DEVELOPMENT OF SUSTAINABLE FIBER REINFORCED SELF COMPACTING CONCRETE USING RECYCLED AGGREGATE

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ABSTRACT

It's a significant step forward for the construction industry's product quality and efficiency that Self-Compacting Concrete (SCC) has been developed. When used on construction sites, SCC increases productivity while also improving working conditions, as well as the overall quality and aesthetics of the concrete. In SCC, the use of fibers helps to prevent fracture development by bridging any gaps in the concrete. When compared to ordinary concrete, they enhance energy absorption. In the fresh condition, Fiber Reinforced Self-Compacting Concrete (FRSCC) combines the advantages of SCC, but in the hardened state, it performs better than ordinary vibrated concrete owing to the inclusion of fibers. For various substitutions of Recycled Concrete Aggregate (RCA) in Natural Aggregate (NA), the current study presents the mechanical characteristics of Glass Fiber Reinforced M20 & M40 grade Self Compacting Concretes. Fiber addition to self-compacting recycled aggregate concrete increased split tensile strength by 10-15% while flexural strength improved by 10%. Concrete's modulus of elasticity has improved. They were also compared to the Indian Standard Code Provisions for Compressive Strength, Split, Flexure and Modulus of Elasticity.

INTRODUCTION

This study looks at the different materials that may be used to make self-consolidating concrete (SCC). SCC is becoming a more popular building material because of its better workability and decreased segregation compared to traditional concrete, as well as its ability to fill in complex formwork sections. SCC has the potential to save energy consumption, costs, and construction time due of its ability to flow and self-compact under its own weight. Despite the fact that SCC is a sustainable concrete in the sense that it uses less energy in its manufacturing as there is no vibration involves in casting of SCC, the ingredients used to produce it constitute a sustainability danger to the environment. SCC's primary binder, ordinary Portland cement (OPC), uses a lot of energy and emits a lot of carbon dioxide into the environment. For this reason, as well as environmental degradation, mining and processing of natural aggregates for use in SCC is a significant source of carbon emissions. Another issue that prevents the widespread adoption of SCC is its high production costs. OPC makes up a significant part of the cost of SCC production since it is used more than regular concrete (CC). As a result, providing alternative materials as a substitute for traditional materials may make SCC more sustainable, and it can also save money while attaining desired SCC characteristics. To achieve sustainability, waste materials are utilized as recycled aggregates. The conversion of this trash into RA (Recycled Aggregates) is a critical step toward creating a more sustainable world. Using RA in concrete instead of discarding it helps to ensure the long-term viability of natural aggregate sources. Concrete recycling is critical for environmental protection and efficient resource use. The use of recycled aggregate in concrete production is now limited, and large amounts of concrete waste are accumulating at disposal sites. Engineers have a difficult task in incorporating these RMC wastes into concrete, and many studies are ongoing.

Recycled concrete aggregate (RCA) is made from buildings waste that have been dismantled for a variety of causes, including the necessity for new building or natural and human catastrophes. When concrete structures are crushed and ground into smaller bits, RCA is produced. This RCA may be utilized as an aggregate in new concrete projects. Normal aggregates (NA) make up the majority of RCA, with adherent mortar accounting for approximately 35%. When it comes to RCA, whether it's fine or coarse aggregate depends on the size of the crushed rock. The adhering mortar on RCA and the overall property of the RCA may be affected by the parent concrete's properties. When opposed to NA, RCA has greater porosity and water absorption due to the adhering mortar. When RCA is added to a concrete mix, it has a greater porosity, which indicates that it will absorb a lot of water. Furthermore, the presence of greater porosity creates weak spots along the matrix, resulting in poorer mechanical characteristics of the RCA composite Due of its high-water absorption, introducing RCA may impair concrete's workability. As can be observed, mixes containing RCA had greater slump values, which may be ascribed to RCA mixing water absorption. It's also worth noting that as the RCA contents have grown, no clear pattern has emerged.

The undertaken “concrete” material for this method is considered because of

- Eco-friendly nature of the SCCs
- Recyclable
- Availability

To compute the characteristics of “SCC”, a number of examinations are conducted, including the passing ability test (L-box), the flowing ability test (V-Funnel and slump T50), the segregation resistance test (U-Box) for “fresh concrete” and, the compressive and flexural strengths, durability, tensile strength, and split tensile strength to determine hardened concrete, characteristics. Several types of performance measures are utilized to measure the quality of proposed SCC, which helps in comparing the systems and motivating the progress. There are many features that differentiate it from other materials, including its workability, which surpasses the maximum degree of consistency defined in EN 206.

Ability for filling, Ability to passing and Resistance to segregation

All three of the above-mentioned criteria must be met by a concrete mix in order for it to be classed as Self-compacting Concrete.

