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Strength characteristics of recycled concrete aggregate with addition of steel fibres

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ABSTRACT

We know construction activities demand a significant amount of natural materials in order to produce cement and aggregate. Procurement of these natural materials significantly modifies the natural sources and creates major environmental problems. Furthermore, sustainable waste management is another major issue faced by countries all over the world. In order to minimize the environmental impact and energy consistency of concrete used for construction facilities, reuse of construction and demolition wastes can be a beneficial way which leads to sustainable engineering approaches to concrete mix design. The recycled concrete aggregate has some properties like the natural aggregates but the strength is less than the natural aggregates. So the strength of concrete made, recycled concrete aggregates is enhanced by the addition of some additives. In this study steel fibers are added in concrete with recycled concrete to increase the workability of the concrete at the same water-cement ratio, in addition, to increase in compressive, tensile & flexural strength of the concrete.

Keywords— *Recycle concrete aggregate, Steel fibre, Compressive strength, Split tensile strength, Flexural strength*

1. INTRODUCTION

Concrete is the most common and useful material in the construction industry and has contributed to the advancement of civilizations throughout the last century. However, construction activities demand a significant amount of natural materials in order to produce cement and aggregate. Procurement of these natural materials significantly modifies the natural sources and creates major environmental problems. Furthermore, sustainable waste management is another major issue faced by countries all over the world. In order to minimize the environmental impact and energy consistency of concrete used for construction facilities, reuse of construction and demolition wastes can be a beneficial way which leads to sustainable engineering approaches to concrete mix design. As many developing countries all over the world are recycling and reuse area alternatives to minimize the impact of energy and raw material consumption on the environment, another waste that can be potentially used for concrete production is recycled concrete aggregate obtained via construction & demolition waste.

Sustainable development of the cement and concrete industry requires the utilization of industrial waste components. At present, for a variety of reasons, the concrete construction industry is not sustainable. Firstly, it consumes huge quantities of virgin materials which can remain for next generations. Secondly, the principal binder in concrete is Portland cement, the production of which is a major contributor to greenhouse gas emissions that are implicated in global warming and climate change. Thirdly, many concrete structures suffer from a lack of durability which may waste the natural resources. So, finding a solution to substitute a practical recycled product for part of the cement seems to be desirable for sustainable development. The utilization as a mineral admixture to partially replace cement could preserve the non-renewable resources required for the production of cement, and could somehow contribute to sustainable construction.

The recycled concrete aggregate has some properties like the natural aggregates but the strength is less than the natural aggregates. We can use the industrial by-product to some extent, which does not affect the fresh and hardened properties of the concrete and gives the similar result as normal concrete.

A large number of researches have been directed toward the utilization of waste materials. To increase the durability of the concrete made with recycled concrete aggregates, admixture & fiber can be used, the admixture increases the workability of the concrete at the same water-cement ratio, whereas the fiber increase compressive, tensile & flexural strength of the concrete. The required durability characteristics are more difficult to define than the strength characteristics, specification often uses a combination of performance & prescriptive requirements, such as workability, compressive strength, Split tensile strength, flexural strength, and water-cement material ratio to achieve a durable concrete. The end result may be a high strength concrete, but this only comes as a construction & demolition waste of requiring a durable concrete.

1.1 Objectives

The main objective is to study the effects of partial replacement of natural aggregates with recycled aggregates and addition of steel fiber, and to compare its compressive, tensile strength flexural strength with standard M30 concrete. This experimental study also finds the optimum percentage of natural aggregates that can be partially replaced with recycled aggregates corresponding to minimum cost. Recycled aggregates are obtained from old demolished concrete and make them of the size of 20mm using a hammer. Partially replacement of natural aggregates with recycled aggregates and adding a different percentage of steel fiber were done. It also results in low cost of concrete.

The objectives of the study are:

- To study the influence of partial replacement of coarse aggregates with recycled aggregates and addition of a different percentage of steel fiber on the compressive strength, tensile strength & flexural strength of grade M30 concrete.
- Determines the optimum percentage replacement of coarse aggregates with recycled aggregates corresponding to minimum cost.
- To develop environment-friendly concrete.
- Durability analysis of concrete i.e. standard grade M30 concrete and concrete having a partial replacement of coarse aggregates with recycled aggregates and steel fibers.

2. MATERIAL AND METHODOLOGY

2.1 Material used

(a) Cement: Ordinary Portland cement of grade 43 is adopted for this work. The brand of cement used was Shree ultra-tech OPC with grade 43. The cement was gray and free from lumps.

