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Impact of Recycled Concrete Aggregate on Abrasion Resistance of Concrete Pavement

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ABSTRACT: The most popular building material in the world is concrete, which contains 60–80% natural aggregates by volume. The limited non-renewable resources are being strained by the growing demand for concrete structures and infrastructure development. Therefore, it is imperative that the construction industry develop sustainable sources, like recycled aggregates, to lessen its impact on the environment and conserve non-renewable resources. Substituting recycled aggregates for natural aggregates in concrete not only provides a sustainable solution to these issues but can also lower construction costs. Recycled Concrete Aggregate (RCA) is made by crushing concrete parts of construction waste and differs from Natural Coarse Aggregate (NCA) as it is less uniform in its properties. For pavement concrete, it's crucial that the material is strong and can withstand surface wear from traffic. This study explores how substituting NCA with RCA in concrete for pavements affects its performance. We tested two different mix series, each with specific water-to-cement ratios of 0.44 and 0.38. The findings indicate that while RCA can decrease the concrete's resistance to wear, it can still be used effectively in pavement concrete.

KEYWORDS: Concrete Recycled aggregate, Construction waste, Abrasion resistance, Pavement

I. INTRODUCTION

Concrete is among the most extensively utilized construction materials worldwide, playing a crucial role in the development of infrastructure, including roads, bridges, and both residential and commercial buildings. This man-made stone derives its strength from the chemical interactions between cement and water, which effectively bind the aggregates. Traditionally, these aggregates, consisting of both fine and coarse particles, have been obtained from natural sources like sand, gravel, and crushed stone. However, the rising global demand for infrastructure has led to an increased need for construction aggregates, resulting in unsustainable extraction practices. This heightened demand contributes to the depletion of natural resources, raising important concerns regarding the long-term viability of natural aggregate extraction. The processes of mining, processing, and transporting aggregates demand substantial energy, leading to increased greenhouse gas emissions, air pollution, and damage to ecosystems. Therefore, it is essential to explore sustainable alternatives to conventional aggregates to reduce environmental impact.

The extraction of traditional aggregates poses significant environmental challenges that extend beyond simple resource depletion. The production of aggregates is highly energy-intensive, which worsens environmental impacts. The reliance on natural aggregates in the construction industry raises important sustainability concerns, especially as urbanization accelerates in developing countries. Therefore, it is crucial to explore sustainable alternatives to traditional aggregates, with recycled concrete aggregate (RCA) emerging as a promising option.

Recycled Concrete Aggregate (RCA) is derived from construction and demolition waste (CDW), a byproduct of the construction industry that includes materials from demolished buildings, old roads, bridges, and other structures. RCA is produced by crushing old concrete into smaller pieces, which can then be used as a substitute for natural aggregates in new concrete. This process not only reduces the amount of waste sent to landfills but also conserves natural resources by substituting a portion of Natural aggregate with recycled material. Abrasion resistance is a critical property of concrete pavements, as it affects their ability to withstand wear and tear caused by vehicular traffic. Concrete pavements must maintain a smooth and intact surface to ensure safe driving conditions and reduce the need for frequent maintenance. Abrasion resistance is influenced by factors such as aggregate hardness, concrete strength, curing methods, and surface finishing techniques. Aggregates with high hardness and durability contribute significantly to a pavement's abrasion resistance.

Studies on RCA's impact on concrete properties, particularly abrasion resistance, have yielded mixed results. Research by Ajdukiewicz et al. (2022) shown that RCA's influence on concrete performance depends on factors such as the quality of the original concrete, the extent of residual mortar, and the treatment methods applied to RCA. Thomas et al. (2022) and Zhang et al. (2021) found that higher RCA content in concrete generally results in reduced abrasion resistance. However, they also noted that incorporating certain admixtures, like fly ash or silica fume, could partially offset this reduction.

Other studies have investigated different methods to enhance RCA's abrasion resistance. Chen et al. (2023) explored the addition of mineral admixtures to improve the microstructure of RCA concrete, finding that these materials can enhance RCA concrete's abrasion resistance by reducing voids and increasing density. Wang et al. (2022) also demonstrated that these pretreatment techniques can enhance RCA quality, resulting in concrete with improved strength and durability. Pretreatment methods aim to improve RCA's surface properties and reduce water absorption, allowing it to bond more effectively with the surrounding cement paste in concrete. By removing loose or porous mortar, pre-treatment can enhance RCA's strength and durability, making it more suitable.