SCOPE OF RESEARCH WORK

Every day, a large quantity of trash is generated in India. Nowadays, similar waste materials are being reused in concrete structures. Rice husk, coconut coir, sugarcane stems, and banana stems are readily accessible as trash in the southern region of India. Such materials must be carefully selected and handled before being used as additives in concrete to change some of the characteristics of it. A fibrous concrete composite material made from these waste components was examined in this research. Concrete construction projects for infrastructure development are on the rise all around the globe, driving up the price of construction materials. Concrete's primary component is aggregate. The scarcity of aggregates has recently arisen as a significant issue due to the widespread use of blasting in mining. Finding alternatives or replacements to a certain degree is necessary to overcome this. Many recycling facilities now recycle destroyed materials, allowing them to be used into building materials (mostly coarse aggregate and sand) instead of landfill. In order to save money and improve the workability of concrete, many typical kinds of construction debris may be utilized in SCC.

The recycled aggregate was collected in large lumps and later they were made it into small lumps manually through pounding it with hammer so that they are suitable to move it into crusher. The screen in crusher is arranged to get 12.0 mm down size of aggregate after crushing the small lumps of “recycled coarse aggregate” and the aggregate was transported from the crusher unit to the research laboratory via a conveyor belt. The sieve analysis of recycled coarse aggregate is shown in Figure. (RCA). 12.0 mm aggregate has a specific gravity of 2.49 and a water absorption rate of 4.45 percent, respectively.

Figure 1 Coarse aggregates to be recycled

Advantages of recycled aggregate

Cost Saving: - Materials are less expensive to produce as need not produce as per normal production and need not to pay royalty. Able to lay down a firm base or foundation withminimum cost.

Save time: -There is no need of booking, ordering and waiting for availability.

Less emission of carbon due to less crushing.

Eco Friendly: - It is the green construction material. Use of recycled aggregates are giving less chance to explore natural aggregates which results in saving environment and ecology ofrock.

Versatility: - Recycled aggregates can be used for number of different functions that are suitable for construction applications, land fillings, landscaping projects and homeimprovements endeavors etc.

Durability: - Recycled aggregate is structurally reliable and safe for use as natural aggregate materials.

PROPERTIES OF RECYCLED AGGREGATES

Because aggregates and their characteristics have an impact on the final product, many important criteria of normal aggregates and recycled aggregates have been evaluated in order to produce grade M30 concrete throughout the manufacturing process.

The physical examination of both normal aggregate and recycled aggregates Fig. 2 had shown that the aggregates' form was angular in both cases. It was discovered, however, that recycled aggregates had a rough texture as a result of the attached amount of mortar in their composition.

Fig.2 Normal Aggregates / Recycled Aggregates

Flakiness Index of Normal and Recycled Aggregate (IS2386, part I -1963):

This indicator indicates the proportion of particles with a weight less than 30% of their mean dimension (as measured by their weight). The test is associated with aggregates larger than 6.3 mm in diameter. The test is conducted using a single-ended metal feeler gauge. The results obtain are as follows.

Flakiness Index for normal aggregate — =21 %

Flakiness Index for normal aggregate — =13.3 %

Excess of flaky particles in concrete aggregate increases quantity of water and sand which decreases workability and affects the durability. Flaky particles in concrete more than 15% are not desirable.

Elongation Index of Normal and RCA (IS 2386, part I - 1963):

It is common practice to conduct this test at the same time as the flakiness index test. The elongation index is defined as the percentage of particles by weight with a longest dimension (length) more than 1.8 times the mean dimension (in mm). The elongation index is defined as the weight of material in various slots expressed as a percentage of the overall weight of sample.

Tests conducted on Normal and RCA as per IS 2386-1963,

IS code 2386 denoting an aggregate's specific gravity (part III) -1963 Water Absorption Test: This test was conducted in line with the specifications specified in IS Code 2386 (Part III)-1963. The Aggregate Crushing Test is specified in IS code 1963-2386. (part IV) Test of Bulk Density-1963-IS code 2386 (part IV) Test for the Aggregate Impact Value-1963-IS code 2386 (part IV) Test of Bulk Density-1963-IS code 2386 (part IV)

Table 1 Results of Recycled Aggregates vs. Regular Aggregates

No	**Test conducted**	**Normal aggregate results**	**Standard Limits**	**RCA results**
1	"Specific gravity"	2.62	Min 2.6	2.34
2	"Water absorption %"	1.27 %	Max 3	7.1 %
3	"Crushing value %"	32	Max 30	13.20 %
4	"Impact value %"	18.70%	Max 30	14.4 %
5	"Bulk Density"20mm 10mm	1520 Kg/m^3 1510 kg/m^3		1310 kg/m^3 1250 kg/m^3
6	"Flakiness Index"	22 %		13.2 %
7	"Elongation Index"	23.9 %		17 %

Bulk density for Normal and Recycled Aggregate-

The ratio of aggregate net weight to the aggregate volume gives bulk density. The bulk density is generally expressed as Kg/Lit

The ratio of aggregate net weight to the aggregate volume in kg/liter gives the bulkdensity.

The various on bulk density factors affecting are as follow:

1. Degree of compaction: Greater compaction gives greater bulk density.
2. Grading: Bulk density increases with improvement in grading as graded aggregatehas less voids.
3. Shape: Rounded particles have greater bulk density, due to fewer voids.

