Reducing environmental impact by Optimizing sustainable concrete mixes using Portland slag cement and recycled aggregate

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Abstract. Concrete is one of the major component used in construction of structures, using recycled materials is becoming essential for environmentally friendly buildings. The purpose of this work is to determine if concrete mixes that comprise Portland Slag Cement (PSC) and Recycled Aggregates (RA) are suitable for use in sustainable construction by examining their mechanical characteristics. Fifteen mix types were evaluated using normal-strength concrete featuring a 0.45 water-to-cement ratio and a compressive strength of 35 MPa. PSC and RA replacement levels ranged from 0% to 50% and 0% to 100%, respectively. A thorough intensive test was performed, which included measurements of the strengths and durability for seven and twenty eight days, as well as analyses of the modulus of elasticity and stress-strain curve. The findings show that RA reduced compressive strength by 10% and modulus of elasticity by 20% when Natural Aggregate (NA) was completely replaced with it. In the presence of RA, however, a 25% substitution of PSC for Ordinary Portland Cement (OPC) prevented the compressive strength from decreasing to 0.92% and raised the modulus of elasticity by 3.7%. The ideal mix, which is composed of 75% OPC, 25% PSC, and 50% RA, greatly improves the mechanical qualities of concrete and is advised for use in reinforced concrete applications because of its possible structural and environmental advantages.

1 Introduction

Building sector depends heavily on the manufacturing of concrete, the material that is created the most extensively worldwide. The research was identified for the investigation of utilizing waste materials which can be used in concrete mixture developed using recycled coarse aggregate and Portland Slag cement, is required due to the environmental impact of traditional concrete production, particularly carbon emissions and the depletion of natural resources [1].

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After depleting natural resources, mankind is looking forward to the utilization of waste or discarded materials as even construction industries have been intensively utilizing natural resources but with awareness and primary focus on environmental issues, even the use of construction waste in even one part towards a better future. As a competitive alternative to NA (atural Aggregate) and a significant contributor to the development of sustainable concrete technologies, RA (Recycle Aggregate) is derived from CDW (Construction Demolish Waste) and reduces landfill usage and damage to the environment. Recyclable aggregate can be used in different forms as this can be turned into a slurry which can be utilized in white cement or even traditional cement to increase its strength and consistency as per inter facial transition zone to enhance its mechanical properties. The results of such a mixture can be compared with a mixture developed using natural aggregates to understand its applications. It has been shown that mechanical, chemical, and thermal procedures can increase the quality of RA, its fluid retention stages, and how it interacts with the concrete mixture [2].

Tones of construction demolished waste (CDW) is generated annually which damages the ecosystem and demands strict measures to reduce its impact of such damages and turn towards sustainable resources. Even though RAC concrete usually has poorer mechanical properties than NA concrete, recycling this waste stream into RAC offers a viable path towards sustainability. Different technologies are investigated in the form of chemical or biological treatment of such recycled concrete aggregates to enhance their strength and customize their properties as per their construction site application. Furthermore, by predicting the durability of RCC beams constructed using RA, new machine learning algorithms are boosting utlizing the demolished waste and recycled aggregates for construction of new projects. Integration of CDW into building materials is made possible by these developments, which together support the objectives of environmental sustainability [3]. The utilization of RA and PSC can be enhanced and customized as per construction needs proving its worth of being ecofriendly. As discussed previously, this mixture finds its utilization in major and minor projects and can be produced by strategically replacing RA and PSC, according to studies; nevertheless, there are drawbacks, including the need for more cement and possible durability decreases [4, 5]. Numerous scientists and researchers have defined the utilization of recycled aggregate which is feasible for cost reduction of the project further reducing its carbon footprints. The utilisation of PSC and RAC, two materials with major environmental benefits, in ecologically friendly concrete compositions is the subject of this study. When any building site is demolished, the waste generated from rebars, tiles, waste aggregates and concrete chunk. Such waste dan be utilized in construction of new structures help managing the waste pollutants for giving it a new life reduction in need of new construction material [7-10]. For the purpose of further optiming the concrete mixture and enhancing the Properties of Ordinary Portland cement, its replaced with some part of GGBFS to turm it into Portland Slag cement increasing concrete durability and reduces CO2 emissions [10–12].