Huang & Liu (2022) have studied the effects of supplementary cementitious materials (SCMs) like fly ash, silica fume, and slag on RCA concrete. SCMs can improve RCA concrete's durability and abrasion resistance by filling voids and refining the microstructure. These materials act as fillers and pozzolans, reacting with the cement paste to produce a denser and more durable concrete matrix. Adding fibers such as steel, polypropylene, or synthetic fibers to RCA concrete can help distribute stresses more evenly throughout the concrete matrix. Tan & Zhang (2022) have shown that fiber-reinforced RCA concrete can achieve higher abrasion resistance and better durability than conventional RCA concrete. Fibers provide additional strength to the concrete matrix, improving its resistance to dynamic loads and surface wear. The purpose of this study is to examine the abrasion resistance of concrete that contains RCA that is derived from the CDW. With an emphasis on mix design optimisation for long-lasting and sustainable concrete pavements, this study attempts to further explore the impact of recycled aggregate on abrasion resistance. The effects of substituting RCA for NCA in the 10–20 mm and 4.75–20 mm size ranges on the abrasion resistance and strength of pavement concrete mixes are analysed.

II. LITERATURE REVIEW

Kumar et al. (2022) focused on the effect of recycled aggregate quality on the performance of concrete. The study revealed that recycled aggregates from high-quality sources contribute to better abrasion resistance in concrete. Singh & Patel (2024) discovered that aggregates from different sources varied in terms of porosity and mortar content, resulting in varying abrasion resistance in concrete. Park et al. (2023) optimized cement content in recycled aggregate concrete to improve abrasion resistance. Their findings showed that a higher cement content can compensate for the reduced strength of recycled aggregates, resulting in a concrete mix with better abrasion performance. Ahmed & Ali (2021) investigated the influence of water-cement ratio on the durability of recycled aggregate concrete, particularly focusing on abrasion resistance. They found that a lower water-cement ratio enhances the concrete's durability by reducing porosity. Tan & Zhang (2022) investigated the combined effects of fiber reinforcement and recycled aggregates on concrete performance. They concluded that fibers counteract the reduction in abrasion resistance caused by recycled aggregates, making the concrete more resistant to surface wear. This study highlights the synergistic effects of fibers and recycled aggregates, offering a potential solution for producing durable concrete pavements with recycled materials.

Li et al. (2021) studied the surface wear performance of recycled aggregate concrete, focusing on factors like aggregate content and cement paste quality. Their results indicated that abrasion resistance can be significantly influenced by the mix design, with higher cement quality leading to better performance. The study emphasizes that controlling mix composition is essential to achieve abrasion-resistant recycled aggregate concrete. Patel et al. (2023) examined the durability of recycled aggregate concrete for pavement applications, with a specific focus on abrasion resistance. They concluded that while recycled aggregates may reduce durability compared to Natural aggregates, appropriate mix modifications and supplementary materials can achieve satisfactory performance.

Firuzi et al. (2024) demonstrated that the addition of 10% fly ash and 5%, 10%, and 15% fine-grained recycled materials increased the compressive strength by 20%, 12%, and 4%, the bending strength by an average of 10%, and the tensile strength by an average of roughly 40% when compared to the control sample. However, the abrasion resistance of all samples containing recycled asphalt has significantly decreased. Since the abrasion of concrete pavements containing limestone aggregate is concerning, Yoshitake et al. (2014) looked into it. Fly ash concrete was used in place of 40% of the cement mass to create the recyclable concrete. For early adequate strength, a water/cementitious material ratio of 0.33 was used to mix limestone rock fine and coarse aggregates into the concrete.

III. MATERIALS & METHODOLOGY

3.1 Materials

The study explores the efficacy of both natural & recycled aggregates in concrete production. The primary binder used was ordinary Portland cement, complemented by crushed quartzite aggregates available in sizes ranging from 4.75 mm - 20 mm. The fine aggregates included land quarried sand, which was characterized for its gradation, water absorption, specific gravity, and bulk density measured respectively as 1.0%, 2.65, and 1600 kg/m^3.

In essence, recycled aggregate concrete (RAC) is a concrete mix made from crushed aggregates & concrete that has previously been utilised in building projects. For comparative purposes, natural crushed quartzite aggregate of similar size ranges (4.75–10 mm and 10–20 mm) was also assessed. Both types of aggregates were evaluated following the relevant Indian Standards to verify their suitability and to compare their gradation. The study found that RCA in the 4.75–10 mm range was significantly finer compared to the natural coarse aggregate (NCA), as indicated in the data presented in Table 6. The sieve analysis revealed that the RCA in the 10 to 20 mm range closely matched the gradation of the NCA, as shown in Table 6. However, the 4.75–10 mm RCA contained about 27% of particles finer than 4.75 mm, necessitating the use of a 3 mm wire net for screening before incorporating this aggregate size into the pavement concrete. This step was crucial to ensure that the RCA would perform adequately within the concrete mix and meet the required standards for pavement construction.