If the mass of material is divided by volume of material, then resultant quantity coming is called Bulk Density. The aggregate is packed or not is known by bulk density measurement. The moisture content, size, shape and grading of aggregate are the factors which affects bulk density. The particles shape affects greatly the packing's closeness which is determined. If the bulk density values are more that clearly means that less voids are to be fill up by cement as well as sand. For calculating there was recommendation by code is known as aggregates bulk density for that particular sample. The recycled aggregates bulk density was found out for size 20 mm as 1320 kg/ m^3 . The recycling aggregates bulk density for sample of size 10 mm found out 1260 kg/m^3. As per as bulk densities of size 10 mm & 20 mm were determined to be 1500 kg/m^3 and 1510 kg/m^3. So these results revealed that denseness of aggregates and uniformity of grading.

INGREDIENTS IN SELF-COMPACTING CONCRETE (SCC)

Cement: Ordinary Portland cement and Portland clinker were the cementitious materials utilized in this research (OPC). 12269-1987, The physical characteristics of the cement are as follows: consistency (37%), specific gravity (3.23), initial setting time (5 minutes), final setting time (355 minutes), fineness (1 percent residue) by sieve test, and soundness (1.5 mm).

Fine Aggregate: Sand having its particle size of less than 4.75 mm, which corresponded to "grading Zone III of IS 383-1970". In accordance with IS 2386- IS code for "Methods of Test" for "Aggregates", the physical properties of sand has determined, and the following outcomes were drawn: 4.75mm maximum size, 1696kg/m3, specific gravity 2.62, water absorption (percentage) 1.37, fineness modulus 3.39, and a void ratio of 37.59 percent are all measured in kg per cubic meter.

Fly ash: It is beneficial to utilize Using fly ash as a partial substitute for cement is a good idea. because of the longevity of the concrete as well as the benefits to the environment that it provides (Snehal Afiniwala et al 2013). In this application, fly-ash (Class-F) in accordance with "IS 3812 (Part I)" has been utilized as a partial substitute for "cement" to save costs.

Coarse Aggregate: Natural crushed aggregates from a quarry (gravel) with particle sizes ranging between 12.5 mm and 20 mm were utilized in this project. The physical findings of "coarse aggregates" were evaluated related to the International Standard IS: 2386. Specific gravity is 2.78, the impact value is 17.18 percent, the crushing value is 21.46 percent, the water absorption is 1.56 percent, the abrasion value is 24.4 percent, the fineness modulus is 5.25, the void ratio is 45.61 percent, and the bulk density is 1610 kilograms per cubic meter.

Recycled Coarse Aggregate: The recycled aggregate was collected in large lumps and later they were made it into small lumps manually through pounding it with hammer so that they are suitable to move it into crusher. The screen is arranged in crusher to get 12.0 mm down size of aggregate. After crushing, the small lumps of recycled coarse aggregate was transferred to research laboratory. The tests like specific aggregate density and water absorption were done and the sieve analysis is conducted as shown in Table 4.6. "Specific gravity" and "water absorption" of 12.0 mm gravel are 2.49 and 4.45% respectively.

Silica fume: The silica fume was supplied by 'SAKSHI CHEM SCIENCES PVT LTD,' and it was in line with ASTM-C standards (1240-2000). Micro silica 920 D is the brand name for this particular product. The silica fume is utilized to partially replace the cement in certain applications.

Superplasticizer: Superplasticizer was used to obtain sufficient workability for the mixes of low water to cement ratios. It was a Sulphonated Naphthalene formaldehyde type of super plasticizer. Master Glenium Sky 8233, BASF Chemical Company Limited, Mumbai, provided the superplasticizer (HRWRA) with specific gravity 1.220-1.225, pH > 6, Aspect Light Brown Liquid, and Relative Density 1.08 + 0.01 at 25°C. (According to the manufacturer's manual)

TESTING PROGRAM

Mixing of relative quantity of the different ingredients used in concrete may be established with the goal of achieving a significant strength while doing it in the most cost-effective manner is called "Concrete mix design". This examination has been carried out in as per "IS: 10262-2009" for preparation of M60 grade of concrete. The proportions of the mix employed in this investigation were as follows: "1.83 2.51 0.3 (C, FA, CA, w/c)" and "1.83 2.51 0.3 (C, FA, CA, w/c)" At 28 days. Intended mean strength for this case is 48.22 MPa, according to the manufacturer. Extensive experimental work was conducted to investigate the change of different factors on "compressive strength", "split tensile strength", "flexural strength", "modulus of elasticity", and "stress-strain curve" of HSC as well as HSSFRC while they were under compression or in tension. The following is the approach that was used in the preset study.

The test program was planned as follows:

First the preliminary tests regarding the properties of materials were conducted to arrive the suitable mix proportions as describe in previous chapter.

Second, the workability and strength tests were conducted based on the mix proportions determined from the preliminary tests.

Third, Main test: This test was conducted to find the mix proportions effect related to the structural properties of beams when subjected to static and repetitive stress.

Various tests conducted are

Workability test: Slump test and Compaction factor

Mechanical properties: "Compressive strength", "Split tensile strength", "Modulus of rupture", "Flexural toughness", "Modulus of Elasticity", "Stress-strain curve" under compression. Flexural behavior of beams under static and repeated loading.

