Comparative Study on the Fresh & Hardened Properties of SCC with C&D Waste Recycled Aggregates

Sneha J.[1*], Anju Thulasi[2]

[1]Dept. of Civil Engineering, Sree Narayana Institute of Technology, Adoor, Pathanamthitta Kerala, India,
[2]Assistant Professor, Dept. of Civil Engineering, Sree Narayana Institute of Technology, Adoor, Pathanamthitta Kerala, India,

*Corresponding author's e-mail: snehajsnit1263@gmail.com
doi: https://doi.org/10.21467/proceedings.160.15

ABSTRACT

The majority of the solid waste produced worldwide comes from construction and demolition (C&D) debris, which is then dumped in landfills. But there is a possibility of appropriately treating and reusing such waste as aggregate in new concrete. Self-Compacting Concrete (SCC) is a high- performance concrete mixture that flows under its own weight while yet exhibiting enough segregation resistance. C&D waste recycled coarse aggregates (RCA) use in SCC has the potential to lessen the cost and environmental impact of concrete. In order to test the impact of RCA on the characteristics of SCC, RCA is employed in the manufacturing of SCC in varied percentage replacements of natural coarse aggregate (NCA).

Keywords: Construction and Demolition (C&D) waste, Self- compacting concrete, Recycled coarse aggregate.

1 Introduction

Concrete that self-compacts or consolidates is one of the notable and inventive advancements in the building industry recently. The key advantage of employing SCC is that it can compact on its own weight without the requirement for vibration. This technology has been used in several nations for building construction. SCC can be used to cast substantially reinforced sections, in locations without access to vibrators for compaction, and in intricate formwork shapes that might otherwise be impossible to cast.

Recycled aggregate concrete (RAC) is typically made from demolition and construction waste and either totally or partially substitutes natural aggregates. Reusing demolition trash can also assist close the gap between aggregate demand and availability for freshly crushed stone. Natural aggregates may completely or partially replace RCA from construction demolition sites in the production of SCC.

2 Literature Review

Garcia-Troncoso, *et al.* (2021) studied the performance of SCC with the incorporation of different types of recycled aggregate such as brick aggregate, concrete block aggregate, concrete aggregate. The study concluded that 100% replacement is possible for concrete brick aggregate (CBA) as there is only slight decrease in the strength. The study has also demonstrated that at high temperatures (400°C and 600°C), both the recycled block aggregate and CBA concretes performed well better than the natural aggregate concrete.

Dong, *et al.* (2022) focused on the significance of transforming waste plastic, industrial byproducts, and concrete waste into sustainable materials for concrete. The findings indicate that by incorporating recycled plastic fibers (RPFs) and supplementary cementitious materials (SCMs) into SCC, the resulting products demonstrate enhanced ecological friendliness. Furthermore, the study observed that the enhancements in mechanical properties achieved through the combined inclusion of recycled plastic fibers (RPFs) and supplementary cementitious materials (SCMs) were significantly more pronounced compared to the improvements obtained when incorporating RPFs and SCMs individually.

Proceedings DOI: 10.21467/proceedings.160; Series: AIJR Proceedings; ISSN: 2582-3922; ISBN: 978-81-965621-9-9

3 Materials and Methodology

This study utilized a combination of sand, cement, fly ash, natural coarse aggregate, and recycled coarse aggregate as its materials. Multiple properties of these materials were examined, such as water absorption, particle size distribution, specific gravity, and bulk density of aggregates. The research also focused on investigating the fresh and hardened characteristics of Self-Compacting Concrete (SCC) incorporating recycled coarse aggregate.

3.1 Materials Used

This research primarily employed Ordinary Portland Cement (OPC), fly ash, coarse aggregate, fine aggregate, recycled coarse aggregate, water, and superplasticizer as its main raw materials.

3.2 Mix Proportion

- For this research, a Self-Compacting Concrete (SCC) of M30 grade was formulated using a design ratio of 1:1.53:1.38 (cement, fine aggregate, coarse aggregate). The mix design was carried out according to the ACI (American Concrete Institute) method, specifically following the guidelines outlined in ACI 211.1.
- Following the establishment of the design ratio, the fresh properties of the self-compacting concrete (SCC) were examined to determine whether they met the specifications set by EFNARC (European Federation for Specialist Construction Chemicals and Concrete Systems) regarding filling ability, passing ability, and segregation resistance. The water-cement ratio employed in this research was 0.423.
- For experimental purposes, a total of eight concrete mixes were created. In each mix, the natural coarse aggregate was substituted with recycled coarse aggregate, with a specific replacement ratio of 0%, 5%, 10%, 15%, 25%, 35%, 45% and 55% by volume as shown in Table 1.