3.2 Mix proportions

It is commonly known that the properties of the pavement concrete surface layer, including abrasion resistance, are influenced by the cement content, water-to-cementitious materials ratio, slump, air content, type of finish, and curing. Two sets of concrete mixtures were made, each of which included 100% RCA, or the replacement of NCA by RCA, in the size range of 10–20 mm, or 4.75 mm–20 mm. Additionally, a control mix made entirely of NCA (100%) was made. On a mass-to-mass basis, RCA took the place of NCA. Set A mixes maintained a free water-to-cement ratio of 0.44, whereas Set B mixes maintained a ratio of 0.38. For Set A and Set B concrete mixes, the mass proportions of the cement, sand, coarse aggregate, water-to-cement ratio, and Water Reducing Agent were 1:2.1:3.86:0.44: 0.0067 and 1: 1.84: 3.26: 0.38: 0.0063, respectively. Table 1 shows the mix details and mix designations.

Table 1 Mix labels and coarse aggregate information.

Mix	**Details**	
M30	NCA 100% (4.75–20 mm)	Set A,
M31	RCA replaced NCA in the 10–20 mm size range.	w/c = 0.44
M32	100% RCA (4.75–20 mm)	
M40	NCA 100% (4.75–20 mm)	Set B,
M41	RCA replaced NCA in the 10–20 mm size range.	w/c = 0.38
M42	100% RCA (4.75–20 mm)	

3.8 Slump & density of concrete

To find out how using recycled concrete aggregate (RCA) in place of natural aggregates impacts the concrete's fresh qualities, tests were conducted on the slump and fresh density of concrete mixes. Concrete slump tests, also known as slump cone tests, are used to assess the consistency or workability of concrete mixes made in labs or on construction sites as work is being done. To ensure that the concrete is of consistent quality throughout construction, concrete slump tests are conducted from batch to batch. The slump is performed in accordance with the protocols outlined in IS: 1199-1959 in India. During the test, the specimen's slump (or vertical settlement) will be measured and recorded in millimetres. To measure the average fresh density, the weight of the concrete that was filled & compacted into molds of known volume (such as cubes and beams) was calculated. This method helps determine how densely the various components of the concrete are packed, which is indicative of the concrete's potential load-bearing capacity and overall performance. By analyzing these properties, researchers can assess the feasibility of using RCA as a sustainable alternative to natural aggregates in concrete production. The weight of a given volume of concrete is measured by its density.

3.9 Abrasion Resistance Test

Heavy traffic on the road causes abrasion, which makes concrete pavement more likely to deteriorate. The ability of a concrete surface to withstand deterioration due to abrasive force actions, such as rubbing, cutting, sliding, and impact forces, is known as abrasion resistance. In this study, we tested how well the concrete can withstand wear and tear by using a method called sand blasting, which follows the guidelines set out in Indian Standard IS: 9284-1993. The sand blasting test method is a procedure used to determine the abrasion resistance of concrete surfaces. This method tests the concrete's ability to resist wear by blasting it with silica sand from an air gun. A concrete specimen is prepared according to standard dimensions (e.g., 300 mm x 300 mm) and cured for a minimum of 28 days to attain the necessary strength. The surface of the specimen is then cleaned to remove any dust, debris, or loose particles. The silica sand used was specially sized to be between 0.50 mm and 1.00 mm. During the test, a total of 4000 grams of this sand was shot at the concrete cube at a pressure of 0.14 N/mm². We measured the cube's abrasion loss by weighing it after it got hit by the sand twice on the same side. This weight loss tells us how much of the concrete was worn away by the sand.

IV. RESULTS & DISCUSSION

4.1 Results

This study is carried out to identify the abrasion properties concrete pavement having recycled aggregates and natural aggregates. The water absorption and composition of recycled concrete aggregates are shown in table 2 below. The table represent the different types of aggregates their mass and the water absorbed by these aggregates.

Table 2: Water absorption and composition of RCA components

Types	**Mass (%)**	**Absorption of water (%)**
Mable	0.41	Negligible
Brick	0.40	14.7
Sand stone (Red)	3.2	Negligible
Aggregate adhered with mortar	5.5	7.6
Concrete aggregate	85.92	0.29
Cement Mortar	4.41	16.92

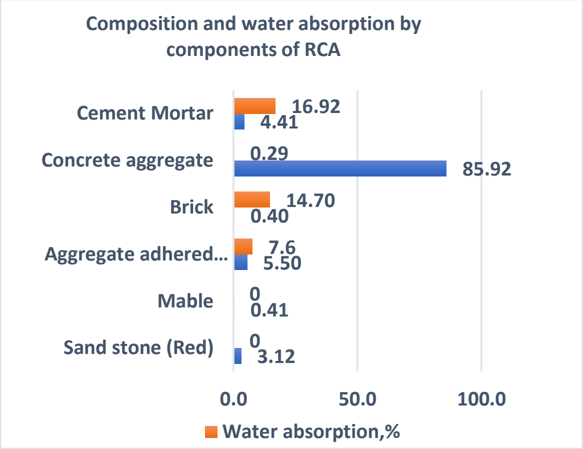


Fig 1: Water absorption and composition of RCA components

The figure 1 represent the composition & water absorption by RCA. Concrete aggregate dominates the composition, making up 85.92% by mass with a very low water absorption rate of 0.29%, which indicates its minimal propensity to retain moisture. Cement mortar, though only 4.41% of the RCA by mass, shows the highest water absorption at 16.92%, suggesting that it can significantly influence the moisture dynamics of RCA. The aggregate adhered with mortar, representing 5.5% of the mass, also has notable water absorption at 7.6%. In contrast, components like brick and marble contribute minimally by mass (0.4% each) but have varied absorption rates, with brick at 14.70% indicating high moisture retention which can impact the drying and curing processes of RCA applications.