Parameters for testing

A wide range of factors may have an impact on the performance of concrete. Most affecting circumstance to be considered while preparing and testing various specimens for this experiment was the replacement of "normal coarse aggregate" in various proportion to "recycled coarse aggregate" in various proportions, dosage of super plasticizer, cement replacement levels with varying proportions of silica fume, use of stone powder and fly ash as filler materials in various percentages, addition of coconut fiber in different volume fractions, and the testing ages

Table 2 Parameters for specimen preparations

Parameters	Range

Super plasticizer	Dosage of 5ml, 10ml and 15ml for all " w/c Ratios" (0.33, 0.3, 0.27, 0.25)
Cement replacement levels	With SF and Fly ash 5%, 10%, 15%, 20%, 25% and 30%
Coarse Aggregate replacement	With RCA 20%, 40%, 60%, 80%, and 100%
Coir fiber	0.1%, 0.3% and 0.5%
Testing ages	3, 7, 28, 90 and 180 days

Specimen Details for HSC and HSSFRC

Compressive strength was determined using specimen of "size 150 mm x 150 mm x 150 mm", tensile strength was determined using round beams of "size 150 mm diameter and 300 mm long", modulus of elasticity was obtain using cylinders of size 100 mm x 500 mm, and flexural strength was determined using reinforced concrete (R.C.) beams of "size 150 mm x 250 mm and 3000 mm", and modulus of rupture was determined using cube. In the experiments, silica fume was used to substitute cement in proportions of 0, 5, 10, 15, 20, 25, 30 and 50%, Mixtures with varying percent replacements of "normal coarse aggregate" to "recycled coarse aggregate" were produced in increments of 20 percent, ranging from 0 to 100 percent replacement of normal coarse aggregate to recycled coarse aggregate. The percentages of stone powder and fly ash used in the aforementioned mixtures varied significantly. Six samples of each mix have been casted to find compressive strength at various ratios of cementing material, and curing times, and three samples were cast for assessing other characteristics, with three samples for each mix. All specimens were cast, let to cure normally, and then subjected to strength testing to determine their overall performance.

TEST RESULTS

RCA has a water absorption capacity higher than that of natural aggregates, as can be shown in Table 3, which shows that the puros nature of "RCA" is higher as of the "natural aggregates". In the RCA concretes, this increases the possibility for water exchange with the surrounding paste, allowing the SCC mortar to absorb or provide more water to the RCA particles as a result of the increased water exchange potential. In order to avoid bias when comparing RCA concretes with natural aggregate-only concretes, RCA should be utilised in the dry stage since it may absorb water from the mortar phase and increase water content somewhat in the saturated phase.

Table 3. SCC fresh Property results

"Mixture No"	"Slump Flow,mm"	"J-Ring, mm"	"Passing Ability, mm"	"Filling Capacity" %	"Column Segregation" %
A1	71	586	12	84,8	2.7
A2	85	-	-	-	-
A3	81	594	0	83,1	6.3
A4	86	610	12	83,7	6.4
A5	78	-	-	-	-
A6	71	587	7	85,7	2.8

A7	73	590	19	84,0	4.7
A8	78	635	57	85,0	9.1
A9	81	622	19	86,3	4.2
A10	81	634	25	84,3	6.3
A11	84	585	0	85,4	10.1
A12	84	571	51	78,2	1.6
A13	86	622	38	87,3	3.3
A14	87	597	25	81,9	5.1
A15	84	622	21	86,4	8.0
A16	81	634	57	82,2	2.0
A17	84	631	54	82,9	10.1
A18	86	634	58	81,9	9.5
A19	88	641	58	82,5	-
A20	91	643	59	83,7	9.9
A21	78	634	58	86,4	11.8
A22	63	631	40	83,5	5.1
A23	62	634	57	83,7	3.4
A24	62	641	57	77,4	2.2
A25	64	638	59	87,6	9.9

Slump test

Conforming to IS 7320-1972, the slump was performed.For the slump testing, several mixes were created by

substituting recycled coarse aggregate produced from waste concrete for the usual fines in the original mixtures. The change in percentage varies from 20 percent to 100 percent recycled aggregate with interval of 20%. It is found that reduction in slump varies from 25 per cent to 58.3 percent. It is observed that slump decrease with recycled aggregate replacement level. With 0% recycled aggregate in the control mix the slump is uppermost. Level of replacement from 20% to 100% shows linear reduce in slump as the recycled aggregate increases.

