Mechanical Properties of Hybrid Fibre Reinforced Concrete using Recycled Aggregate

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ABSTRACT

This experimental work describes mechanical properties of hybrid fibre reinforced concrete with recycled aggregate. Now a day an interest has been shown in use of recycled aggregate in concrete for replacement of coarse aggregate. In this study, normal coarse aggregate is replaced by 25% recycled aggregate. The hybrid fibre, combination of polypropylene and nylon fibres are added to enhance the strength of concrete at volume fraction 0.5%, 0.75%, 1%, 1.25%, 1.5%. The mechanical properties of concrete represent compressive strength, split tensile strength, flexural strength properties are studied and the bond strength using pullout test are also conducted.

Key Words: Hybrid Fibre, Compressive Strength, Split Tensile Strength, Fflexural Strength, Pullout Strength Test.

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1. INTRODUCTION

In now a day, increase in the construction and demolition activity increases the amount of waste produced all over the world. These construction and demolition waste materials are usually used for land filled. However with new environmental regulations and shortage in the availability of land space, disposal of concrete waste has been a major environmental challenge. On the other hand India having largest construction activities, which causes a large shortage in the availability of natural resources, mainly aggregate. Demolished concrete structures are proved that it is an alternative source of construction material. Many countries have been working for new innovation on how to reduce and reuse, recycle the generated waste. In fact many governments all over the world have now introduced some various measures aimed to reducing the use of primary aggregates and recycling, where it is technically, economically, or environmentally acceptable. Old demolished concrete structures can be recycled to obtain recycled aggregate (RA). The primary aggregate can be used along with recycled aggregate effectively to get various needs in infrastructures.

Construction and demolition waste is defined as the solid waste generated by the remodeling, renovation, construction, repair, alteration or demolition works. The recycled aggregates have same properties like natural

aggregates but the strength of recycled aggregates is less than natural aggregates. Recycled aggregate have high water absorption, less specific gravity, less bulk density and less structural strength. But it have also some benefits, conserve decreasing natural aggregates resources, protection of environment, use of construction wastes, save money and create additional job opportunities. To increase the durability and strength of the concrete made with recycled concrete aggregates, fibre can be used, the fibre increase compressive, tensile & flexural strength of the concrete. The different types of fibres used as concrete reinforcement are synthetic fibres, natural fibers, glass fibres and steel fibres. The different types of synthetic fibers used are Polypropylene, Nylon, Polythene and Polyester.

A composite can be termed as hybrid, if two or more types of fibres are rationally combined in a common matrix to produce a composite that drives benefits from each of the individual's fibers. In the improvement of mechanical properties of concrete, addition of short discontinuous fibres have an important role. It decreases brittleness, increases elastic modulus, controls cracks initiation and its subsequent growth and propagation. This study the combination of polypropylene and nylon is used to improve the strength of concrete made with recycled aggregates. The applications of hybrid fibre reinforced concrete are roads and pavements, offshore structures, runways, ground supported slabs, overlays and toppings, machine foundation, tanks and pools.

The aim of this study is to evaluate effective use of recycled concrete aggregates with fiber to achieve the desire needs. To study mechanical properties of hybrid fibre reinforced concrete with recycled aggregates with varying percentage of polypropylene and nylon at 0.5%, 0.75%, 1%, 1.25%, 1.5%.

2. MATERIALS

The different materials used in present study were Portland cement (53 grade), fine aggregates, coarse aggregates, polypropylene fiber, nylon fiber, water and super plasticizer.

A. Cement

For the present study 53 grade Ordinary Portland Cement was used. The properties of cement is shown in the Table 1.

Table 1 Properties of cement

Properties	Results
Cement	53 grade OPC
Specific gravity	3.06
Fineness	3.24%
Initial setting time	92 minutes
Final setting time	440 minutes
Standard consistency	31%

B. Aggregates

The specific gravity and fineness modulus of fine aggregate was 2.63 and 3.19 % respectively. It comes under zone II. The crushed gravels were used as coarse aggregate of maximum size 20mm. The specific gravity of coarse

aggregate was 2.70 and fineness modulus was 7.09. The rounded shape sand of size less than 4.75mm was used. Coarse aggregate is replaced by 25% of recycled concrete aggregate having specific gravity of 2.54 and fineness modulus is 7.15 %. Recycled aggregate is shown in fig. 1. The water absorption rate of normal coarse aggregate and recycled aggregate is 0.48% and 1.51% respectively.

Fig. 1 Recycled concrete aggregates

C. Water

Water suitable for drinking was used for mixing and curing of concrete specimens. It should be free from impurities.