4.2 Properties of aggregates (RCA and NCA)

Several tests are used to analyse the physical characteristics of recycled and natural aggregates. Table 7 provides a comparison between the physical properties of Recycled Concrete Aggregate (RCA) and Natural Concrete Aggregate (NCA).

Table 3: Aggregates relative physical characteristics (RCA and NCA)

Physical property	**RCA**	**NCA**
Specific gravity	2.24, 2.47	2.72
Aggregate crushing value (in %)	23.9–30.8	20.3–28.18
Bulk Density (in kg/m3)	1475–1525	1575–1655
Water absorption (in %)	4.25 (for 10–20 mm)	0.49
Water absorption (in %)	6.9 (for 4.75–10 mm)	0.75
Soundness	16.19	4.98
(by Sodium Sulphate solution)		
Impact Value, (WAIV) %	18.6–21.2	12.5
Loss Angeles Abrasion (in %)	30.3–33.9	21.4–21.7

RCA generally has a lower specific gravity ranging between 2.24 and 2.47 compared to NCA's 2.72, indicating that RCA is less dense. The aggregate crushing value, which measures the aggregate's resistance to crushing, is slightly higher for RCA (23.9–30.8%) compared to NCA (20.3–28.18%), suggesting RCA may be less durable. In terms of bulk density, RCA measures between 1475 & 1525 kg/m³, which is lower than NCA's 1575 to 1655 kg/m³, further indicating the lighter nature of RCA. Water absorption rates are significantly higher in RCA, with values of 4.25% for 10–20 mm aggregate and 6.8% for 4.75–10 mm aggregate, compared to NCA’s lower rates of 0.49% and 0.75%, respectively, showing RCA's higher porosity. RCA has a higher Los Angeles (LA) abrasion percentage (30.3–33.9%), which is significantly higher than NCA's 21.4–21.7%, suggesting that RCA is more susceptible to wear and degradation.

4.3 Properties of cement

Table 4 lists the cement's physical characteristics in relation to the acceptable limits listed in IS 8112, the Indian Standard requirements for ordinary Portland cement of grade 43.

Table 4: Specific Gravity & consistency of Cement

Physical Property	**Value**	**IS 8112's permissible range**
Specific gravity	3.15	3.10–3.15
Normal consistency (in %)	32.2	28–32

The specific gravity of the material is reported as 3.15, which falls within the permissible range set by IS 8112 of 3.10 to 3.15. This indicates that the cement has an acceptable density relative to water and meets the standard requirements for specific gravity, suggesting proper composition and potentially good quality. The normal consistency of the cement is 32.2%, which is at the upper limit of the permissible range of 28% to 32% as specified by IS 8112.

Table 5: Cement's compressive strength

Physical Properties	**Strength**	**IS 8112's permissible range**
Compressive strength		
7 Days (in MPa)	35.76	>33
28 Days (in MPa)	51.3	>43

The compressive strength of cement, show that it exceeds the minimum requirements set by IS 8112 for 43-grade ordinary Portland cement. At 7 days, the compressive strength is measured at 35.76 MPa. By 28 days, the strength further increases to 51.3 MPa, well above the specified minimum of 43 MPa (Table 5). The setting time data for cement, conforms well within the limits set by IS 8112 for 43-grade ordinary Portland cement. The initial setting time is recorded at 120 minutes, which is well above the minimum requirement of 30 minutes (Table 6).

Table 6: Setting time of Cement

Physical Property	**Duration**	**IS 8112's permissible limit**
Setting Time		
Initial setting time (in min)	120	>30
Final setting time (in min)	240	<600

The final setting time is noted at 240 minutes, comfortably below the maximum limit of 600 minutes. This shows that the cement sets into a hardened state within a reasonable timeframe, which is essential for continuing construction activities without long delays.

4.4 Gradation of fine aggregate through sieve analysis

The sieve analysis (Table 7) represents the gradation of fine aggregate, detailing the percentage of material passing through various sieve sizes and its corresponding grading zone. The results indicates that 100% of the aggregate passes through the 10.00 mm and 4.750 mm sieves. As the sieve size decreases to 2.36 mm, 99% of the material passes through, while 89% passes the 1.18 mm sieve, indicating a gradual increase in finer particles.