RA and GGBFS are being investigated as sustainable alternatives to NA and OPC in the manufacturing of concrete. The research is primarily focused towards analyzing the effect of concrete prepared using various proportions of natural aggregate and ordinary Portland cement with variation in GGBFS on its properties considering its hardening and strength properties further considering even its durability. Adding RA and GGBFS increases workability, according to the results. Even though tensile, flexural, and compressive strengths all typically declined when recycled aggregate and ground granulated blast furnace slag levels rose and the decline of hardening properties was less noticeable than that in compressive strength [13]. The volume of voids and water absorption increased when RA was added, indicating decreased durability. However, by improving the interfacial transition zone and bonding properties, GGBFS was able to lessen the adverse effects. The concrete mixture constituting fifty percent recycled aggregate and fourty percent ground granulated blast furnace slag can achieve the desired strength and prove to be environmentally acceptable followed by the appropriate strength similar to the similar grade conventional concrete. To balance strength and sustainability, this ideal combination is recommended as a sensible option for upcoming construction applications.

A further study explores the enhancement in green imperishable RCC structure using RA along with GGBFS supplemented with lime. Lime effectively activates the GGBFS, boosting attributes such as strength and durability which were roughly 7.75 percent to 20.25 percent, according to research, accessing the trends and particle chemistry of concrete. Concrete prices drop by 7.15% to 11.80%, and ecological consequences drop by 32.5% to 67%, according to economic and environmental impact analyses. An ideal blend of 50% RA and 40% GGBFS produced results that were on par with conventional concrete and promoted sustainability by reducing waste and environmental damage. The researcher has primarily focused on the use of GGBS along with RA proving its commitment towards ecofriendly green structures and identifying its application in the construction industry [14]. Researchers have worked towards replacing binder with SFA and natural admixture to explore the performance and environmental advantages of slag-pozzolanic cement (CEM V) as a less carbon dioxide-intensive alternative to conventional Portland cement. According to the research, a mixture developed using slag-pozzolanic cement presents a drop in structure integrity, their denser microstructural growth improves concrete's endurance over time, boosting its long-term performance. According to the results, CEM V concrete keeps dense pressure in enhancing resistance and needs more superplasticizers for workability. Compared to conventional cement types, CEM V exhibits greater longevity further enhancing percolation even after any reduction in durability in the range of 15-25% even after ninety days. Further, by including these sustainable materials broadly, the study promotes updating building standards and realistic adoption strategies. It emphasises the durability and environmental benefits of using RA in contemporary construction [15].

Optimal TATs (Turnaround Time) have a major impact on the mechanical characteristics and microstructure of recycled blended cement (RBC) pastes, according to studies. Substantial improvement in durability from 9.35%-21.12% is visible which improves thermal activation temperature which generally lands below 780 °C. Dual Structure formation consists of hydration concoction, improving durability and reliability. These results highlight the necessity of exact TAT control to optimise the advantages and show how SCMs (supplementary cementitious materials) can improve cement's durability and environmental sustainability. Through the utilization of eco-friendly materials in concrete manufacturing, this research optimises material qualities while minimising environmental impacts, which makes a substantial contribution to sustainable construction practices [16].

Natural aggregate can be completely replaced with recycled aggregate, and such concrete mixtures were prepared and analyzed. The range of water-to-cement (w/c) ratios examined in this study is 0.3 to 0.7. In addition to their durability qualities, which include resistance to corrosion, carbonation, water permeability, and chloride ion permeability, the mixture was assessed for strength and durability which ranged between 22-55 MPa. Durability results were found satisfactory even with using a complete concrete mix developed entirely using recycled concrete aggregate. Such a method is using construction waste proves to be vital for environmental safety and reduction in hazardous fumes generated using construction materials and its transportation as recycled aggregate can be sourced locally. The primary motive advocates for the development of ecologically friendly building materials by the construction sector [17].

Numerous studies and researches have identified to identifying the enhancements of concrete mixes developed using recycled coarse aggregate and replacing ordinary portland cement

with portland slag cement to enhance the sustainability of concrete. The properties of the mixture can be customized as per the need of construction projects by optimizing the content of concrete mixtures variable to its grade. There is still scope for further research on understand the properties of materials which can replace traditional construction materials to some extent in order to identify its long term appliance and durability [18-22]. It primarily focus towards replacing natural aggregate with recycled aggregate and ordinary Portland cement with Portland Slag Cement in different proportions to understand the right concrete mix for satisfactory results.
The paper primarily focuses towards the utilization of sustainable building materials due to its increasing demand, the concrete mix developed in this study uses recycled demolished waste and Portland Slag Cement. Utilization of construction waste is increased in study, which decreases the requirement for natural resources, landfill usage, and carbon emissions. The research's useful information can also be used by engineers and policymakers to make educated decisions on sustainability. By implementing new industry standards for the utilisation of recycled materials, construction processes might experience a revolution and improve the economic outcomes of the sector. Lastly, the study's findings are essential in developing concrete civil engineering applications and future research that stress resource efficiency and durability [23-24].