D. Fibres

Combination of synthetic fibre polypropylene and nylon fibres is used for this investigation as shown in fig. 2 and the property of the fibres is shown in Table 2. The polypropylene has tensile strength 561.0 – 867.0 N/mm^2 and density is 0.92 gm/cm^3 and nylon have tensile strength 998 N/mm^2 and density is 1.10 gm/cm^3. Mainly the length, diameter and aspect ratio of polypropylene and nylon is considered for this study.

Table 2 Properties of fibres

Properties	Polypropylene	Nylon
Length	12mm	19mm
Diameter	0.05mm	0.1mm
Aspect ratio	240	190

a) Nylon fiber **b) Polypropylene fiber**

Fig. 2 Fibers used

E. Super plasticizer

DARACEM 921FF has been used as super plasticizer. It can be used with most types of portland cements. It has been used 0.6% by the weight of cement.

F. Mix proportion

IS 10262:2009 is used for perform the mix design. The grade of concrete prepared was M30. The proportion used in the investigation is shown in Table 3. It gives the amount of materials used for making $1m^3$ concrete.

Table 3 Mix proportion details

Cement	Fine aggregate	Coarse aggregate	w/c ratio
1	1.62	3.62	0.43
365.33 kg/m^3	591.83 kg/m^3	1322.49 kg/m^3	

3. RESULTS AND DISCUSSIONS

A. Fresh concrete properties

After casting the slump cone test and compaction factor test was conducted. It was observed that the workability reduced when the volume of fibre increases. This may be due to higher water absorption of recycled aggregate and hydrophilic character of fibre. Decrease in the amount of workability of concrete with fibres is less due to the addition of admixture. The Fig. 3 shows the slump cone test results. The Fig. 4 shows the compaction factor test results. Beyond the optimum percentage of fibre addition, there is a balling effect of fibres occurred and it causes workability.