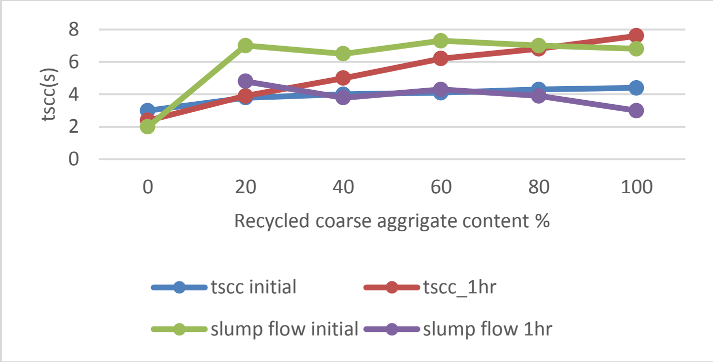

Figure 4: "Effect of RCA content on slump flow and t 500 for SCC"

There is a similarity in test series conducted for various water-cement ratio. Coarse recycled aggregates have a greater ability to form mortar paste due to which any addition of water will gets soaked which then results low contact of water to concrete. Which ultimately results in reduction in slump due to loss of workability. Findings of the tests, Normal Concrete Recycled Concrete (20%)- 60, Recycled Concrete (40%) – 45, Recycled Concrete (60%) -40, and Recycled Concrete (80%) – 28 with reduction of slump in percentage 0, 25,

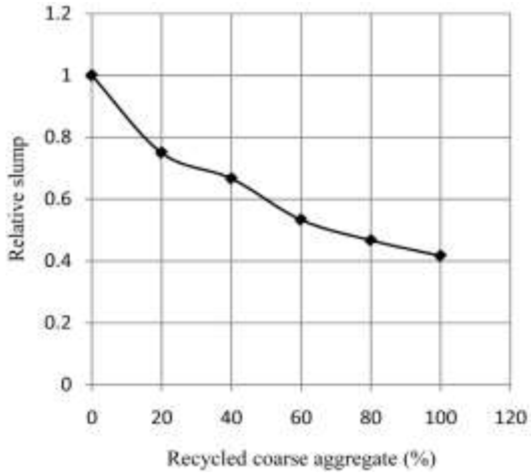

Fig 5- Relative Slump vs recycled coarse aggregate.33.5, 46.7, and 53.3 respectively.

DENSITY OF CONCRETE

The table is giving the values of density when replacement was done by recycled aggregate partially as well as fully. It can be concluded that the "density" achieve from replacing aggregate by recycled aggregate was not having any consistent relation for 3 day and 14 days. For 3 day and 14 days there was tolerable performances found. But as days increases the densities was decreased with increase of recycled aggregate percentage. The table is showing the test results. The density was too much less for completely 100 % replacing of waste recycled aggregates. It reduces 7.1 % density in case 100 % replacing the recycled aggregate to normal aggregate. And it reduces just 1.1 % density in case replacing the 20 % percentage. This is just because the 100 % replacing was having more mortar attachment to recycled waste aggregate. The recycled waste aggregate has more air contains than traditional aggregate. It increases the porosity due to aeration. Thus, it had more air content therefore densities were also less. This density values were found same to other research papers value which had done same study.

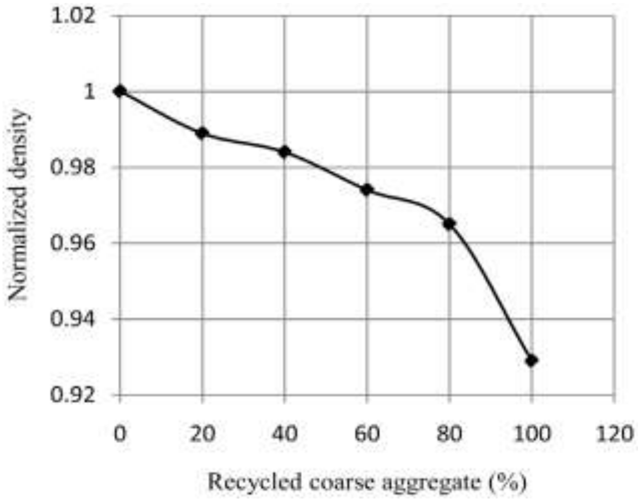

Figure 6 Density related to reference concrete of recycled aggregate for 28 days.

L-box test:

The results of the L-box computer test are shown in Figure 5.2. This test determines the SCC's passage ability and quantifies its appropriateness for usage in a member with crowded reinforcement. When coarse RCA is used in place of natural fine aggregates, only a very small decrease in B0 is seen at the 80 percent and 100 percent RCA usage levels, as shown in the figure The contrast between the control SCC and the SCCs containing 80 percent RCA and 100 percent RCA becomes much more apparent an hour after mixing, when the L-box test is carried out. According to the results, the blocking ratio was decreased by about 8% and 10% when RCA SCCs made up of 80% and 100% of the samples were compared to the control SCC.

