضًا تسليط الضوء على الفجوات المختلفة التي يجب سدها من خلال الفهم العلمي والميداني في هذه الورقة ، إلى جانب تحديد نطاقات البحث المستقبلية المحتملة .

الكلمات المفتاحية: الخرسانة المرصوصة بالحدل, الركام المعاد تدويره , مواد هدم المباني المعاد تدويرها.

1. INTRODUCTION

Due to its reduced expense and reduced building time, Roller-Compacted Concrete Pavement, also known as RCCP, became a popular substitute for the older style of jointed plain concrete pavements, or JPCP **(Harrington et al., 2010; Khayat and Libre, 2014; Aghaeipour and Madhkhan, 2020)**. The roller-compacted concrete pavement technique combines three distinct innovations: soil compaction, asphalt pavement, and concrete pavement **(ACI 327R, 2015).** Because it integrates the best features of asphalt, concrete, and soil technologies, One economical and easy-to-plan-and-build choice for pavement is roller-compacted concrete pavements **(Marchand and Gauthier, 2005; Harrington et al., 2010; Lee et al., 2014)**. The material components of roller-compacted concrete pavements are similar to Joint plain concrete pavement JPCP in their composition. The mixing operations are the most noticeable difference when comparing RCC with regular concrete. (**Abbas, 2022b**)., Soil compaction-mixed RCC has the same qualities as JPCP but uses more fine aggregates and less cement and water **(Harrington et al., 2010)**. Conversely, RCCP construction procedures resemble asphalt pavement engineering procedures. In Roller-compacted concrete pavements, asphalt paving stones are typically used for installation, and traditional vibratory drum or rubber-tired rollers are used for compression **(Harrington et al., 2010; Lee et al., 2014; Chhabra et al., 2021).** Figure 1 depicts the common apparatus and machinery used for mixing, placing, and condensing fresh roller-compacted concrete pavement mixtures. In general, roller compacted concrete pavements apply to both as a base course and a surface course; when employed as a base layer, Almost the same amount of cement is needed as for concrete and dry lean concretes but is frequently greater than what is essential for generating cement-treated base (**Yrjanson and Packard, 1980; Greene et al., 2011; Kasu et al., 2020; Singh et al., 2018b; Chhabra et al., 2021).** When RCCP is used as a surface layer, a greater compressive strength between 28-41 MPa at 28 days after water curing is often sought **(ACI 327R, 2014)**.