Table 7: Grading of fine aggregate through the sieve analysis

S No	Sieve size (in mm)	Passing (in %)	Sand grading zone
1	10.00	100	Grading occurs between Zones II and III.
2	4.750	100	
3	2.360	99	
4	1.180	89	
5	0.600	59	
6	0.300	17	
7	0.150	6	

The overall gradation of the sand falls between Grading Zones II and III (Figure 2). Further reduction in sieve size to 0.600 mm shows that 59% of the material passes, and this percentage sharply drops to 17% for the 0.300 mm sieve and further down to 6% for the 0.150 mm sieve, showcasing a significant portion of the sand's composition being medium to fine grains.

4.5 Abrasion resistance of concrete mixes of set A and set B

The provided graph and associated data table detail the results of an abrasion test conducted on three different concrete mix sets labelled M30, M31, and M32 to assess average mass loss due to abrasion (Table 8 & Figure 3).

Table 8: Abrasion resistance for concrete mixes of set A

Set A concrete mix			
Abrasion loss	**M30 (NCA 100%)**	**M31 (10–20 mm NAC substituted with RCA)**	**M32 (RCA 100%)**
Average mass loss (%)	0.204	0.226	0.24

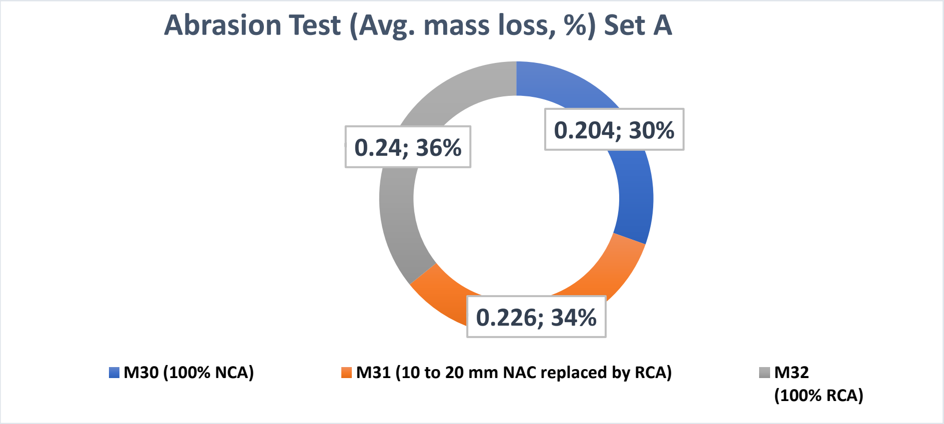


Figure 3: Abrasion resistance of concrete mixes of set A

M30, consisting entirely of Natural Concrete Aggregate (NCA), shows an average mass loss of 0.204% and is represented in blue on the graph. M31, which incorporates 10 to 20 mm of Recycled Concrete Aggregate (RCA) replacing some NCA, exhibits slightly higher abrasion with an average mass loss of 0.226%. M32, another mix utilizing 100% RCA like M30 but potentially under different conditions or compositions, presents the highest abrasion susceptibility with a mass loss of 0.24%, depicted in gray. These results visually underscore that mixes containing RCA (M31) tend to have higher abrasion losses than pure NCA mixes, but the increase in wear is relatively modest.

The table 9 & figure 4 provided display the results of an abrasion test for Set B, comparing three different concrete mixes M40, M41, and M42 with their corresponding average mass losses due to abrasion. The M40, made entirely of Natural Concrete Aggregate (NCA), exhibits the lowest average mass loss at 0.179%, which accounts for 29% of the total abrasion loss. M41, which uses RCA to replace 10 to 20 mm of NAC, shows a higher average mass loss of 0.213%, and comprising 35% of the total abrasion loss.

Table 9: Abrasion resistance for concrete mixes of set B

Set B concrete mix			
Loss of abrasion	**M40 (NCA 100%)**	**M41 (10–20 mm NAC substituted with RCA)**	**M42 (RCA 100%)**
average mass loss (%)	0.179	0.213	0.22

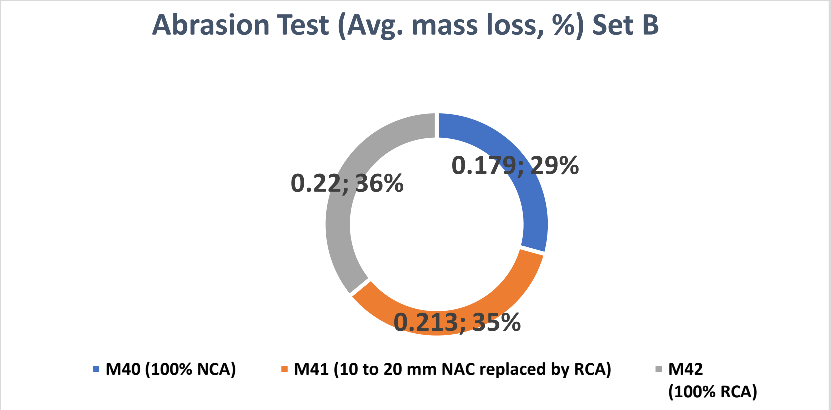


Figure 4: Abrasion resistance of concrete mixes of set B

This suggests a slightly reduced abrasion resistance due to the incorporation of RCA. The M42, another 100% RCA mix like M40 but potentially differing in other variables, recorded the highest abrasion loss at 0.22%, shown in gray and forming 36% of the total abrasion loss.