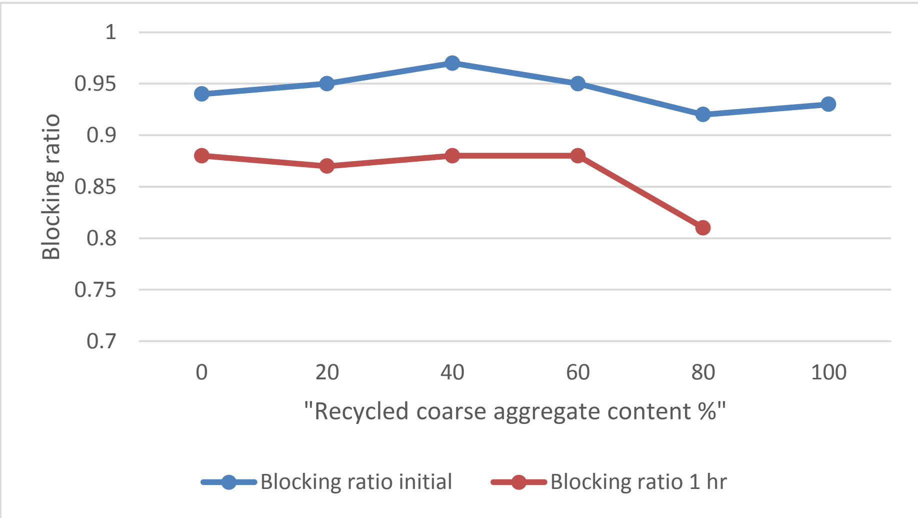

Figure 7: “Effect of RCA content on Blocking ratio of SCC mixes”

The passing ability tolerance for the SCC containing 100 percent RCA is 0.80, which is in line with the findings of the slump flow test. The RCA's continuous absorption of free water after concrete mixing may have produced this time-dependent shift in blocking ratio at greater levels of RCA utilisation. When the RCA concentration of the cells was raised, the segregation resistance of the SCCs increased as well. This is most likely because recycled concrete aggregates have a higher water absorption capacity, as previously mentioned. Using EN206-9:2010 as a guide, all of the SCCs were found to be appropriate, with each SCC mix falling into the sieve separation resistance class SR2 (segregation component 15%) and each SCC mix falling into the sieve segregation resistance class SR3.

IMPORTANT FINDINGS OF THE STUDY

Strength Properties. Figure 8 presents the test outcomes for "concrete compressive strength", "splitting tensile strength", and the "static modulus of elasticity" in relation to the control mix results. FIGURE 5.8 makes it simple to compare the test outcomes for the control mix and the test outcomes for demonstrating the strength characteristics of the RCA SCC compared to the control SCC Take, for example, the RCA 40 mix. Its compressive strength value was 8 percent higher than the compressive strength value of the control mix, resulting in an overall relative compressive strength performance of 108 percent. As a result, the RCA with a 40 percent compressive strength bar in (figure 5.8) is located above the 100 percent line, indicating that it has a greater compressive strength than the SCC in control.

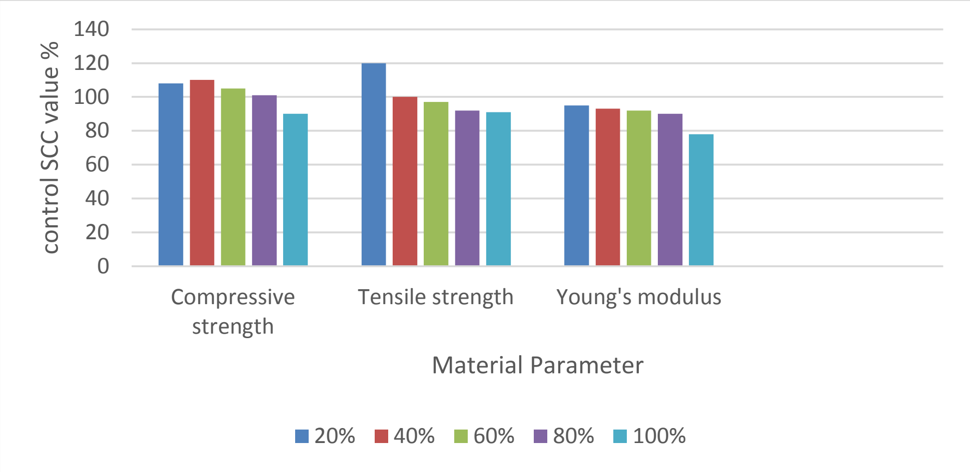

Fig.8:"Relative comparison of RCA and control concrete strength properties".

It's clear from Figure 5.8 that using recycled concrete in place of conventional aggregates results in an increase in compressive strength of between 8% and about 11%. The rate of "compressive strength" reduction is nearly precisely identical to that of the "control concrete" at 40 percent exchange, while the rate of "compressive strength" reduction up to 10 percent lower at 100 percent replacement with recycled aggregate. SCC concretes having different percentages of these materials may be compared by 20 percent, 40 percent, and 60 percent RCA for a concrete with a weight-to-compaction ratio of 0.33, the results were almost identical. It is discovered that the change in compressive strength is "+6 percent, +9 percent, and 2 percent" for "20 percent, 40 percent, and 60 percent replacement", respectively. In an investigation of "high-performance vibrated concretes", similar patterns were discovered, but the modifications for the vibrated concretes under investigation were on average smaller in stature