2 Materials and its Properties

In this study, two different cement compositions, one of which is traditional Ordinary Portland Cement (OPC) and Portland Slag Cement (PSC) were used in this investigation as per Indian Standards IS 455- 2015. The cement compositions are manufactured as per Indian Standards.

2.1 Ordinary Portland Cement

Ordinary Portland Cement (OPC) is a common type of cement used in construction. As per IS: 269-2015 (Indian Standard Specification for Ordinary Portland Cement), OPC is defined as a hydraulic cement produced by pulverizing clinker, usually mixed with a small amount of gypsum or calcium sulfate, to regulate the setting time. It is primarily used for general construction purposes whose general properties is shown in Table 1.

Table 1. Composition and Properties of Ordinary Portland Cement.

Synthetic Compound	Amount Values
SC1	21.18%
SC2	5.85%
SC3	4.86%
SC4	64.57%
SC5	2.47%
SC6	2.73%
SC7	1.27%

SC8	1.51%
SC9	1.06%
SC10 (ppm)	2.84
IR	1.66%
Loss on ignition	3.54%
C_3S	53.09%
C_2S	20.21%
C_3A	7.09%
C_4AF	12.12%
Material Characteristics	
F (cm2/g)	3440 cm2/g
X (mm)	1.49
Contractive Loads (Mpa)	
Two Days (Mpa)	20.786
Twenty-Eight Days	47.28 MPa
IST	174 min
FST	245 min
Free lime	0.74%

*IST- Initial Setting Time, FST- Final Setting Time, SC1- SiO2, SC2-Al2O3, SC3-Fe2O3, SC4- CaO2 SC5- M gO2, SC6- SO3, SC7-K2O, SC8-Na2O, SC9-CL, SC10-Cr+ 6, IR-Insoluble residue, F-Fineness, X- Expansion

2.2 Portland Slag Cement

A type of blended cement known as Portland Slag Cement (PSC) is specified by IS: 455-2015 (Indian Standard Specification for Portland Slag Cement). Granulated blast furnace slag (GGBS), gypsum, and Portland cement clinker are closely mixed and processed to create it. As an alternative, Portland cement and finely ground slag are blended, with a slag percentage ranging from 25% to 70% by mass.
Hydraulic cement is called in general terms but its scientific names stand as Ground Granulated Blast Furnace Slag and even Portland Cement Slag is manufactured using gypsum and waste product of mining industry. In general, the final cement has less clinker than OPC. Durability and defence against sulphate attacks are some characteristics of PSC's well-known. Concrete's long-term performance is enhanced and the environmental impact of cement manufacturing is lessened by supplemental concrete ingredients. Such material can prove to be reliable and resistant towards harsh weather and can be customized as per the

different geography found in the globe. Table 2 depicts the properties of the Portland Slag Cement.

Table 2. Composition and Properties of PSC-Portland Slag Cement.

Chemical composition	Amount Results
SC1	26.28%
SC2	8.42%
SC3	3.86%
SC4	58.57%
SC5	3.47%
SC6	2.11%
SC7	1.59%
SC8	1.42%
SC9	1.03%
SC10 (ppm)	2.32
IR	1.57%
Loss on ignition	1.32%
Material Characteristics	
F (cm2/g)	4390
X (mm)	1.51
Contractive Load	
Two Days	19.59 MPa
Twenty-Eight Days	33.44 MPa
IST	200 min
FST	250 min
Free lime	0.29%

*IST- Initial Setting Time, FST- Final Setting Time, CC1-K_2O, CC2-Na_2O, CC3-CL, CC4-Cr+ 6, IR-Insoluble residue, F-Fineness, X- Expansion

3 Properties of Aggregate

3.1 Fine Aggregate (FA)

Natural sand, which is mostly siliceous, was chosen for this study's fine aggregate because it is clean, devoid of contaminants and organic compounds, and has a fineness modulus of 2.53. In order to verify compliance with IS 383: 2016, numerous experiments evaluated the characteristics of FA [22] which is presented in Fig 1 and defined in Table 3.