4.6 Flexural strength of concrete mixes

The table 10 and Figure 5 represent the flexural strength of three different concrete mixes in Set A, measured at 7 days and 28 days after mixing.

Table 10: Flexural strength of set A concrete mixture

	Concrete mix Set A		
Flexural strength (in MPa)	**M30 (NCA 100%)**	**M31 (10–20 mm NAC substituted with RCA)**	**M32 (RCA 100%)**
7-day	4.3	4.1	3.7
28-day	5.1	4.7	3.9

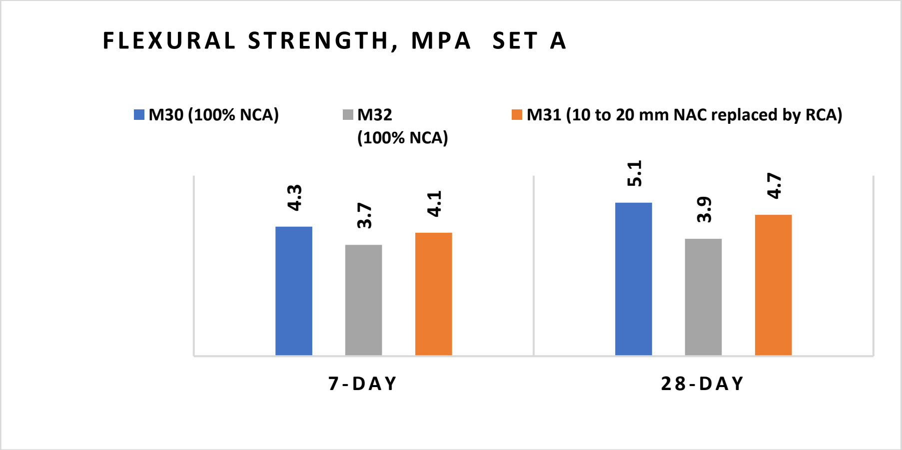


Figure 5: Concrete mix flexural strength Set A

Mix M30, which is made entirely of Natural Concrete Aggregate (NCA), shows the highest flexural strength at both intervals, with 4.3 MPa in 7 days and 5.1 MPa in 28 days. Mix M31, where 10 to 20 mm of NCA is replaced by Recycled Concrete Aggregate (RCA), exhibits slightly lower strength levels of 4.1 MPa in 7 days and 4.7 MPa in 28 days, indicating that the replacement of NCA with RCA slightly reduces the flexural strength. Mix M32, also 100% RCA like M30, demonstrates the lowest strength of the three mixes, with 3.7 MPa in 7 days and 3.9 MPa in 28 days, suggesting that while it is composed of the same type of aggregate as M30. The Table 11 and figure 6 for Set B illustrates the flexural strength of three different concrete mixes over 7 days & 28 days. Mix M40, which is composed entirely of Natural Concrete Aggregate (NCA), consistently demonstrates the highest flexural strength across both testing periods, with 5.4 MPa in 7 days & 6 MPa in 28 days.

Table 11: Flexural strength of set B concrete mixtures

Concrete mix Set B			
Flexural strength, MPa	**M40 (NCA 100%)**	**M41 (10–20 mm NAC substituted with RCA)**	**M42 (RCA 100%)**
7-day	5.4	5	4.7
28-day	6	5.9	5.2

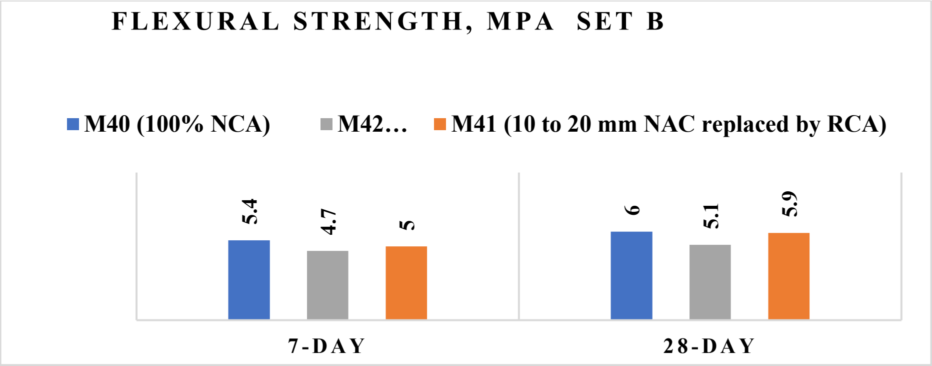
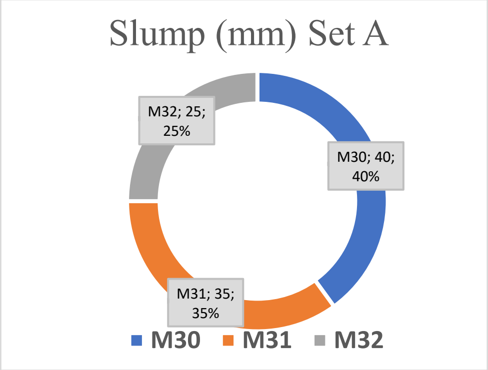