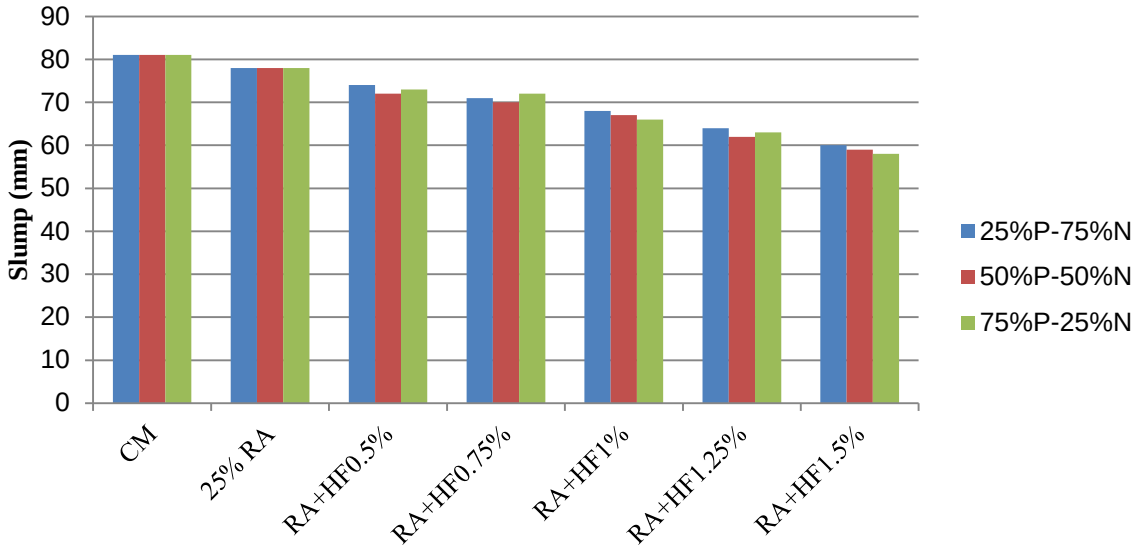

Fig. 3 Slump value for various mixes

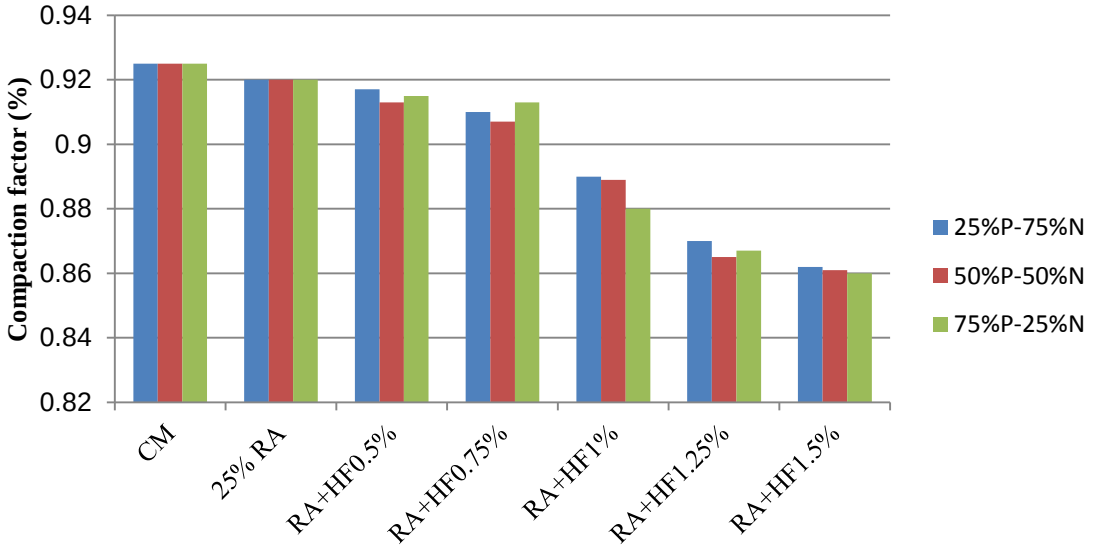

Fig. 4 Compaction factor for various mixes

B. Cube Compressive Strength

For each mix, three cube specimens each of size 150 mm x 150 mm x 150 mm were tested according to the IS 516:1959 specifications, after 7 and 28 days of casting. The values obtained for cube compressive strength for varying percentage of hybrid fibres given in Table 4 and fig. 5. From the results, the concrete with recycled aggregate reduces the compressive strength compared to control mix. The result shows that the addition of the hybrid fibre in the recycled aggregate concrete improved the compressive strength for 7 days and 28 days. The decrease in compressive strength is observed when percentage of fibres increases beyond 1%. The increase in the compressive strength is due to the increase in bonding effect and bridging effect of fibre with matrix. With the increase in percentage volume of fibre beyond its optimum value (which is 1% in present case) compressive

strength decreases, this is due to the increase in interference of fibre with each other or balling effect of fibre. This will produce internal voids in concrete mix which leads to decrease the total density of mix and thereby decrease the compressive strength of the mix. Decrease in compressive strength also due to the balling effect of fibre.

Table 4 Cube compressive strength for various mixes

Mix designation	Compressive strength(N/mm^2)	
	7th day	28th day
Control mix	25	39
25% recycled aggregates	22	37.77