Table 1: *Mix Designation with Respect to Replacement Percentage*

Mix designation	Coarse aggregates	Recycled coarse aggregate
NC-SCC	100%	0%
M1	95%	5%
M2	90%	10%
M3	85%	15%
M4	75%	25%
M5	65%	35%
M6	55%	45%
M7	45%	55%

4 Experimental Methods

The testing phase of the research was divided into two main parts: the evaluation of fresh properties and the examination of hardened properties. The fresh properties of self- compacting concrete, including tests such as Slump Flow, L- box, and V-funnel, were conducted, and the results were recorded in Table 3. Laboratory testing was conducted to assess the hardened concrete properties, including compressive strength, flexural strength, and split tensile strength. The findings are presented in the form of graphical plots, along with discussions and analysis. Additionally, a comparative study between self-compacting concrete utilizing recycled coarse aggregate (RCA) and natural coarse aggregate (NCA) is also provided.

4.1 Fresh properties of SCC

The primary distinction between SCC and regular concrete lies in their fresh behavior. SCC needs to exhibit specific fresh properties, including the ability to flow, pass through obstructions, and fill spaces without segregation or bleeding. Consequently, evaluating the fresh behavior of SCC is crucial before its casting. The flowability of SCC mixtures was assessed through tests such as the slump flow test and J-ring test. The V-funnel test and slump flow time were employed to test the filling ability and viscosity of SCC mixtures, while the L-box test was used to evaluate their passing ability.

4.2 Hardened properties of SCC

To investigate how the mechanical properties of SCC are affected by RCA, different mixtures are prepared with varying percentages of RCA relative to the weight of NCA. Each mixture undergoes testing for compressive strength, split tensile strength, and flexural strength at 7 days, 14 days, and 28 days.

Figure 1: *Specimens of compressive strength test.*

The compressive strength test involves casting concrete cubes with dimensions of 150 mm × 150 mm × 150 mm. Figure 1 shows the specimens casted for testing the compressive strength of concrete. For flexural strength testing, plain concrete beams measuring 500 mm in length and 100 mm in width are used. Figure 2 shows the specimens casted for testing the flexural strength of concrete. Split tensile strength is tested using cylindrical concrete specimens measuring 300 mm in height and 150 mm in width. Figure 3 shows the specimens casted for testing the tensile strength of concrete. For flexural strength testing, plain concrete beams measuring 500 mm in length and 100 mm in width are used. During the casting process, compaction is not applied, and the concrete is poured into the molds without additional The tests are performed at intervals of 7, 14, and 28 days to assess the strength properties of the SCC mixtures.

Figure 2: *Specimens of flexural strength test*

Figure 3: *Specimens of split tensile strength test*

5 Test Results and Discussions

5.1 Fresh properties

5.1.1 Slump flow test

The slump flow diameter of all the mix up to M5 fulfilled the requirement of EFNARC 2005. The mixes M6 and M7 show low slump values as the addition of RCA absorbs more water and reduces the flowability of the concrete. Figure 4 shows the spread of SCC during the slump flow test.

Table 2: *Slump Flow Value*

MIX	SLUMP FLOW (mm)
NC-SCC	720
M1	700
M2	688
M3	695
M4	682
M5	675
M6	635
M7	620

Figure 4: *Flow spread of SCC*

5.1.2 J ring test

The J-ring test evaluates the passing ability of SCC through tight spaces, such as reinforcing bars. A specially designed J-ring is placed on top of the slump cone, and the concrete is allowed to flow. The ring helps to simulate obstructions, and the amount of concrete passing through the ring is measured. As the levels of recycled aggregate (RCA) increased, there was an observed increase in the J- ring value, indicating a reduction in the ability of Self- Consolidating Concrete (SCC) to pass through narrow spaces. This can be attributed to the presence of old cement mortars adhering to the RCA particles and the presence of multiple edge angles in the RCAs. When a significant portion of Natural Coarse Aggregate (NCA) was replaced with RCA, the obstructed aggregate particles impeded the flow of SCC. The increased internal resistance and friction caused by these factors negatively affected the concrete's ability to pass through surfaces. Figure 5 represents the result obtained from J-Ring test.

