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Influence of Polypropylene Fibers on recycled aggregate concrete

[1]Ranjeet Kumar, PG Scholar, Department of CE, BIT Sindri, Dhanbad, India
[2] Dr. Krishna Murari, Associate Professor, Department of CE, BIT Sindri, Dhanbad, India
[1]ranjeetkumar124222@gmail.com@gmail.com, [2]krishna.sindri@gmail.com

ABSTRACT - **This article presents the influence of polypropylene fibers on recycled aggregate concrete. Experimental studies are carried out with addition of 0%, 0.5%, 0.75% and 1% polypropylene fibers in natural aggregate concrete (NAC) and recycled aggregate concrete (RAC). The recycled aggregate concrete is prepared with 100% replacement of recycled coarse aggregate with natural coarse aggregate. The present study is primarily aimed to investigate the influence of additions of polypropylene fibers into low strength recycled aggregate concrete on the basis of a number of parameters such as compressive strength, split tensile strength, flexural strength. The analysis of experimental results illustrates that the behavior of concrete is substantially influenced by the incorporation of coarse recycled aggregates and polypropylene fibers in concrete. Moreover, with optimum fibers content the enhanced properties can be achieved for both natural and recycled aggregate concrete.**

Keywords* — *Compressive Strength, Split Tensile Strength, Flexural Strength, Polypropylene fiber, Recycled aggregate concrete, Recycled coarse aggregate, Urban transformation.

I. INTRODUCTION

Cement concrete is most important material for construction industry. Basically, the concrete consists of cement, fine and coarse aggregates, these all mixed with the help scenario of water. In the present for making concrete very acquit shortage of good quality aggregates. Hence, the concrete or industry people are looking towards alternative material for aggregates. Now days the researchers are focusing on recycle aggregate to establish as an alternative material for aggregates.

A large amount of construction and demolition (C&D) waste are generated worldwide because of rapid urbanization. Due to the absence of proper methods of recycling and environmental norms related to its disposal, most of them are sent to landfills. Presently, almost all the countries are facing acute shortage of landfills for dumping huge amount of solid waste generated due to demolition of aged concrete structures [4].

The aggregates produced from these demolition wastes particularly, recycled coarse aggregates (RCAs) can be effectively used as construction materials. The partial or full replacement of natural aggregates with recycled aggregates in concrete may solve number of problems faced by the civilization such as, environmental pollution, acute shortage of natural resources and waste disposal lands. However, the use of recycled aggregate concrete in the structural member is very limited due to the lack of confidence. Therefore, in order to make recycled aggregates particularly, recycled coarse aggregates usable for structural applications particularly for low strength application, study to enhance the behavior of recycled aggregate concrete is extremely significant in estimating proper design and performances of structural members. Construction and demolition disposal has also emerged as a problem in India [5]. India is presently generating construction and demolition waste to the tune of 23.75 million tons annually as per the Hindu online of March 2000, which is comparable to some of the developed nations and these figures are likely to double fold in the next 7 years. The management of construction and demolition waste is a major concern due to increased quantity of demolition rubble, continuing shortage of dumping sites, increase in cost of disposal and transportation and above all the concern about environment degradation. The increasing problems associated with construction and demolition waste have led to a rethinking in developed countries and many of these countries have started.

1.1 OBJECTIVE

1. To improve the strength of recycled aggregate concrete with the addition of polypropylene.
2. The earth surface can be saved, and ecological disturbance will be reduced.
3. Best tool adopted for effective solid waste management.
4. To emphasis reduce, recycle, and reuse concept in current construction field.
5. The problems of disposal and maintenance cost of land filling is reduced.

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6. Due to use of recycled aggregate in construction, energy and cost of transportation of natural resources and excavation is significantly saved. This in turn directly reduces the impact of waste material on environment.
7. To reduce the demand of natural aggregate.