(b) Aggregates: In this research work fine aggregates used was river sand, coarse aggregates used were crushed stones (natural and recycled course aggregate according to concrete mix. design). These materials were easily available from the local market.

(c) Fine Aggregates: In this research the fine aggregates that are used is the river sand.

(d) Coarse Aggregates:-Locally available crushed stone aggregates of 20 mm nominal maximum size were used as coarse aggregate.

(e) Recycle Concrete Aggregates (RCA): For my experimental program, I have used old demolished concrete and make its size to 20mm using a hammer. The recycled concrete aggregate has similar properties as that of natural aggregates, but water absorption is more in case of recycled aggregates. The specific gravity of recycled aggregates is found to be less than the specific gravity of natural aggregates.

(f) Corrugated Steel Fibres: For increasing the strength of the recycled concrete I have used corrugated steel fibers which I purchased from STEWOLS INDIA (P) LTD.5-8B, Nagpur. As the workability of concrete decreases with the addition of long length fiber, I have used 25 mm length corrugated steel fiber and having 1mm dia. in section.

(g) Admixture: For my experimental program I have used Master Glenium SKY 8630, it is an admixture based on modified polycarboxylic ether. This admixture has been developed for applications in high-performance concrete where the more durability and performance is required. Master Glenium SKY 8630 is free of chloride & low alkali. It can be used with all types of cement.

(h) Water: The water used was the potable water as supplied in the Concrete technology laboratory of our Institute. Water used for mixing should be clean and free from injurious amounts of acids, oil, alkalis', salts and sugar, organic materials or other substances that may be deleterious for the concrete. As per IS: 456-2000 potable water should be used for curing and mixing of concrete. So potable water was used for the preparation of all concrete specimens.

2.2 Concrete Mix Design Material Details

Cement Used = OPC 43 Grade
Specific Gravity of Cement = 3.24
Fineness (Specific Surface %) = 9
Fineness Modulus Fine Aggregate = 2.57
Fineness Modulus Course Aggregate = 6.55
Specific Gravity of Coarse Aggregate = 2.64
Water absorption Course Aggregate % = 0.81
Bulk density (loose) Course Aggregate Kg/m^3 = 2.7
Fineness Modulus Recycle Aggregate = 6.41
Specific Gravity Recycle Aggregate = 2.7
Water absorption (%) Recycle Aggregate = 4.5

2.3 Properties of Fibre

Length of Fiber = 25mm
Diameter = 1mm
Aspect ratio = 25
Shape = Corrugated
Corrugated = Fe-415

2.4 Mix Proportion

Table 1: Design mix. Concrete use replacement in RCA and Steel fibres are below percentage.

RCA\Steel fibre	0%	0.5%	1%
0%	M 1	M 2	M 3
50%	M 4	M 5	M 6
100%	M 7	M 8	M 9

2.5 Concrete Mix Design (M30)

Design Stipulations

(1) Characteristic comp. strength required

In the field at 28 days = 30 MPa

Level of quality control = Good

Test Data for Materials

(1) Specific Gravity of Cement = 3.15

(2) Comp. Strength of Cement at 7 days satisfies the requirement of Indian standard

Assume standard Deviation = 5

Mean Target strength = 30+1.65 X 5=38.25 MPa

3. RESULT AND DISCUSSION

3.1 The **compressive strength** test was conducted at curing ages of 7 and 28 days. The average compressive strength test results of all the mixes at different curing ages are shown in Table 2.

Table 2: Average compressive strength at 7 and 28 Days

S. no	Mix ID	Compressive strength	
		7 days	28 days
1	M 1	30.26	40.25
2	M 2	34.9	45.02
3	M 3	38.02	47.17
4	M 4	31.36	32.37
5	M 5	32.11	36.68
6	M 6	32.93	38.85
7	M 7	24.68	29.98
8	M 8	25.52	31.74
9	M 9	28.77	32.77