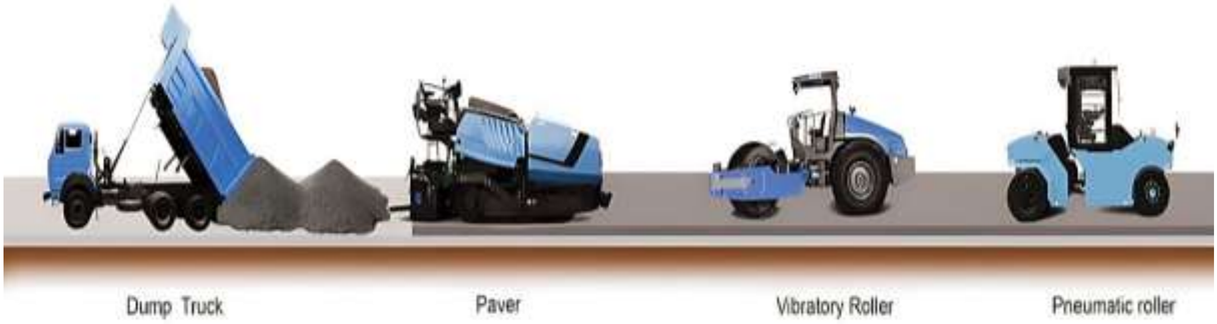

Figure 1. Equipment used for RCCP construction **(Selvam et al., 2022)**

Several environmental problems have emerged as a result of the world's growing trash output **(Abbas et al., 2022)**. Reducing the use of nonrenewable resources has been the primary focus of efforts to integrate sustainability into the roadway business in recent years **(Abbas, 2022a)**. A more sustainable pavement could be achieved by optimal mix design, innovative paving processes, and a decrease in the demand for virgin materials **(Mashnad and Sobhan, 2001; Chan et al., 2011; Mohammed et al., 2021)**. You can use recycled materials as an alternative to virgin ones, or even all of them. One of the public substitute aggregates for RCCP is recycled concrete aggregates (RCA), mixed recycled concrete aggregates (MRCA), and reclaimed asphalt pavement (RAP). Using these recycled aggregates has many aids, such as lessing carbon emissions, dealing with solid waste disposal problems, saving money on transportation costs related to original materials, and lessing the price of aggregates obtained from nature **(Shi et al., 2018; Piao et al., 2021)**.

Nevertheless, there are limitations on efficiently using aggregates of recycled materials. For example, RCA has a layer of adhered porous old mortar, which may decrease strength **(Safiuddin et al., 2013)**. Similarly, it has been found that the energy of interfacial bonding between cement-mortar paste and asphalt-coated RAP aggregates is significantly lower, resulting in significant strength reductions **(Brand and Roesler**, **2017; Brand and Roesler, 2017)**. RAP cross-recycling is a widespread practice today. Despite being used again in asphalt pavements, not every RAP is recyclable. By 2015, US contractors had reported 88% (nearly 85.1 million tons) of excess RAP **(Shi et al., 2018)**.

Consequently, correct waste disposal and/or the efficient use of these extras RAP in concrete pavements are frequently appreciated. **(Singh et al., 2020c)** noted that RAP might be applied to both types of pavement (concrete and bituminous); however, the optimal proportion of RAP must be determined according to the fresh and the target mix's hardened state behavior. Despite reductions in strength, using RAP in concrete has multiple advantages, including increased ductility, cracking resistance, and greater impact resilience than regular concrete **(Brand and Roesler, 2017; Shi et al., 2019; Piao et al., 2021)**.

This work investigates the suitability of RCCP mixes for roads utilizing different waste materials.

2. CHARACTERIZATION OF ALTERNATIVE AGGREGATES

As demand for construction materials rises, there is a tremendous need to use alternative materials for sustainable development **(Abbas, 2022)**. According to the characteristics of the primary source, the morphological and mechanical properties of different aggregates can be different. This means they must be mapped carefully and connected to how well the concrete turns out. For example, the primary components of construction and demolition (C&D) waste are RCA and RAP, which are very different, **Table 1.** RCA is derived from demolishing concrete structures and is typical. The aggregates are covered with an old mortar layer with a rough surface that sticks together **(Tu et al., 2006)**. Like mixed recycled concrete aggregates containing a higher portion of ceramic particles and a porous adhered old mortar layer, it needs more water to absorb **(Lopez-Uceda et al., 2020)**.

Table 1. The physical characteristics and composition of recycled aggregates

Aggregate Type	Asphalt content (%)	Mortars and concrete (%)	Specific gravity	Water absorption	References
RCA	1.3	71	2.51	4.69	**(Lopez-Uceda et al., 2018)**
	1.7	59	2.22	6.1	**(Lopez-Uceda et al., 2020)**
	-	-	2.19	7.63	**(Fardin and Santos, 2020)**
Mixed RCA	1.5-1.1	51-55	2.08-2.16	7.4-9.2	**(Lopez-Uceda et al., 2020)**
Fine RAP	-	-	1.8	0.91	**(Settari et al., 2015)**
	-	-	2.27	1.4	**(Fakhri and Amoosoltani, 2017)**
	4.5	-	2.35	2.35	**(Debbarma et al., 2019b)**
Coarse RAP	-	-	2.14-2.3	0.7-1	**(Settari et al., 2015)**
	1.9	-	2.41	0.40	**(Debbarma et al., 2019b)**