II. DETAILS OF THE MATERIALS AND TESTING

The following materials were used in the present study
Materials Used: Details are presented in table below

Table I Details of material used

Name of the material	**Source of the materials**
Cement	PSC manufactured byACC Cement
Fine aggregate	Zone II. Obtained from Barkar River, Jharkhand
Coarse aggregate	Obtained from Baliyapur, Jharkhand
Recycled coarse aggregates	Recycled Coarse Aggregate obtained from different types of cube mould demolished waste concrete
Polypropylene fiber	Waltar enterprises, Kalamboli, Navi Mumbai

The used material of natural coarse aggregate, natural fine aggregate, recycled coarse aggregate, polypropylene fibers can be viewed in figure1.

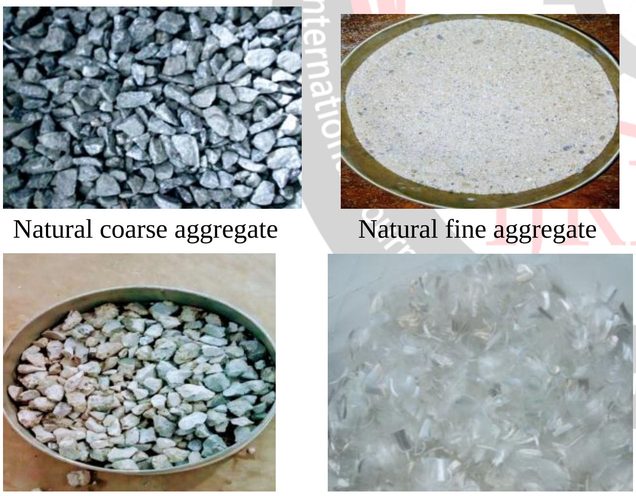

Fig 1: Materials

2.1 Cement

Portland slag cement (PSC) with trade name ACC CEMENT, conforming to IS: 455-1989 was used in the entire experimental work. To avoid the long storage times and to avoid the loss of strength, cement was procured according to the phase wise requirement. The cement was storage in bags in air tight room to have minimum exposure to the humidity. The detail of physical properties of cement is presented in table II.

Table II Physical and mechanical properties of cement

Properties	**Results**
Consistency	32%
Initial setting time	92 minutes
Final setting time	285 minutes
Soundness	Expansion 3 mm
Specific gravity	3.12
Fineness	03% Retain on 90 micron sieve
Compressive strength	In N/mm^2
3 days	16.85
7 days	24.95
28 days	33.45

2.2 Polypropylene fiber

Polypropylene is a thermoplastic polymer. It has high melting point of 160°c, high ignition point of 590°c, low thermal and electrical conductivity and hydrophobic and chemically inert nature which does not absorb or react with concrete moisture and its cost is low. The detail of physical properties of polypropylene is presented in table III.

Table III Physical properties of Polypropylene fibers

Material	100% virgin polypropylene (pp)
Length	12.0+/- 0.25mm
Diameter	24 micron (approx)
Aspect ratio	500 (approx)
Melt point	162 degree centigrade
Specific gravity	0.91
Thermal and electric conductivity	Low
Alkali resistance	100% alkali proof
Acid and salt resistance	High

2.3 Fine aggregate

The natural fine aggregate (NFA) used for the experimental work was locally and conformed to grading zone II as per BIS (IS: 383-1970). The detail of physical properties of fine aggregate is presented in table IV.

Table IV Physical properties of fine aggregate

Test	Test result of NFA
Zone	II
Fineness modulus	2.6
Moisture content	0.4%

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Specific gravity	2.62
Water absorption	1.2%

2.4 Natural coarse aggregate

Locally available Natural aggregate having the maximum size 20 mm was used in the present work. The 20 mm aggregates were first sieved through 20 mm sieve and then it was washed to remove dust and dirt and was dried to surface-dry condition to ensure the water cement ratio is not affected. Test sieves conforming to BIS (IS: 460-1962 Specification of 80 mm, 40 mm, 10 mm, 4.75 mm) were used for sieving. The detail of physical properties of natural coarse aggregate is presented in table V.