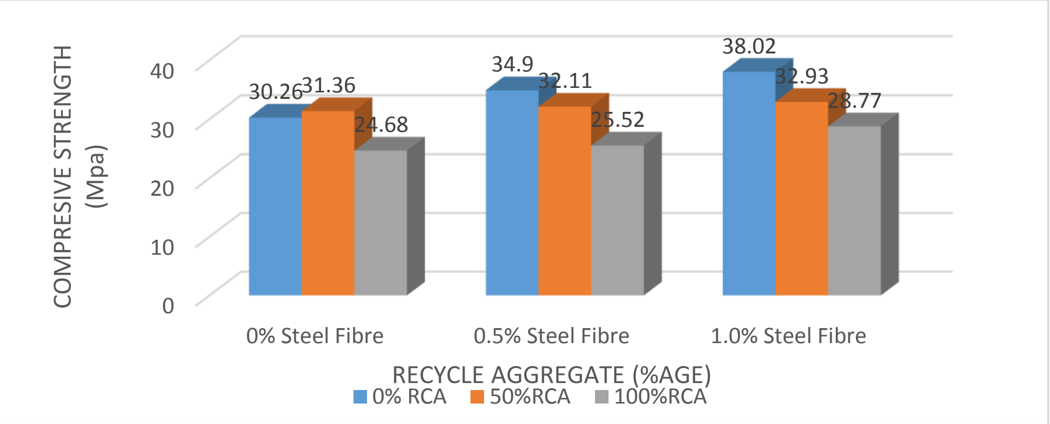

Fig. 1: Effect of adding RCA on 7 days compressive strength

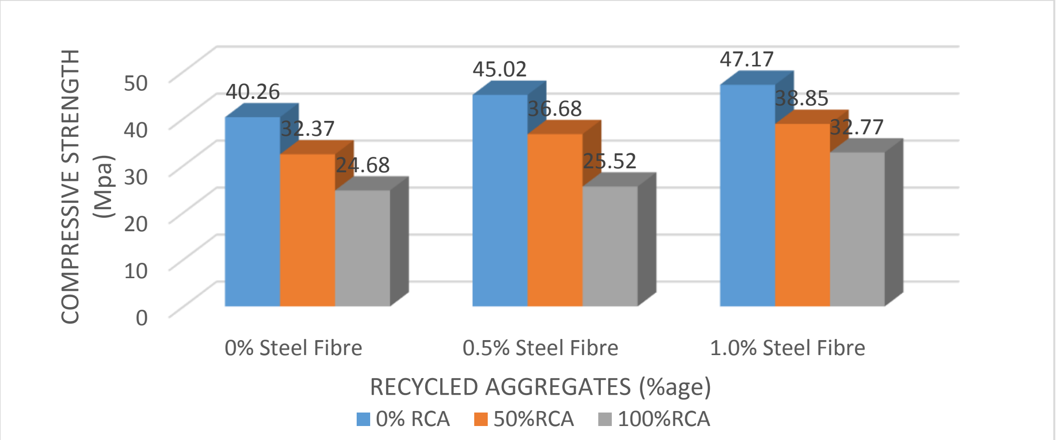

Fig. 2: Effect of adding RCA on 28 days compressive strength

The above results show that compressive strength decreases with the increase of partial replacement of coarse aggregates with recycled aggregates. And an increase in compressive strength was observed as the percentage of steel fiber increases.

3.2 The **splitting tensile strength** test was conducted at curing ages of 7 and 28 days. The average splitting tensile strength test results of all the mixes at different curing ages are shown in Table 3.

Table 3: Average tensile strength at 7 and 28 Days

S. no.	Mix ID	Tensile strength	
		7 days	28 days
1	M 1	4.32	5.48
2	M 2	4.66	6.48
3	M 3	5.42	6.72
4	M 4	3.86	5.41
5	M 5	4.15	5.75
6	M 6	4.76	6.23
7	M 7	2.88	4.27
8	M 8	3.10	3.86
9	M 9	3.43	3.37