In contrast, Recycled asphalt pavement (RAP) is the result of destroying previous structures, dilapidated bituminous/asphalt roads; it consists of aggregates coated in a thin layer of asphalt that is both smooth and hydrophobic **(Shi et al., 2017; Dubey et al., 2020)**. The percentage of residual mortar found in RCAs typically falls somewhere between 30 and 60 percent, and their specific gravities usually fall somewhere between 2.1 and 2.5 **(Safiuddin et al., 2013)**. Recycled asphalt pavement has a ratio of asphalt from 2% to 7.5% by weight, with the rough fraction naturally with a specific gravity of 1.8-2.4 and the finer fraction of 2.1-2.6 **(Singh et al., 2018a; Debbarma et al., 2020).** In contrast to aggregates found in nature, RCA usually has a higher absorption because of the ones that stick to porous mortar. Recycled asphalt pavements (RAP) have a hydrophobic covering that limits how much water they can absorb. However, because of their high capacity to absorb water, Recycled asphalt pavements (RAP) may be more significant if the material was extracted using an uncontrolled milling method, which results in the production of external water-soaking dust contaminants **(Brand and Roesler, 2017; Singh et al., 2018a)**.

3. THE EFFECT OF DIFFERENT AGGREGATES ON THE PROPERTIES OF THE RCCP

3.1 Fresh Properties

3.1.1 Optimum Moisture Content (OMC)

RCCP mixes must be packed down with static/vibratory rollers developed using the soil compaction method; moisture content (OMC) must be suitable for attaining Maximum Dry Density (MDD). According to ASTM D1557 **(ASTM D1557, 2012)**, a modified proctor method is used. This technique is used to ascertain the OMC of RCCP blends whenever possible. However, the standard proctor method, as per ASTM D698, could be used if the aggregates are weak **(Harrington et al., 2010)**. Since the Superpave gyratory compactor can more accurately replicate field compaction conditions in the lab, it has been used by some researchers to ascertain the OMC and to prepare laboratory specimens **(Amer et al., 2004; LaHucik and Roesler, 2017)**. When using natural aggregates, the OMC of RCCP mixes is typically between 5 and 8 % (by mass) of the total dry materials **(Harrington et al., 2010)**. But when RCA is used in a 5-30% proportion, the OMC is typically higher by about 1.6-5.1% **(Fardin and dos Santos, 2020).** At higher levels of RCA replacement, 50-100%, the OMC increase could be much higher, about 25-35% higher than the standard RCCP. **(Lopez-Uceda et al., 2018).** Old mortar stuck to the RCA absorbs more water, contributing to the OMC's rise **(Ashteyat et al., 2022)**. The fresh properties may also be significantly affected by the RCA's composition. A 35-53% increase in OMC has been associated with MRCA from mixed C&D waste **(Lopez-Uceda et al., 2020).** One possible explanation is that the mixed RCA contains more ceramic waste (11.4-23.4%), calling for additional water to attain optimal density **(Lopez-Uceda et al., 2020).** RCA's higher water absorption capacities have been observed in the literature to cause an increase in OMC values when incorporated into a material. A range of OMC from 1.6% to 34.5% has been established for RCA when using alternative aggregates.

3.1.2 Maximum Dry Density MDD

RCA could decrease MDD because it has a lower specific gravity. On the other hand, the percentage of variation in the slope of the OMC-MDD chart of the RCA-RCCP mix may be flatter than the control Roller Compacted Concrete Pavements (RCCP). This means that RCA-RCCP mixes are more resilient to variations in water content during compaction without sacrificing dry density than control mixes **(Settari et al., 2015).** Similar to RCA, the implementation of low-density RAP has been documented to decrease the MDD of RCCP mixtures by approximately 5 percent **(Mohammed and Adamu, 2018; Debbarma et al., 2019b; Debbarma et al., 2019a)**. Still, adding RAP makes the material easier to work with and pack down. The asphalt layer acts as a lubricant, and RAP aggregates are not as sharp as new aggregates **(Modarres and Hosseini, 2014)**. No matter what alternative aggregates were used in (RCCP) mixes. It was found that there wasn't much difference in MDDs. Therefore, it demonstrates this alternative aggregates' potential, as the hardened strength of RCCP is directly proportional to the fullest fresh mix compactness. The impacts of various aggregates on the reactivity and freshness of RCCP mixes are described in **Table 2**.

Table 2. Literature **s**ummary that demonstrates how different aggregates affect new RCCP properties.