Figure 6: Flexural strength of concrete mixes Set B

Mix M41, in which 10 to 20 mm of NCA is substituted with Recycled Concrete Aggregate (RCA), shows slightly lower strengths than M40 but performs commendably with strengths of 5 MPa in 7 days and 5.9 MPa in 28 days, suggesting that RCA can perform nearly as well as NCA. Mix M42, another 100% RCA concrete like M40, shows the lowest strength in this set, with 4.7 MPa in 7 days & 5.2 MPa in 28 days, indicating that, similar to Set A, factors other than the type of aggregate, such as mix design or curing practices, might influence its lower performance compared to M40.

4.7 Slump and the fresh density of concrete mixes

The figure 7 illustrate the slump & fresh density of three concrete mixes (M30, M31, and M32) from Set A. The slump test, which measures the consistency and workability of the concrete, shows that Mix M30 has the highest slump at 40 mm, indicating better workability, followed by Mix M31 at 35 mm, and M32 with the lowest at 25 mm.



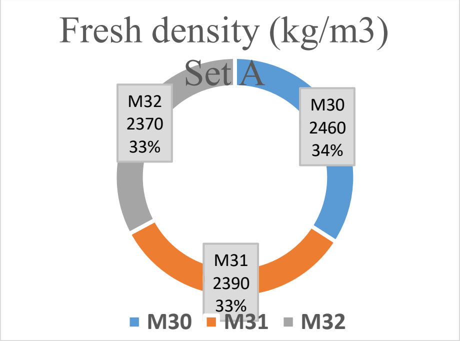
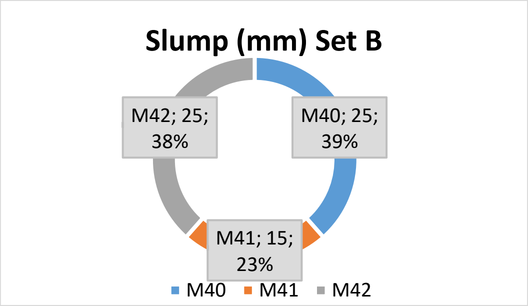


Figure 7: Slump and the fresh density of set A

Regarding fresh density, which reflects the mass of the concrete mix per unit volume and can be an indicator of the compactness and the number of voids in the concrete, Mix M30 again exhibits the highest density at 2460 kg/m3. This is followed closely by Mix M31 at 2390 kg/m3 and M32 at 2370 kg/m3. The fresh densities indicate that M30 not only shows better workability but also higher compactness. The figure 8 for Set B provide insights into the slump & fresh density of three concrete mixes: M40, M41, and M42. The slump test results show that M40 and M42 both have a slump of 25 mm, indicating a medium consistency suitable for general construction purposes.M41 has a significantly lower slump value of 15 mm



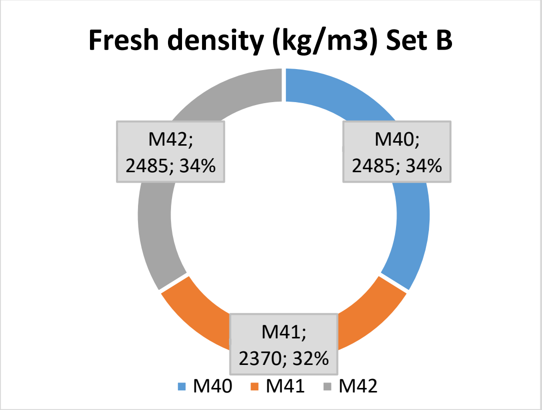


Figure 8: Slump and the fresh density of set B

In terms of fresh density, M40 and M42 again report identical values at 2485 kg/m³, which are the highest among the three mixes, pointing to higher compactness and possibly a denser aggregate packing. M41 has a noticeably lower fresh density of 2370 kg/m³, reflecting a less compact mix which could be due to variations in aggregate types, sizes, or moisture content. These results indicate that while M40 and M42 could be expected to behave similarly in terms of handling and structural properties due to their identical slump and density values.