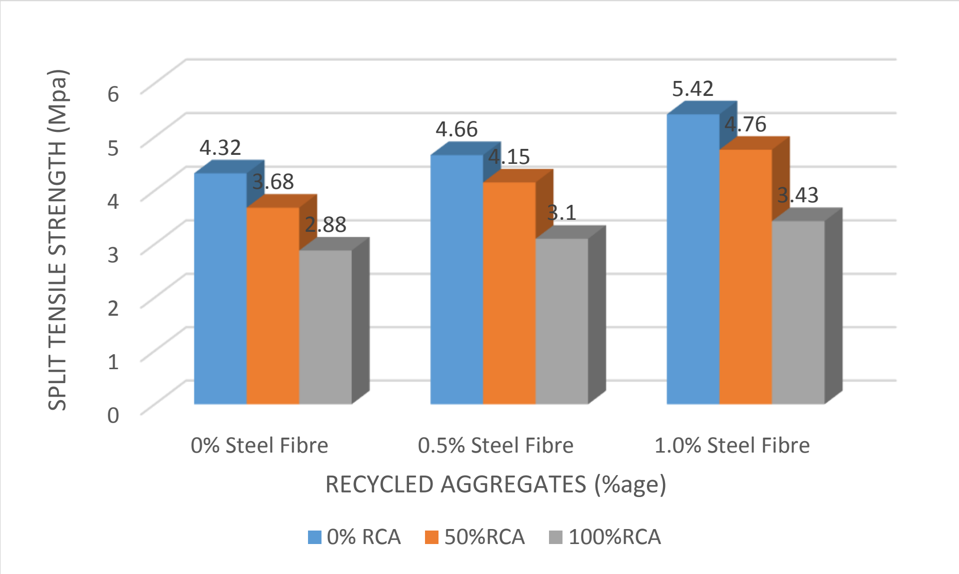

Fig. 3: Effect of adding RCA on 7 Days Split tensile strength

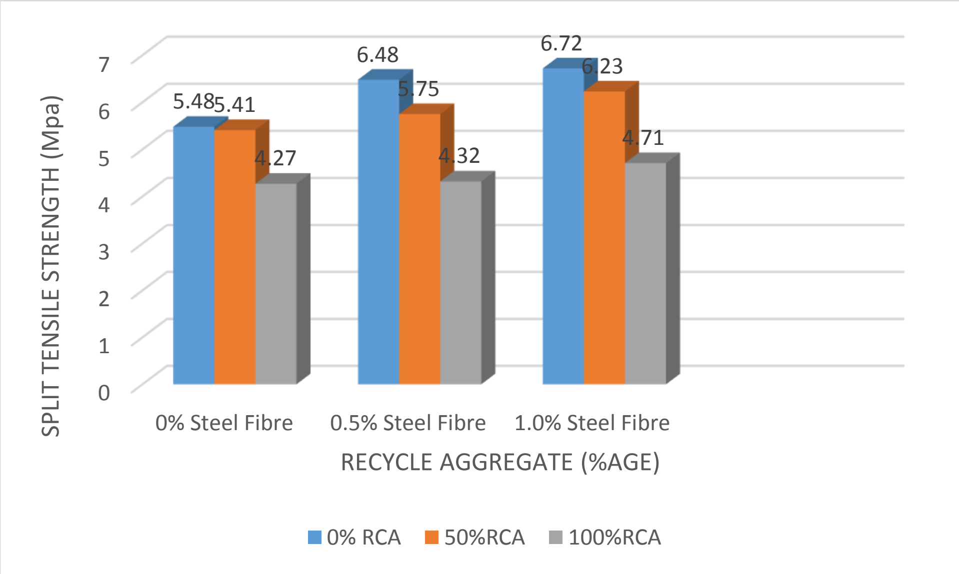

Fig. 4: Effect of adding RCA on 28 days Split tensile strength

The above results show that split tensile strength decreases with the increase of partial replacement of coarse aggregates with recycled aggregates. And an increase in split tensile strength was observed as the percentage of steel fibre increases.

3.3 The **Flexural strength test** was conducted at curing ages of 28 and 56 days. The average flexural strength test results of all the mixes at different curing ages are shown in Table 4.

Table 4: Average flexural strength at 28 and 56 days

S. no	Mix ID	Flexural strength (Mpa)	
		28 days	56 days
1	M 1	4.17	5.23
2	M 2	4.78	6.35
3	M 3	5.26	6.40
4	M 4	3.22	4.68
5	M 5	3.25	5.85
6	M 6	3.36	5.73
7	M 7	2.62	4.10
8	M 8	2.78	4.20
9	M 9	2.81	3.78