Aggregate type	Percentage of replacement (%)	Difference in Optimum moistur content (%)	Difference in dry density (%)	References
RCA	5, 15, and 30	1.6, 3.2, and 5.1	0.8, 4.5, and 4.6	**(Fardin and Santos, 2020)**
	50 and 100	8.3 to 30	2.2 to 4.7	**(Lopez-Uceda et al., 2018)**
	100	17 to 35	1.8 to 3.1	**(Lopez-Uceda et al., 2020)**
Mixed RCA	100	7 to 8	3 to 4	**(Lopez-Uceda et al., 2020)**
RAP	0 and 100	8.4 to 11.8	3.2 to 5.4	**(Modarres and Hosseini, 2014)**
	16	10	0.2	**(Ferrebee et al., 2014)**
	20, 30, 40, 60 and 100	1.8, 3.6, 4.5, 5.9 and 7.1	1.7, 2.6, 3.3, 5.8, and 7.7	**(Mohammed and Adamu, 2018)**
	100 coarse RAP	3.3 to 11.1	2.6 to 4.3	**(Settari et al., 2015)**
	100 coarse RAP	2.1	2.5	**(Debbarma et al., 2019b)**
	50 and 100	3.3 and 9.8	0.9 and 2.1	**(Debbarma et al., 2019a)**
	50 total RAP	4.1	3.8	**(Debbarma et al., 2019 b)**
	100 total RAP	4.1 to 10	5 to 8	**(Settari et al., 2015)**

3.2 Mechanical Properties

Crucial mechanical characteristics of RCCP, including its compressive strength, flexural strength, and split tensile strength, are examined concerning the impact of different aggregates on these properties. The thickness design of RCCP is primarily determined by its compressive and flexural strengths, with recommended limits from several governing institutions listed in **Table 3**.

3.2.1 Compressive Strength

The alternative aggregates to RCCP mixtures have the potential to significantly modify their ultimate compressive strength because of their complex composition. Compressive strength in RCCP mixes may be reduced by 35% when RCA is used. Roughly 29% reduction in compressive strength is reported as 30% RCA is used **(Fardin and Santos, 2020)**. Concurrently, a reduction in strength by 35% is recorded as RCA is completely replaced **(Lopez-Uceda et al., 2018)**. It is observed a weak compressive strength of the conventional adhering mortar surrounding RCAs. In the new cement mortar combination a smaller Interfacial Transition Zone (ITZ) has been resulted **(Tavakoli et al., 2020; Lopez-Uceda et al., 2020; Hosseinnezhad et al., 2021)**. Previous works reported that using mixed RCA is accompanied with 24-31%, compared to a 12-18% decrease in compressive strength as RCA from an unmixed source is utilized **(Lopez-Uceda et al., 2020).** Masonry, which generally reduces compressive strength, may be a sign of this **(Xuan et al., 2012)**. RAP will likely cause RCCP mixtures' compressive strength to decrease, just like RCA did. Reducing compressive strength by 9–67% is possible when using RAP in RCP mixtures, and this is true independent of the RAP portions used **(Xuan et al., 2012; Modarres and Hosseini, 2014; Settari et al., 2015; Fakhri and Amoosoltani, 2017; Debbarma et al., 2019b)**.

Table 3. Recommendations for RCCP strength at 28 days of curing

Standards	Recommended strength		Country of origin
	Compressive Strength (MPa)	Flexural strength (MPa)	
ACI 327	28 to 41	3.5 to 7	USA
Portland Cement Association	27.6 to 68.9	3.4 to 6.9	USA
American Concrete Pavement Association	28 (If no freeze and thaw) 31 (If exposed to freeze and thaw)	-	USA
British Airport Authority	-	4	British
France	20	-	France

A coating of asphalt over the RAP explains this decline. The presence of this layer hinders the interfacial bond between the cement mortar and RAP particles. Despite this, using a rough portion of RAP could only affect a smaller loss of strength of approximately 25%. In the meantime, it is possible to anticipate reductions of approximately 40–60% when utilizing finer and/or combined fractions of recycled asphalt pavement aggregates **(Modarres and Hosseini, 2014; Debbarma et al., 2019b)**. It has been determined that adding RCA or RAP to RCCP will decrease the material's compressive strength **(Lam et al., 2017; Lam et al., 2018)**.