Table 3. Assessment of Properties of FA.

Experiment	Outcomes
Sg	2.65
Uw and Voids	1.69
FM	2.52
Absorption	1.20%
<\	3.48%

*Sg- Specific Gravity, Uw- Unit Weight, FM- Fineness Modulus.

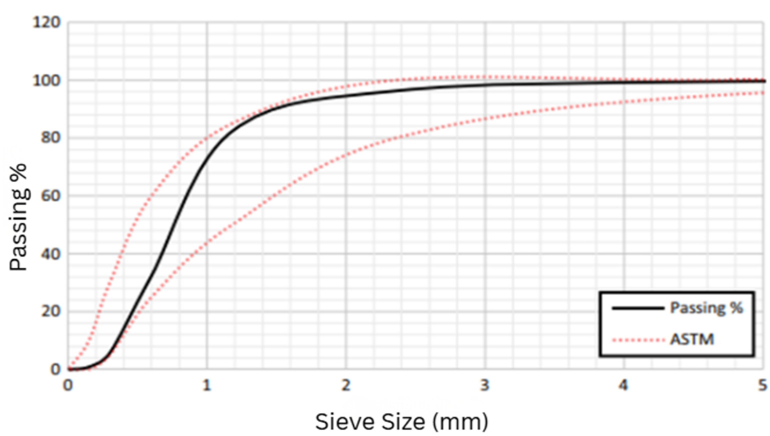

Fig. 1. Sieve Curve for FA (as per IS 1893 Part I-2015)

3.2 Natural Coarse Aggregate

The coarse aggregate utilised in this study is pure, unimpurity-free crushed limestone no larger than 19 mm and free of organic components. Extensive testing determined its qualities, which comply with IS 383: 2016. To ensure compliance and dependability, it further verifies that the coarse aggregate's properties fully meet the required norms [22] which is shown in Fig 2 and defined in Table 4.

Table 4. Properties of CA

Experiment	Outcomes

Sg	2.79
Uw and Voids	1.9
Crushing	24
Absorption	0.80%
<\	1.80%

*Sg- Specific Gravity, Uw- Unit Weight, FM- Fineness Modulus.

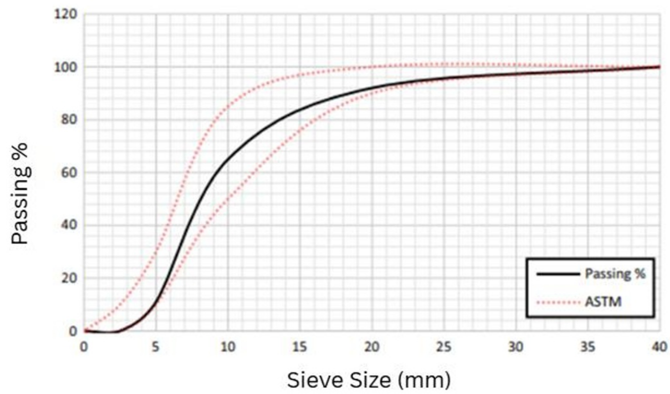

Fig. 2. Sieve Curve for CA (as per IS 1893 Part I-2015)

3.3 Recycled Coarse Aggregate

Coarse aggregate that is obtained by processing materials that were previously utilised in construction is known as recycled coarse aggregate, or RCA. After being processed to satisfy particular quality and grading standards, these aggregates are usually obtained from the demolition of concrete structures. In construction, RCA encourages waste control and sustainability. The Indian Standard Specification for Coarse and Fine Aggregates for Concrete, or IS: 383-2016, is the main source of norms and regulations about recycled aggregates. In this code, recycled aggregates are specified in terms of their quality, grading, and allowable impurity limitations.

No more than 5% of RCA should be made up of harmful materials such tiles, bricks, or other foreign objects. It is important to limit the amount of chloride, particularly in applications using reinforced concrete. The Properties of the Recycled coarse aggregates is shown in Table 5.

Table 5. Recycled Coarse Aggregate Properties

Properties	Values
BG	3.43
A	5.6

*BG-Bulk Specific Gravity, A- Absorption

The samples that were being evaluated were mixed and cured using pure, drinkable water that was free of contaminants. To guarantee the creation of concrete with normal strength, the water-to-binder ratio was meticulously controlled, kept at 0.45 by weight.