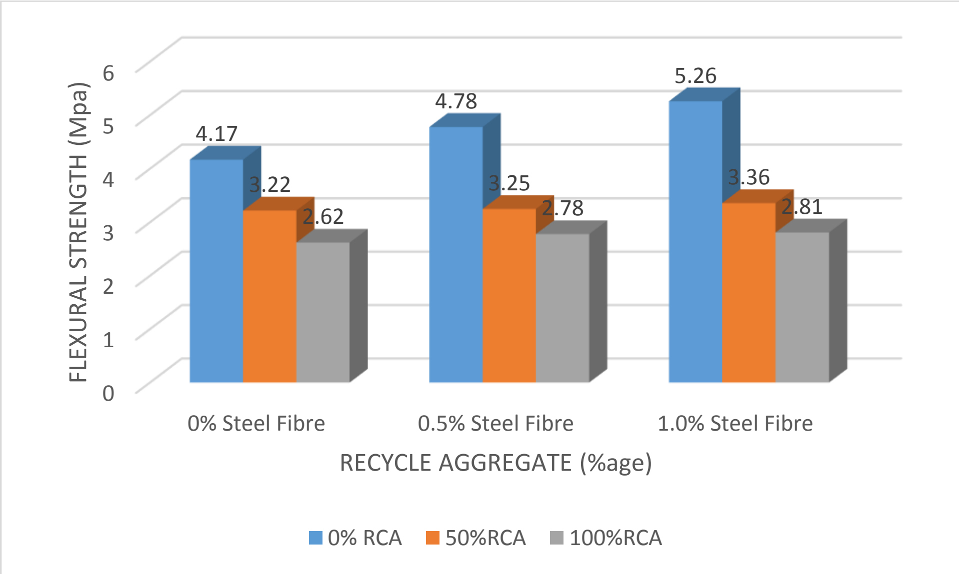

Fig. 5: Effect of adding RCA on 28 days flexural strength

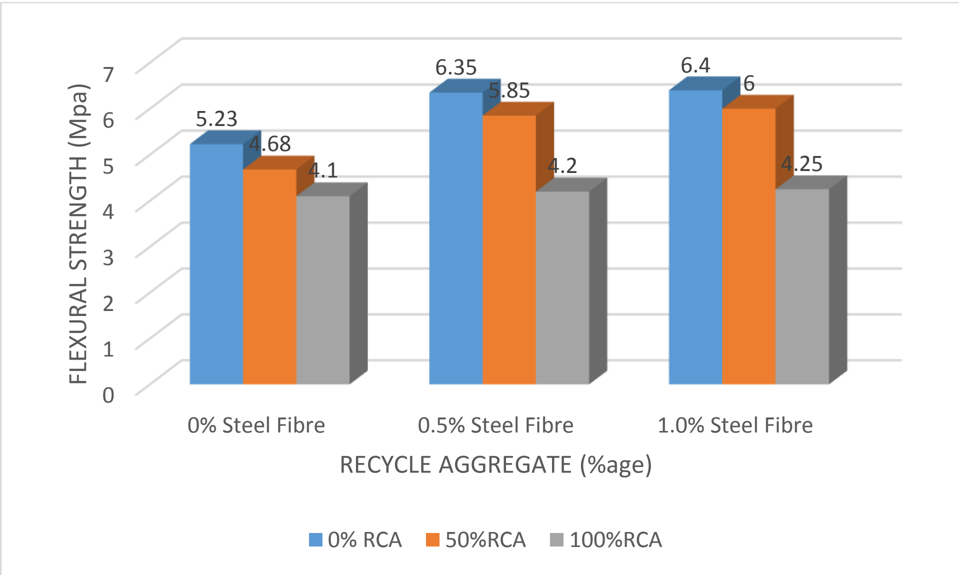

Fig. 6: Effect of adding RCA on 56 days flexural strength

The above results show that flexural strength decreases with the increase of partial replacement of coarse aggregates with recycled aggregates. And an increase in split tensile strength was observed as the percentage of steel fibre increases. 50% replacement of RCA with NA gives similar flexural strength as normal concrete.

Result: Hence we can make 50% replacement OF NCA with RCA and addition of 1.0% steel fibers.

4. CONCLUSION

- As the replacement of Natural aggregates by RCA in concrete mix increase, the workability of the concrete mix was found to decrease as compared to control mix and the additional of steel fibres into the concrete mix also decrease the workability.
- The addition of RCA in concrete mix there is reduction in the compressive strength at 50% as compare to control mix whereas further addition of RCA at 100% decrease the compressive strength inclusion of steel fibres into concrete mixes increases the compressive strength at 0.5% fibres content as compared to the control mix whereas further addition of fibre at 1% with RCA there is small increase in the compressive strength for all mixes as compared to control mix.

- The incorporation of RCA in the concrete mix was found to decrease in the split tensile strength at 50% and 100% replacement whereas slightly increases when amount 0.5% reinforced with steel fibres but was more than control mix into concrete mixes increases the splitting tensile strength and was maximum at 1% steel fibre content for all concrete mixes.
- The inclusion of RCA and fibre into the concrete mix gives same splitting tensile strength as compared to the control mix.
- Recycled and reuse of building waste has been found to be an appropriate solution to the problems of dumping hundreds of thousands of tons of debris accompanied by a shortage of natural aggregates.

5. SCOPE FOR FUTURE RESEARCH WORK

Based on the present trend of using recycled aggregates in concrete, the possibility of research in the following areas can be explained.

- To promote sustainable development in the protection of natural resources and reduces the disposal of demolition waste from old concrete.
- Durability properties such as compressive strength, tensile strength, and flexural strength can be increased using steel fibre at different proportion.

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