3.2.2 Flexural Strength

The flexural strength of cement concrete pavements is an essential mix design and pavement design parameter. The water-cement ratio and the aggregates' overall grade distribution are the most influential factors in the flexural behavior of concrete pavements. Similar to compressive strength, the addition of RCA has a negative effect on the flexural strength of RCCP mixtures by approximately 12-27%, regardless of the RCA fraction and/or replacement levels **(Lopez-Uceda et al., 2018; Fardin and Santos, 2020; Khalid and Abbas, 2023)**. Higher porosity in the ITZ is caused by the poor area where the cement mortar and RCA meet, which in turn decreases the flexural strength.

Flexural strength in RCCP mixes may decrease by about 5-31% when RAP is used as a replacement for some of the natural aggregates **(Fakhri and Amoosoltani, 2017; Debbarma et al., 2019b; Debbarma et al., 2019a; Modarres and Hosseini, 2014)**. However, coarse RAP uses a smaller reduction in flexural strength when compared to fine and/or combined RAP fractions **(Debbarma et al., 2019a; Modarres and Hosseini, 2014)**. This is because coarse RAP fractions have a lower asphalt concentration (1.9%) than fine and/or combined RAP parts (4.5%). However, the presence of the layer of asphalt encapsulating the RAP will significantly reduce its flexural strength because of inadequate cement mortar and RAP interfacial bond strength. In contrast, the viscoelastic nature of asphalt may help strengthen RCCP mixes **(Fakhri and Amoosoltani, 2017)** if an asphalt layer is present. Consequently, utilizing RAP could enhance the load-bearing capacity of RCCP if a thicker slab is used to compensate for the decrease in flexural strength. **(Debbarma and Ransinchung, 2020b)**. As a result of this analysis, it was possible to deduce that the overall trend in RCCP combinations that contain alternative aggregates is a drop in compressive strength. The current authors determine the correlations between the flexural and compressive strengths of RCCP mixes with various aggregates. These mixes were created using a variety of different aggregates.

3.2.3 Split Tensile Strength

It is shown that when using a larger granularity of RCA at a proportion of 100%, about 18% of the split tensile strength is lost when RCCP mixes are used **(Lopez-Uceda et al., 2020)**. The deformation resistance of the cement mortar and RCA particles was lower than predicted before the limit split tensile strength was reached. This was caused by insufficient interfacial bonding. In addition, about 23% of the divided tensile strength is lost when ceramic wastes are added to RCA-RCCP mixes **(Settari et al., 2015)**. Also, adding RAP decreases the split tensile strength of RCCP mixes, no matter how long they have been cured **(Modarres and Hosseini, 2014; Ferrebee et al., 2014; Settari et al., 2015; Debbarma et al., 2019a)**. One study indicated that adding 16% coarse RAP to split tensile strength reduced it by around 16% **(Ferrebee et al., 2014)**. A similar 26% reduction was observed when 100% coarse RAP was utilized **(Settari et al., 2015)**. The asphalt layer surrounding the RAP makes it harder for an excellent bond to form between the cement mortar and the RAP aggregates, which lowers the strength of the concrete. Adding RCA and RAP could cause the split tensile strength to go down. More lab studies could help determine how these waste products affect the RCCP mixture's split tensile strength.

3.3 Durability Properties

3.3.1 Porosity

Porosity is an essential characteristic that affects everything that makes cement concrete mixes last for a long time. Higher porosity usually means that there are more voids in the concrete system. More voids suggest that foreign contaminants can get in, which could cause serious problems with durability. RCCP mixes could have a porosity as low as 4% or as high as 19% **(Debbarma and Ransinchung, 2020b)**. However, RCCP mixes' porosity can change noticeably due to incorporating different aggregates. For instance, it has been documented that increasing the amount of RCA replacement results in a corresponding increase in porosity. Researchers found that using 50% and 100% coarse RCA led to a 28% and 46% increase in porosity, respectively **(Lopez-Uceda et al., 2020)**. Inadequate cement mortar–RCA interfacial bonding occurs because of old mortar surrounding the RCA building, leading to increased porosity in the interfacial region.