4 Mix Design

Using FA along with RCA, 15 concrete samples needed to be created, combining OPC and PSC with different ratios. After 28 days, 35 MPa was determined to be the ideal compressive strength. The ACI method was used to equate the control mixture as stated below in equation no 1 using the reference of "Equivalent Mortar Volume". The concrete mixes were designed without using any chemical or mineral admixture. The absence of segregation or honeycombing in any of the specimens is noteworthy and further, the samples are cured with water for twenty- eight days.

The concrete mixes should be designed as per Indian standards and the user needs to be more careful while segregating recycled coarse aggregate for its usage in the concrete mix in different proportions. The mixture is developed using ordinary Portland cement and Portland slag cement in variable proportions along with water and fine aggregate using the EMV (Energy Minimization and Void Optimization) approach. The mix proportions used in this study were structured according to the Equivalent Mortar Volume (EMV) concept. The assumption behind EMV is that the combined mortar volume (comprising cementitious paste, fine aggregate and the mortar attached to recycled coarse aggregate) remains static during NA replacement with RCA. The EMV concept maintains consistent mortar volume across all mixtures to study RCA effects on concrete performance without varying paste content.

Utilization of recycled concrete aggregate proves to be a viable option for sustainable construction, as the project states its utilization of RCA which enhances its desirable properties in enhancing its strength and durability. The materials need to be analyzed to understand their penetration properties and understand their resistance towards acid attacks which may lead to corrosion. These properties can be attained while testing with different proportions of concrete mixtures utilizing the EMV approach. To close the spaces between the crushed stone and enhance the asphalt's overall soundness and versatility, the volume of mortar required must be determined. Then, the mixture is designed as per Indian Standards where precise proportions of water, cement, and additives are determined.

$$\text{VRM} = \text{Mass of RCA} \times (\text{Absorption of RCA} - \text{Absorption of NA}) / 100\ldots \quad (1)$$

The equivalence above defines stability in results as the sample content was found to be stable to the strength achieved by a traditional mixture, the equation is customed utilizing the EMV method. According to the sourcing and processing of the recycled material, this change takes into account the grout that is currently attached to the RCA.

To maintain the combination's intended qualities while accounting for the moisture content of recycled aggregates, moisture percentage adjustments are crucial. Sample mixtures developed using recycled coarse aggregate can be found fruitful for the environment and prove to be cost-effective matching initial performance goals. Adherence to regional norms is essential, in directing the RAC design process. A rigorous design, testing, and validation process is essential for designing concrete mixture which needs to be customized as per the application of the project which meets the needs of the construction project and the cherry on the cake will be its advantage of being eco-friendly approach. The different mixes of the samples if defined in Table 6.

Table 6. Combination Design of Samples

Block	Sample Name	OPC	PSC	A	Natural Aggregate	Recycled Coarse Aggregate	W
Block A	S1	480	NA	858	1135	NA	276.5
	S2	465	NA	816	890	397	269.75
	S3	450	NA	796	640	696	263
	S4	440	NA	773	374	1020	258.5
	S5	430	NA	767	NA	1333	254
Block B	S6	387.5	202.5	858	1135	NA	276.5
	S7	376.25	198.75	816	890	397	269.75
	S8	365	195	796	640	696	263
	S9	357.5	192.5	773	374	1020	258.5
	S10	350	190	767	NA	1333	254
Block C	S11	295	295	858	1135	NA	276.5
	S12	287.5	287.5	816	890	397	269.75
	S13	280	280	796	640	696	263
	S14	275	275	773	374	1020	258.5
	S15	270	270	767	NA	1333	254

*A- Sand, W- water, OPC-Ordinary Portland cement, PSC- Portland Slag Cement

Dust, contaminants, and any contaminated powders that might have adhered to the aggregate particles were removed from the coarse aggregates using a rigorous procedure that included sifting and washing. Advanced hardware is available for concrete mixtures with different capacities but traditionally the old age 60 kg capacity mixtures are generally used for the purpose. Cement and other dry ingredients, such as fine and coarse aggregates, were manually added to the drum mixer for 30 seconds. For two minutes, the ingredients were combined after half of the necessary water was supplied. Two more minutes of mixing ensued after the addition of the remaining water. After the concrete had reached the appropriate consistency, it was poured into forms and moulds. For cubes, cylinders, and prisms, the cast concrete was vibrated over a vibrating table after mixing. In addition to ensuring enough compaction, this procedure helped create a smooth, finished surface that could be further polished with a trowel. The concrete specimen are prepared after a 24-hour curing period from casting. The specimens were then placed in a water basin and allowed to cure for a full 28 days. To guarantee the development of the necessary durability and hardness, this stage is essential. The mechanical characteristics of the specimens were then examined seven and twenty-eight days after casting.