Compressive strength increased by up to 50% with the addition of RCA, which may be due to a number of factors. We have discussed the fact that enhanced surface roughness of recycled aggregates may result in improved cement aggregate bonding in this research. The function of the differences in "water absorption coefficients" between recycled aggregates and normal aggregates is also likely to have an impact in some way on this. In these and other published research, it has been shown that Increasing water absorption, reduces the w/c ratio in the ITZ, thus enhancing the strength of the cement slurry while simultaneously strengthening the connection among aggregates and cement. However, as previously stated, if an excessive amount of water is absorbed, the concrete will have inadequate water content and poor hydration, which will result in a reduction in strength development. A potential reason for the rise in "compressive strength" up to 40 percent RCA level, followed by a reduction in "compressive strength" from 50 percent RCA to 100 percent RCA is the optimum water content balance, where the w/c ratio stays constant at 0.33 regardless of the RCA concentration. It should be noted, however, that the compressive strength was found to drop by less than 10% even after 100 percent substitution with RCA, suggesting that RCA is a suitable material for this application. According to Figure 5.6, the tensile strength findings follow a similar trend as the "compressive strength" results, with the "tensile strength" first rising at lower levels of RCA usage and then decreasing as the percentage of RCA content increases beyond 50 percent. The tensile strength of the 40 percent RCA replacement is almost 18 percent higher than that of the control SCC replacement. When the RCA content is higher than 40%, the tensile strength changes in a more subtle manner. A comparable case study revealed that the tensile strength of SCCs with 40 percent RCA coarse aggregates and 100 percent RCA coarse aggregates was reduced by about 2.8 percent and 16 percent, respectively, when compared to SCCs with the control mix. When compared to natural aggregates, we discovered that the splitting tensile strength of 20 percent, 40 percent, and 60 percent RCA decreased by 8.3 percent, 10.1 percent, and 14 percent, respectively. This was due to the greater porosity and lower specific gravity of the RCA. It should be noted, however, that, in contrast to the results of the experiments conducted herein, higher water content in mix designs was shown to be associated with increased RCA concentration. As a consequence, we discovered that the application of 20 percent RCA improved the splitting tensile strength by between roughly 3 percent to 21 percent, which is consistent with the findings presented here. Finally, in terms of Figure 5.8, it is evident that the use of RCA at any degree of replacement resulted in a decrease in the modulus of elasticity of the material. As the proportion of RCA rises, the decrease in modulus of elasticity increases, reaching a maximum of 22.2 percent for the concrete that contains 100 percent of RCA. The decrease for the 80 percent RCA mix is similarly significant, coming in at 9.5 percent of the overall reduction. It has been pointed out by, that such reductions are anticipated given that the modulus of elasticity of concrete is linked to the modulus of elasticity of coarse aggregate, with research showing that the modulus of elasticity is proportional to the inverse of the aggregate density (Figure 1).

With respect to the three strength property tests, the experimental programmed found that using RCA in proportions ranging from 20% to 40% does not have a detrimental effect on the compressive and tensile strength of SCC in the long term. In fact, even at the highest level of RCA usage, decreases in these metrics were less than 10% when compared to the SCC used as a reference for comparison. But as the use of RCA increased, the decrease in young's modulus grew more apparent across all SCCs, with the elasticity module for the 100 percent RCA SCC being 22 percent less than that of the control SCC, indicating a problem with the brittleness of SCCs completely made of RCA..

Fracture Properties. After determining the fracture properties of both control SCC and the mixed SCC that contains recycled concrete, as described in the preceding section, the results are presented graphically in the form of relative performance, with a plot of the fracture properties of each mix containing recycled concrete plotted against the values for the control SCC. This makes it simple to compare the performance of the RCA and SCC mixes, as well as the control SCC mix, on a visual basis. The change in fracture energy as a function of increasing RCA concentration is shown in Figure 5.9. RCA was shown to have a very little effect on fracture energy in concrete, as can be seen in the plot, with the fracture energy of the concrete being 93.7 percent and 93.4 percent of the control concrete, respectively. However, at the 60 percent RCA utilization level, a dramatic decrease in fracture energy occurs, with the 80 percent RCA mix and the 100 percent RCA mix both resulting in a 24 percent reduction in fracture energy. Despite this, there are only a few numbers of research that have examined the fracture energy of conventional vibrated concretes that include RCA, with some studies only considering RCA concentrations of 0 percent (control) or 100 percent (experiment). We looked at a control concrete, RCA concrete at 40 percent, 60 percent, 80 percent, and 100 percent, and RCA concrete at 100 percent RCA. This trend was seen in a previous study, which showed that fracture energy was 95.8 percent of the control concrete at a 40 percent replacement level; however, for the 100 percent RCA vibrated concrete, the fracture energy was decreased by 34 percent compared to the control concrete A balance between aggregate strength and aggregate bond may explain the trend of sustained fracture energy up to 40 percent residual fracture energy followed by a sharp decrease at RCA levels higher than 40 percent.