More water is needed in the fresh mix because of the RCA's high water absorption, which results in a porous, interconnected structure and increased porosity in the hardened concrete. Several researches on conventional concrete have demonstrated that the appearance of particles that have accumulated in RAP and porous ITZ increases the porosity of the concrete matrix. **(Brand and Roesler, 2017; Abraham and Ransinchung, 2018; Singh et al., 2018c)**. On the other hand, it was found that using RAP decreased the porosity of RCCP by 20–48%, no matter how much RAP was used or how much was replaced **(Debbarma et al., 2019 b; Lopez-Uceda et al., 2020)**. This reduction was achieved because asphalt softened and pores became clogged while in the drying oven and the boiling phase of the ASTM C642 procedure (**Tam et al., 2005**). By extending the drying time to 8 days and lowering the drying temperature to 48.2 °C, respectively, It is possible to prevent asphalt from melting during the oven-drying period and pores from getting clogged up **(Tam et al., 2005**). It is clear from reading the existing literature that the impact of aggregate type on RCCP mix porosity has not been thoroughly investigated. Additional research is necessary to fully comprehend the effects of different aggregates on how long RCCP mixes last.

3.3.2 Water Absorption

The aggregates used also affect the water absorption of RCCP mixtures. However, there is limited data on this topic. **(Debbarma et al., 2019b)** found that RAP's lower water absorption allowed for a 20-42% reduction in RCCP's water needs, and regardless of the RAP ratio or degree of replacement, this effect persisted. They also found that more closely packed particles could make them soak up more water by around 19%. When mixed with RAP particles, they may make tiny spaces holding water. This makes the concrete system better at absorbing water. Also, more water may be absorbed by the finer fraction of RAP if it contains external dust contaminants. In contrast, the coarser fractions of RAP may absorb less water but less water than a mix with only natural aggregates **(Debbarma et al., 2019b).** It makes sense that few studies look at how different aggregates affect how much water RCCP mixes can absorb. Also, as far as the author knows, there is no study about how RCA and EAFSS-RCCP mix absorb water.

4. STRENGTH OF RCCP WITH ALTERNATIVE AGGREGATES AND RELATED FACTORS

4.1 Recycled Concrete Aggregates

The mixing water percentage is the most influential factor in RCA's strength properties, the proportion of water to the binder, how strong the old paste was, saturation level and water absorption rate of RCA, and the ITZ between the RCA and the mortar **(Safiuddin et al., 2013; Leite and Monteiro, 2016; Shi et al., 2020)**. Old ITZ, new ITZ between old and new mortar, and ITZ between uncoated RCA and new mortar are the three types of ITZ found in RCA concrete. Because of its porous nature, old ITZ significantly weakens the effect of RCA concrete. Which facilitates the development of cracks **(Otsuki et al., 2003)**. In contrast, the new ITZ controls how well RCA concrete performs in terms of strength; otherwise, no change in strength was reported for RCA-RCCP. This could be because the density of the old, porous ITZ is too high for the moisture products to make up for, and most of RCCP's load-carrying capacity comes from how the rocks fit together. Despite the new ITZ's ability to govern strength performance, the old ITZ's failure prevents any strength improvement, leading to weaker RCA-RCCP mixes.

Additionally, the strength of RCA-RCCP mixes is greatly affected by the RCA replacement level and w/c ratio. For example, **(Lopez-Uceda et al., 2018)** made it clear that because of the high water absorption of RCA, the w/c ratio increases as RCA content rises. Because RCA's increased pore volume affects the porosity, strength, and transport properties (water absorption, permeability, etc.) as the RCA content rises. The curing time used to produce RCA concrete's hardened state further influences its strength. **(Lopez-Uceda et al., 2018)** found that mixes containing RCA completely or partially replaced virgin aggregates in increasing compressive strength between 28 and 90 days. The mortar in the ITZ may enhanced its ability to retain extra bricks over time, that could clarify this phenomenon. Hardened concrete strength is significantly affected by the cement content of the RCA-RCCP mixture. RCA-RCCP mix with 110 kg/m^3 of cement has a compressive strength of around 4.5-5.7 MPa, which is very low. **(Lopez-Uceda et al., 2018)** found that RCAs varied in composition and curing times. They reported a raising in compressive strength from 18.2-22.2 MPa to 27.6-40.6 MPa as the cement content is raised from 175 to 350 kg/m^3 in RCA concrete.