5 Results & Discussion

Different PSC replacements (0%, 25%, and 50%) were incorporated into three different groups of mix combinations (Block A, Block B, and Block C). Natural aggregate was replaced with recycled aggregate at 25%, 50%, 75%, and 100%. For all 15 mix combinations, concrete cubes measuring 158 mm by 158 mm by 158 mm were cast while keeping the water-to-cement (W/C) ratio at 0.45. Table 7 gives the compressive strength values for different samples. A balance between mechanical performance and EMV along with material indicators allowed selection of the best sustainable mix. While the control mix with 100% OPC and NA achieved the highest 28-day compressive strength its composition included maximal clinker content resulting in the highest environmental impact. The intermediate-level PSC–RCA blend mix Sx demonstrated compressive strength at 28 days comparable to the control mix while significantly cutting down the use of virgin aggregate and OPC. The combination of lower EMV scores and better material efficiency shown in Table 7 and the corresponding figures demonstrates this outcome. The selection of mix Sx resulted from its balance between slight strength reduction and substantial environmental benefit.

Table 7. Comparative Assessment of compressive strength for different composition

Sample Name	Compressive Strength fcu (calculated from cube)
S1	38.38
S2	36.47
S3	35.23
S4	37.19
S5	35.4
S6	36.56
S7	35.87
S8	37.27
S9	36.22
S10	36.39
S11	38.35
S12	35.58

S13	36.55
S14	35.87
S15	34.51

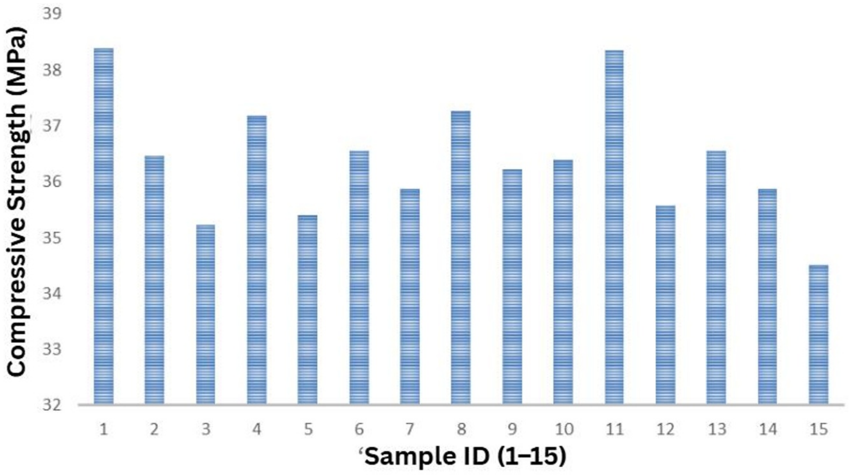

Fig. 3. Average compressive strength of cubes after 28 days of curing

The examinations are conducted on the specimen cured for seven days and twenty eight days. The equipment with 2000 KN compressive testing equipment was used as per the Indian Standard 2016. Each mix's average compressive strength results were carefully documented after the tests were performed on triplicate specimens Increasing RCA replacement percentage results in a general reduction in compressive strength for Block A: S3 with 50% RCA mix yielded the lowest value of 35.23 MPa and S5 containing 100% RCA mix produced a significant reduction to 35.40 MPa when compared against S1 control mix at 38.38 Mpa. This decrease may be because of the older mortar's weaker bonding properties. The results of Block B stated that the robustness of samples decreased with an increase in concentration of recycled coarse aggregate, although the decline is not as pronounced as it would be in the 100% OPC mix. The hydration properties of PSC, which strengthen the concrete's micro-structure, may be the reason why PSC may improve the interracial bonding with RCA.

There is a noticeable trend where the strength rises up to 50% RCA content in Block C and then falls. This might point to an ideal ratio of new binding materials to existing recycled coarse aggregate mixture, increasing its specific point.