V. CONCLUSIONS

This study examines the impact on pavement concrete's abrasion resistance of substituting recycled concrete aggregates of comparable size derived from CDW recycling for natural coarse aggregates in concrete mixes. The following are the study's key findings. Natural coarse aggregate outperformed recycled coarse aggregate in terms of physical characteristics.

- The fresh density of concrete mixes is decreased by 6–8% when recycled aggregate is used in place of natural aggregate.
- Concrete with recycled aggregate had lower compressive and flexural strengths than concrete with natural aggregate. When recycled aggregate is used in place of all-natural aggregate, such as 4.75 to 20 mm, this decrease is significantly more noticeable.
- Concrete with recycled aggregate had substantially lower abrasion resistance than concrete with natural aggregate. Concrete mixtures that only used larger-sized recycled aggregate (10–20 mm) instead of all recycled aggregate (4.75–20 mm) demonstrated superior abrasion resistance. All concrete mixes, nevertheless, exhibit abrasion resistance qualities that are suitable for paving concrete.

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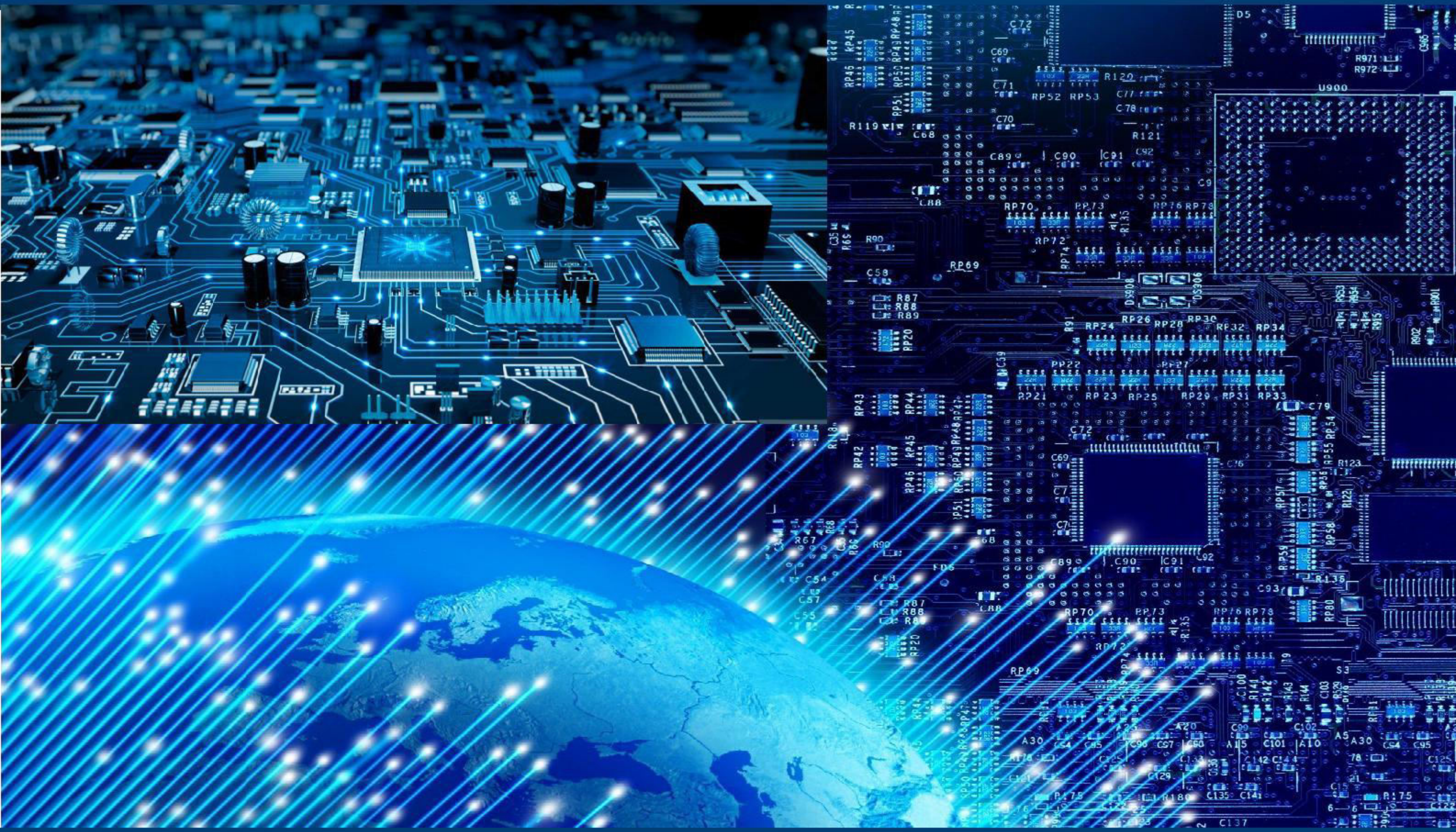

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