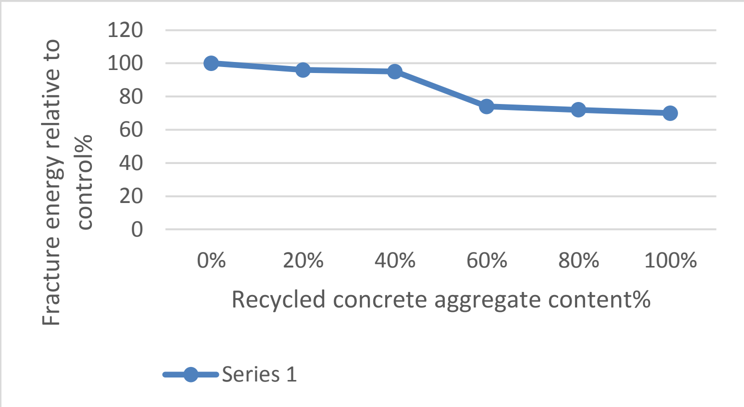

Figure.9: “Influence of RCA content on fracture energy”

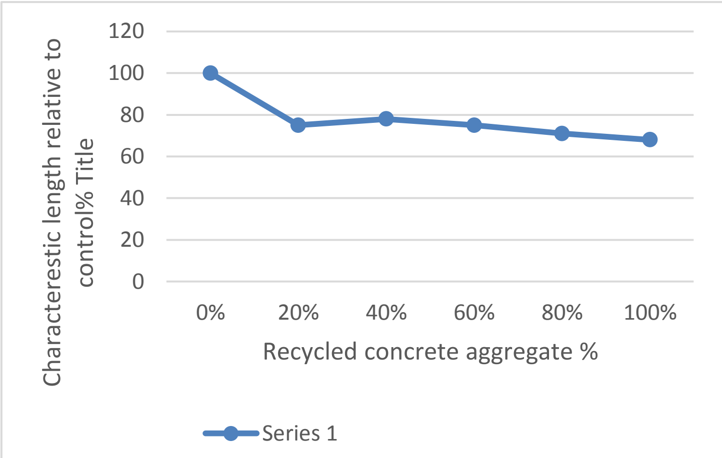

Figure 10: “Influence of RCA content on characteristic length”

Because of the use of RCA, it is possible to strengthen the binding between aggregate and cement paste; nevertheless, it is usually observed that when aggregate strength falls, fracture energy reduces. As a result, if a significant proportion of the overall coarse aggregate volume is composed of the weaker RCA (as compared to natural aggregate), it is reasonable to anticipate the fracture energy to be reduced significantly. The fact that this does not occur until after SCC has reached the 40 percent RCA utilisation level studied in this study, on the other hand, is a fascinating experimental result. The change in characteristic length, lch, mod, as a function of increasing RCA concentration is shown in Figure 5.10. Mod parameter, as mentioned in Section 2, assesses the brittleness-derived fracture energy as well as the modulus of elasticity and the compressive and tensile strengths of materials. RCA concretes exhibit a significant decrease in characteristic length (i.e., enhanced brittleness), as can be seen in the plot, with relative lch, mod values ranging from 78.8 percent to 66.0 percent for the RCA concretes when used at all levels. For the most part, this is due to the concrete's reduced modulus of elasticity, which is the major reason (discussed previously in the context of Figure 5.9). Because the 20 percent RCA mix has significantly higher fc and ft values than control concrete, the low relative lch,mod value may be explained by the higher fc and ft values seen in the 20 percent RCA mix. Again, due to a dearth of prior research in this area, we are unable to compare our findings with those of other studies looking at SCC, including RCAs. This research, on the other hand, found typical length values for a wide range of vibrated concretes including RCAs. There were reductions in characteristic length ranging from 0% to 35% with an average reduction of 16% when using 100% recycled concrete in three different concrete strength groups compared to control concrete. Using RCAs resulted in significantly more brittle concrete, with differences in characteristic length ranging from 18% to 31%, according to the conclusions of the study given above on SCCs and RCAs.

CONCLUSIONS

- The results of the testing programmed showed that the use of RCA in amounts ranging from 20 percent to 40 percent did not have a detrimental effect on the compressive and "tensile strength" of the SCC.
- As an example, the "compressive strength" of the RCA 40 mix was 6 percent higher than the "compressive strength of the control mix".
- Fracture energy was determined to be 97.8% of the control concrete's value at the 40% replacement level, while it was decreased by 34% for the 100% RCA vibrated concrete.
- According to the test findings, the "compressive strength" of plant B samples, which include 10 percent "silica fume", is higher than the "compressive strength" of plant A specimens, which contain 5 percent "silica fume" content, and even higher than the "compressive strength" of 15 percent silica fume (Plant C specimen).
- The highest value of split tensile strength achieved is 7.16 MPa, which is about 25 percent higher than the value produced with the control concrete. The highest strength is achieved for 10 percent silica fume concrete after 28 days of curing time.
- As "silica fume" is substituted for cement by 10%, the highest increase in modulus of rupture found at 28, 90, and 180 days is 15.48 percent, 17.5 percent, and 16.84 percent, respectively, when compared to control concrete.
- The combination of cement with 10% silica fume and 0.3 percent coir fiber in volume fractions had the best compressive strength results on the 3, 7, 28, 90, and 180-day tests, out of all the combinations tested.
- To guarantee that silica fume concrete and silica fume concrete mixed with coir fiber has adequate workability, it was determined that the superplasticizer dose for this HSSFRC should be 10 mm per kg of cement.
- With increasing silica fume concentration, as compared to control concrete, the compressive strength grows more rapidly. Using OPC cement to replace 10% of the silica fume in a concrete mix, the highest improvement in compressive strength was 11.21 percent, followed by 13.62 percent, and then 11.84 percent after 28 days, 90 days, and 180 days of curing.

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