Concrete's performance seems to be significantly influenced by the interaction between PSC and RCA. The mechanical interlocking offered by RCA may be beneficial at particular inclusion levels, whereas the hydration products of PSC may be able to fill voids more successfully. Mixtures that replace 50% part of Ordinary Portland cement with Portland Slag Cement OPC and fifty percent of recycled coarse aggregate with RCA, in particular, show promise for increased strength. Such samples reduce waste and conserve natural resources, which proves to be eco-friendly and viable for the long term. Therefore, making the most of RCA and PSC could be a big step towards environmentally sustainable building methods.

According to twenty-eight days of strength investigation, samples containing hundred percent Ordinary Portland cement continuously perform better than those including RAC.

With 0% RAC, the strongest results are shown, and as the RAC content rises, they gradually decrease.
PSC is added to blends that contain 75% OPC and 25% PSC, which mitigates the strength loss caused by RAC. Despite having somewhat lower peak compressive strengths than pure OPC mixes, PSC appears to have a mitigating effect on the detrimental effects of the attached mortar on RAC, as evidenced by the less noticeable strength decline with RAC additions. The stronger connection between the recycled aggregates and cement paste is probably caused by the finer particles and chemical interactions of PSC.
A material's resistance to deformation or failure under bending or flexural strain is measured by its flexural strength, which is sometimes referred to as its modulus of rupture, bending strength, or transverse rupture strength. It reflects the maximum bending stress that a material can bear before breaking. A specimen's flexural strength is evaluated by subjecting it to a weight at its centre while supporting it at both ends in a three-point or four-point bending test. The output of Table 8 shows the flexure strength of samples.

Table 8. Comparative assessment of Flexural Strength for 28 days

Sample Name	Flexural Strength (Calculated from cube)
S1	3.71
S2	3.52
S3	3.46
S4	3.66
S5	3.51
S6	3.61
S7	3.48
S8	3.79
S9	3.66
S10	3.78
S11	3.76
S12	3.54
S13	3.69
S14	3.48
S15	3.44

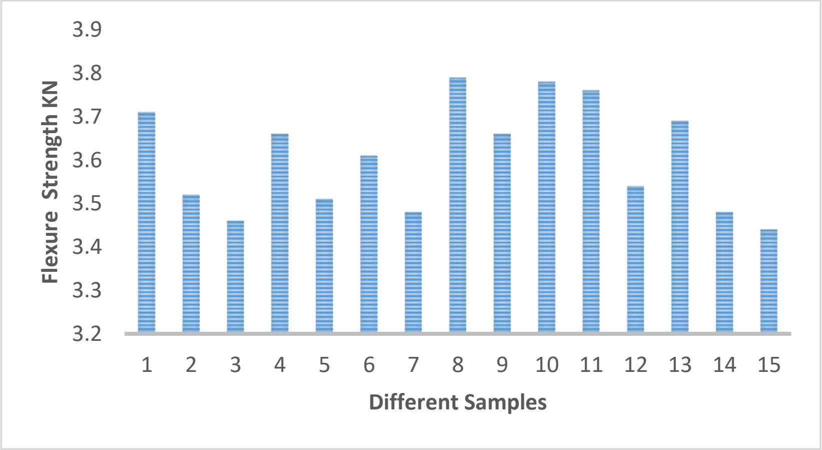

Fig. 4. Comparison of Flexural Strength od samples

The flexural strength as represented in Fig 4 was found maximum for the sample S10 75%OPC-25%PSC- 100%RCA where the results were found satisfactory considering a conventional concrete of the same grade. The favourable combination of using slag demands strength in cubes and the results were found favourable evn without using any admixture. The samples are tested for Split Tensile Strength which is presented in Table 9.

Table 9. Assessment of Split Tensile Strength kN for different samples

Sample Name	Split Tensile Strength
S_1	6.17
S_2	5.86
S_3	5.76
S_4	6.08
S_5	5.82
S_6	5.99
S_7	5.78
S_8	6.31
S_9	6.11
S_10	6.29
S_11	6.25
S_12	5.89
S_13	6.14
S_14	5.81