4.2 Recycled Asphalt Pavement Aggregates

The strength properties of RAP concrete mixtures are affected mainly by the weak and porous interfacial transition zones (ITZs) that exist between the RAP and the cement-mortar paste **(Mukhopadhyay and Shi, 2016; Debbarma and Ransinchung, 2020a)**. Because asphalt is viscoelastic, the split extends through the asphalt instead of going through the gravel. **(Huang et al., 2005)**. So, it is more common for RAP concrete mixes to fail due to asphalt cohesion than cement-asphalt adhesion **(Brand and Roesler, 2017)**. The strength of RAP-RCCP mixes is affected by how old the RAP is, how much asphalt and agglomerated particles are in it, how much RAP is used, and how big the aggregates are. **(Debbarma et al., 2019a)** found that upon the RAP fraction used less-oxidized RAP could result in a significant decrease in strength of between 26% and 67%. However, only a 9-37% decrease in compressive strength is seen when highly oxidized RAP is used **(Debbarma et al., 2019b)**. The mechanical strength will decrease proportionally to the asphalt concentration and vice versa. The RAP's strength can be drastically weakened by the higher asphalt concentration of the finer fraction **(Modarres and Hosseini, 2014)**. Results showed that coarse RAP, with its lower asphalt concentration, had a less negative effect than the finer and combined RAP fractions **(Modarres and Hosseini, 2014; Debbarma et al., 2019a)**. Higher concentrations of agglomerated particles are typically undesirable because they can lead to water voids when smaller RAP fractions agglomerate. These water gaps are not only fragile locations that can be broken easily by physical forces but can also negatively impact transport properties. Besides, the performance of RCCP mixes is also affected by how the RAP particles are spread out in size. For example, RAP crushed in a managed fashion may generate gap-graded fine RAP aggregates, which may lead to difficulties with workability. On the other hand, a full-depth reclamation method can yield relatively well-graded RAP aggregates, leading to better-performing concrete **(Debbarma et al., 2019a)**. However, since this generates so much dust, it may not be environmentally friendly, which could alter the properties of the concrete. Six compressive strengths of RAP-combined RCCP mixes were reported to be increased by increasing the cementitious content **(Fakhri and Amoosoltani, 2017)**.

5. CONCLUSIONS

Alternative aggregates and mineral admixtures appear to have significant potential for maximizing the economic and environmental benefits of RCCP applications. Through recycling, these unwanted materials can be reused into fresh concrete. Considerable cost savings can be realized. In this study, characteristic features of RCCP mixes made with different aggregates and binders were carefully looked at, it can be concluded that:

- Most RAP aggregates have a low-density, smooth, hydrophobic asphalt coating around them. This coating could reduce the OMC and MDD of RCCP mixes. The asphalt coating on this film could make it harder for RAP to stick together with cement-mortar paste, making it weaker. While agglomerates and dust may have the reverse impact, RAP's water-repellent characteristics can help decrease water absorption and porosity. You can utilize 50% RAP in pavement applications, and it won't significantly impact strength, porosity, or water absorption. However, although increased RAP content might not be mechanically practical, it could enhance pavements' tensile strength and energy absorption.

• The quality of the source significantly impacts how RCA behaves. Mixed RCA may lack quality and/or value compared to RCA obtained from pure hunks of concrete material. Most RCA has been coated in a thin layer of stuck mortar, which is extremely permeable and may degrade its initial state and hardened properties of RCCP. However, using 50% RCA instead of the usual coarse aggregates could make the road pavement base strong enough to use. The percentage of RCA for RCCP would rise with the help of physicochemical and physicomechanical therapies.

The above conclusion from the literature review shows that RCCP could use different types of aggregate without losing strength. Also, using waste materials in RCCP could have several benefits, such as reducing greenhouse gas emissions and global warming, lowering the need for natural aggregates, preserving valuable land resources, lowering transportation costs, and delivering economic construction.

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