Figure 5: *J-ring test*

Table 3: *J-Ring Test Results*

MIX	J- RING (cm)
NC-SCC	4.2
M1	4
M2	4.9
M3	5.5
M4	5.6
M5	6.0
M6	6.8
M7	7.2

5.1.3 V- funnel test

The V-funnel test was employed to assess the filling capacity of SCC. In this test, the V-funnel was filled with fresh concrete, and the flow time was measured. The flow time refers to the duration between the orifice opening and the complete release of the concrete under its own weight. By examining Table 4, it is evident that the inclusion of RCA leads to an increase in the V-funnel time. Figure 6 represents the V-funnel test.

Table 4: *V-Funnel Test Results*

MIX	V- funnel (sec)
NC-SCC	10.25
M1	10.42
M2	10.41
M3	10.54
M4	11.1
M5	11.3
M6	11.5
M7	11.9

Figure 6: *V-Funnel test*

Proceedings DOI: 10.21467/proceedings.160
ISBN: 978-81-965621-9-9

Series: AIJR Proceedings
ISSN: 2582-3922

5.1.4 L box test

The L-box test is utilized to evaluate the filling and passing ability of Self- Consolidating Concrete (SCC), and any significant instability or segregation can be visually identified. The stability of the SCC, which refers to its resistance to segregation, can be assessed by visual observation. Figure 7 shows the arrangement for L-box test. When examining the concrete sample in the L- box, if the coarse aggregate particles extend to the far end of the horizontal section of the box, it indicates a high level of resistance to segregation. In other words, when the concrete maintains its uniformity and the aggregates are evenly distributed without significant separation, it demonstrates good resistance to segregation. The result of the test is tabulated in Table 5.

Figure 7: *L Box Test*

Table 5: *L Box Test Results*

MIX	L box test
NC-SCC	0.88
M1	0.89
M2	0.89
M3	0.91
M4	0.93
M5	0.94
M6	0.97
M7	0.98

5.2 Hardened Properties

5.2.1 Compressive strength

Table 6 shows the obtained result of compressive strength tests of various mixes and the graphical representation of the result is shown in Figure 8.

Table 6: *Compressive Strength Test Results*

MIX	COMPRESSIVE STRENTH(N/mm^2)		
	7 days	14 days	28 days
NC-SCC	20.8	23.5	29.89
M1	20.4	21.9	29.82
M2	21.13	22.51	29.88
M3	19.14	24.89	29.60
M4	22.51	23.56	29.78
M5	26.66	28.34	29.9
M6	22.23	24.12	28.7
M7	21.03	22.09	28.33

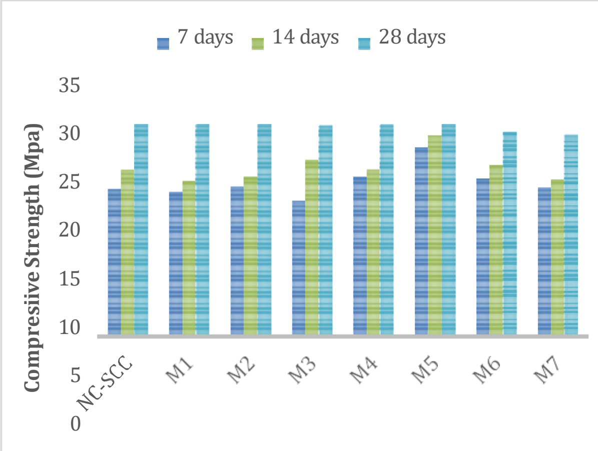

Figure 8: *Compressive strength of different mixes.*

5.2.2 Splitting tensile strength

The test result obtained from the tensile strength testing is shown in Table 7 and the graphical representation of the results is shown in Figure 9.