S_15	5.72

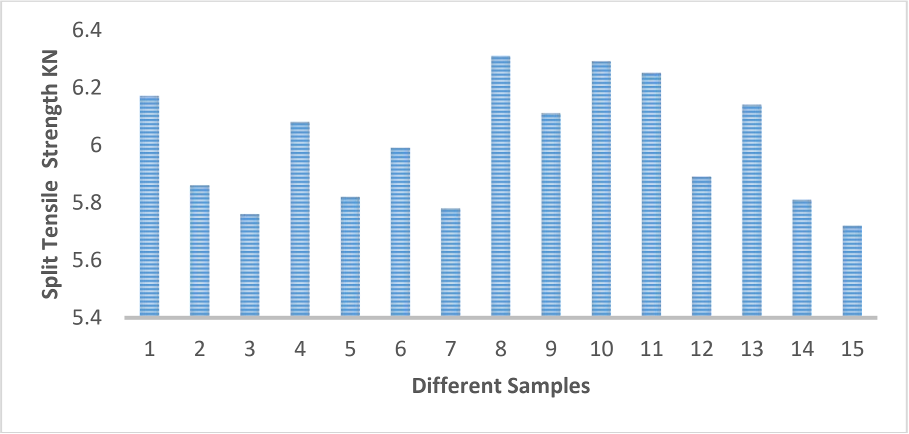

Fig. 5. Different samples and their Split Tensile Strength

Fig 5 shows the sample mixes and their split tensile strength. On comparing splitting strength to compressive strength, the former indicates how well the concrete can withstand tensile stresses and is less sensitive to variations in RAC content. PSC-free mixes tend to exhibit more fluctuation in splitting strength as the RAC concentration rises. The lower quality of the recycled aggregates may cause the aggregate cement matrix to lose its integrity, which could result in a drop in splitting strength. The splitting strength is stabilised by the addition of PSC, which significantly lowers the loss. In mixes without PSC, for example, a 100% substitution of RAC for natural aggregates may result in a 15–20% reduction in splitting strength; however, PSC can mitigate this effect, reducing the amount of the decline to 5–10%. This implies that the concrete's resistance to direct tensile pressures is still quite strong. There is a discernible drop in Young's modulus as the amount of RAC increases, which is to be expected considering that RAC is naturally less stiff than natural aggregates. Young's modulus may decrease by 15% to 20% in mixtures that entirely substitute RAC for natural aggregates and do not include PSC. But adding PSC seems to somewhat counteract these losses, especially in blends that have a moderate amount of Recycled coarse aggregate replacement. When Portland Slag Cement is taken into account, the depletion was found to be in between ten percent to fifteen percent. The concrete's overall performance is improved by PSC's ability to compensate for the stiffness deficiencies caused by RAC, as evidenced by the modulus recovery.

6 Conclusions

As RA concentration increased, the study found that compressive strength significantly decreased. Specifically, for mixes made without PSC, a strength loss of up to 16.5% occurred when 100% of NA was substituted with RA. Because the aggregate-cement bond's quality is reduced, this reduction emphasizes the difficulties in employing RA in structural applications. The paper has following key conclusions:

i. The traditional concrete mixture was prepared using Ordinary Portland cement and disc Luding recycled aggregate, and the strength decline was reduced to just 0.92% when 25% PSC was added to concrete mixtures. The results further stated that Portland slag cement was found to enhance the bond between the recycled aggregate and concrete mixture, increasing the integrity of the concrete.

ii. Modulus of elasticity generally showed a negative trend as the RA concentration rose; the most notable decrease was noted at 15.3% in mixtures that contained only RA and no PSC. The concrete's ability to support weight may be impacted by this change in stiffness.

iii. Even when 50% of the NA was swapped out for RA, mixes containing 25% PSC and 75% OPC demonstrated a 3.7% lift in modulus of elasticity. The efficiency of PSC in preserving and improving the stiffness of RA- inclusive mixes is demonstrated by this result, which is essential for their structural application.

iv. According to the study, the optimal blend consists of 75% OPC and 25% PSC, with 50% NA replaced by RA. This composition strikes a compromise between preserving robustness and improving longevity.

v. During the hydration of cement, $Ca(OH)_2$ is generated when reacted with slag, More calcium silicate hydrate (CSH) is produced by PSC, which enhances the interfacial transition zone. This procedure efficiently counteracts the weak spots in RA generated by the old mortar by strengthening the bonding qualities between the cement paste and RA and densifying the concrete matrix.

vi. Environmental sustainability is greatly enhanced by RA and PSC since they lessen the carbon footprint linked to the production of concrete and the need for minerals from clean quarries. The study emphasizes the significance of these materials in preserving natural resources and reducing waste in landfills, which is essential given the depletion of world resources and environmental damage.

vii. According to the research, PSC may be used more widely to improve the quality of concrete that contains RA, which will increase its use in the building sector and possibly establish new standards for environmentally friendly building methods.

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