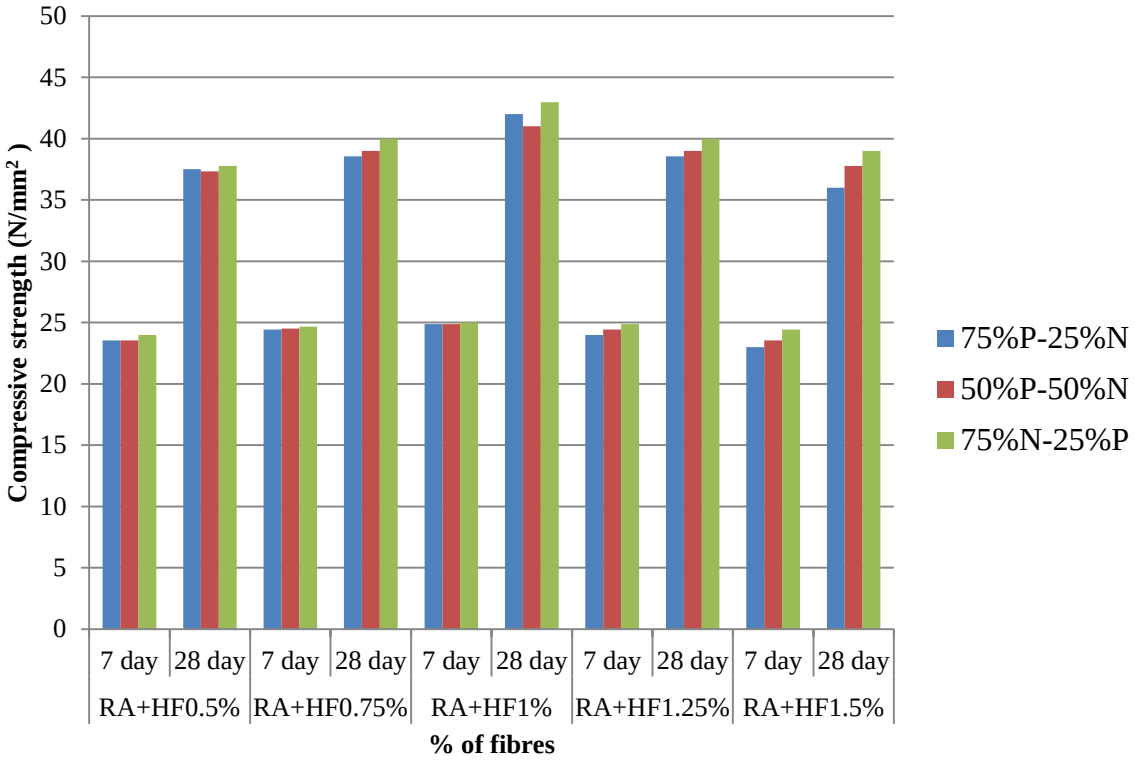

Fig. 5 Compressive strength for various mixes

C. Split tensile strength

For studying the split tensile behaviour, cylinders of fibrous concrete with volume fraction at 1% for combination 25%P-75%N. After the experiment, the results obtained are shown in Table 5. The flexural strength of recycled aggregate concrete is decreases when compare with control mix. The addition of hybrid fibre in the recycled aggregate concrete increases the flexural strength because of the holding capacity of the fibres which helps in preventing the splitting of concrete.

Table 5 Split tensile strength for various mixes

Mix designation	7 day (N/mm^2)	28 day (N/mm^2)
CM	3.1	4.9
25% recycled aggregates	3.0	4.7
RA+HF1%(25%P-75%N)	4.7	5.5

D. Flexural strength

On conducting the flexural strength test, the failure load was observed and the strength was calculated which is shown in Table 6. The failure pattern of plain and hybrid fibrous concrete with recycled aggregate in flexural strength test shows that fibrous concrete are more ductile as compared to plain concrete and is shown in fig. 6. This is because when the matrix cracked, the load was transferred from the composite to the fibres at the crack surfaces, which prevents the brittle failure of the composite.

a) Control mix **b) Recycled aggregate concrete** **c) RAC with hybrid fibre**

Fig. 6 Failure pattern of specimen after flexural strength test

Table 6 Flexural strength for various mixes

Mix designation	7 day (N/mm^2)	28 day (N/mm^2)
CM	4.5	6.1
25% recycled aggregates	4.3	6.0
RA+HF1%(25%P-75%N)	5.5	7.0

E. Pullout test

After the pullout test, we can observed that for the control mix resulting the failure of concrete and it was a split failure and also for concrete with recycled aggregate split failure on concrete and steel slip from the cube. For the hybrid fibre reinforced concrete with recycled aggregate causes steel break off due to the bond strength character of fibres. The failure pattern is shown in fig. 7 and result is tabulated in table 7.

a) Control mix **b) Recycled aggregate concrete** **c) RAC with hybrid fibre**

Fig. 7 Failure pattern of specimen after pullout test

The bond strength **is** worked out by the following formula

$$\text{Bond strength} = \frac{W \times 1000}{2\pi RL} \quad \text{----------} \quad (1)$$

Where, W = Load taken by the bar in tonnes

R = Radius of bar in cm

L= Length of embedded bar in cm.

Table 7 Steel bond strength and failure type

MIX	Bond strength (kg f/cm^2)	Failure type
CM	8.0	Split failure
25%RA	7.87	Split and slip failure
RA+HF1%(25%P-75%N)	8.54	Steel break off

4. CONCLUSIONS

In this experimental study hardened properties of hybrid fibre reinforced concrete with recycled aggregates with varying percentage of polypropylene and nylon at 0.5%, 0.75%, 1%, 1.25%, 1.5% were find out. From the results, following conclusions were drawn.

- The experimental result shows that concrete with 25% coarse aggregate replaced by recycled concrete aggregate reduces the compressive strength.
- Addition of polypropylene and nylon fiber improved the compressive strength, flexural strength and split tensile strength of concrete with recycled concrete aggregate. Compressive strength of hybrid fibre reinforced concrete with recycled aggregate increases with increase in the percentage of fibres upto 1% of fibres and then decreases.
- From the experimental results it was observed that the specimen with fibre content 1% with combination of polypropylene and nylon fibre of 25% and 75% produce better results than the other.

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