Table 7: *Tensile Strength Test Results*

MIX	TENSILE STRENTH(N/mm^2)		
	7 days	14 days	28 days
NC-SCC	1.74	2.75	3.83
M1	1.3	2.1	3.8
M2	1.12	1.9	3.84
M3	1.09	2.01	3.79
M4	1.90	1.96	3.65
M5	2.54	2.61	3.79
M6	2.14	2.28	3.61
M7	1.9	1.91	3.55

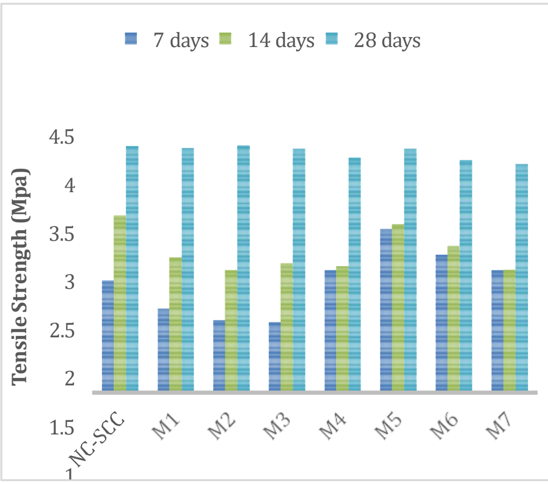

Figure 9: *Tensile strength of different mixes.*

5.2.3 Flexural strength

The test result obtained from the flexural strength testing is shown in Table 8 and the graphical representation of the results is shown in Figure 10.

Table 8: *Flexural Strength Test Results*

MIX	FLEXURAL STRENTH(N/mm^2)		
	7 days	14 days	28 days
NC-SCC	1.92	3.98	4.89
M1	1.90	3.95	4.76
M2	1.85	3.84	4.88
M3	1.81	3.81	4.69
M4	1.79	2.96	3.99
M5	1.75	2.91	4.12
M6	1.72	2.91	4.2
M7	1.69	2.6	4.01

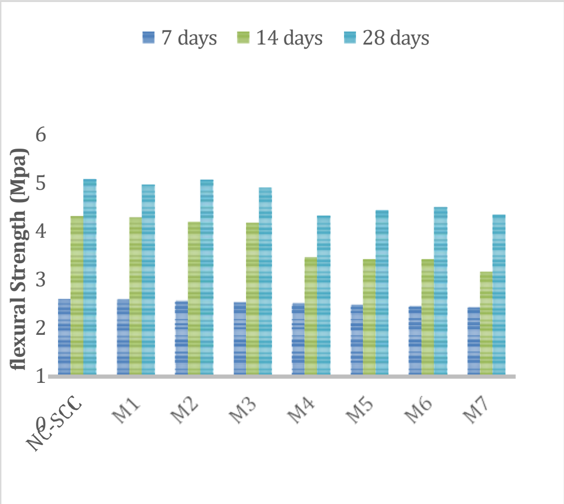

Figure 10: *Tensile strength of different mixes.*

6 Conclusions

In conclusion, the uncontrolled mining of natural aggregates for concrete production stresses the environment and threatens the construction industry's ability to grow sustainably. Simultaneously, the large amount of waste generated by the demolishing of structures is an issue that needs to be solved right now. This waste should and can be recycled to make RCA, which are then used to make concrete. However, SCC now represents a concrete manufacturing and placement technique that tends to replace traditional concrete with a number of benefits. Therefore, it is crucial to show that creating SCC while replacing the NA with RA is feasible.

When adopting current approaches of concrete design, the RA's high water absorption rate requires an equal reduction in the actual amount of the mixing water. RA's fundamental quality and the replacement ratio of the NA will both affect the performance of SCC while using RA. The use of RA in the manufacturing of SCC is generally agreed to be justifiable and technically feasible, but some considerations must be taken to match the performance characteristics of this type of concrete to the performance demanded in each circumstance. However, further developments are still required for the use of this new material in a more widespread and accepted manner by the industry, specifically the creation of standards to measure the water absorption of recycled aggregates.

7 Publisher’s Note

AIJR remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

How to Cite

Sneha & Thulasi (2023). Comparative Study on the Fresh & Hardened Properties of SCC with C&D Waste Recycled Aggregates. *AIJR Proceedings*, 130-138. https://doi.org/10.21467/proceedings.160.15

References

Dong, Chunru , Qingyang Zhang, Chuan Chen, Tianxun Jiang, Zhanggen Guo, Yi Liu, and Shanli Lin. 2022. "Fresh and hardened properties of recycled plastic fiber reinforced self-compacting concrete made with recycled concrete aggregate and fly ash, slag, silica fume." *Journal of Building Engineering.*

Garcia-Troncoso, Natividad, Lufan Li, Quan Cheng, Kim Hung Mo, and Tung-Chai Ling. 2021. "Comparative study on the properties and high temperature resistance of self-compacting concrete with various types of recycled aggregates." *Case Studies in Construction Materials* e00678.