Table V Physical properties of natural coarse aggregate

Properties	Test result of NCA
Moisture content	0%
Water absorption	0.4%
Specific gravity	2.72
Fineness modulus	6.94
Crushing value	28.32%
Impact value	19.20%

2.5 Recycle coarse aggregate

The recycled coarse aggregate obtained from the different types of cube mould and demolished waste concrete from the hostel building of BIT Sindri Campus was used in the entire experimental work. The RCA obtained from waste concrete consists of adhered mortar on original. RCA having the maximum size 20 mm was used in the present work. The detail of physical properties of natural coarse aggregate is presented in table VI.

Table VI Physical properties of recycle coarse aggregate

Test	Result
Specific gravity	2.52
Water absorption	2.63%
Crushing value	34.33%
Impact value	28.34%

2.6 Selection of mix design

Three different mix design M_1, M_2 and M_3 were prepared for three different water-cement ratios to get M25 as per IS: 10262-2009. The most appropriate mix design was selected on the basis of slump value and compressive strength as shown in table VII.

Table VII Result of mix design

Design Mix	SI. No.	w/c ratio	Mix proportion	Slump (mm)	Compressive Strength (N/mm^2)	
					7 days	28 days
M_1	1	0.46	1:1.58:2.84	60	29.39	35.10
M_2	2	0.47	1:1.63:2.89	65	27.32	33.42
M_3	3	0.48	1:1.66:2.93	75	25.74	32.67

The target strength for M25 is given by

$$F_{ct} = f_{ck} + K \times S$$
$$= 25 + 1.65 \times 4$$
$$= 31.60\ N/mm^2, \text{ where } S = 4$$

M_3 achieves the target strength of M25 and its slump comes in the range of medium degree of workability as per IS 456. As per IS 456 in this range of workability, we can use this concrete in conditions of heavily reinforced sections in slab, beams, columns, pavement etc. So we select the mix design M_3 for this project work.

III. RESULTS AND DISCUSSION

Properties of concrete

There are two states of Concrete

- Fresh concrete
- Hardened concrete

3.1 Properties of fresh concrete

Workability

The properties of fresh concrete are assessed by workability in terms of slump value. To check the slump value of fresh concrete in the range of 50-75 mm, the slump cone test is conducted on all concrete mixes. The slump cone is specified by BIS (IS: 7320-1974) is used to measure the slump of fresh concrete. The slump cone is placed on a smooth surface (metal base plate) and filled with concrete in three layers, each layer is compacted uniformly by 25 blows with a standard 16 mm diameter tamping rod, and the top surface is struck off by means of sawing and rolling motion of the tamping rod. The mould is lift slowly without shaking and the unsupported concrete is the slump. Height of slump is measured.

The variation of workability for both RAC and NAC with change in fiber content is illustrated in graph I. Due to the higher porosity of adhered mortar on to the recycled aggregates; the workability of RAC is much lower than NAC. It can also be observed from figure that with the increase in fiber content in concrete, the workability decreases. The reason for the increase in frictional resistance between ingredients of concrete and polypropylene.

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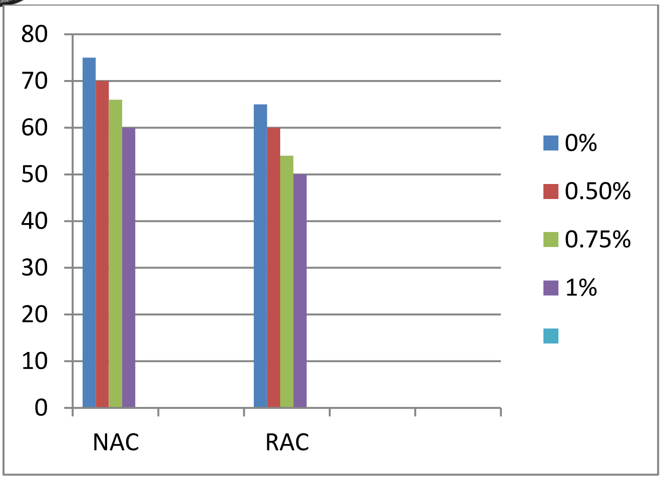


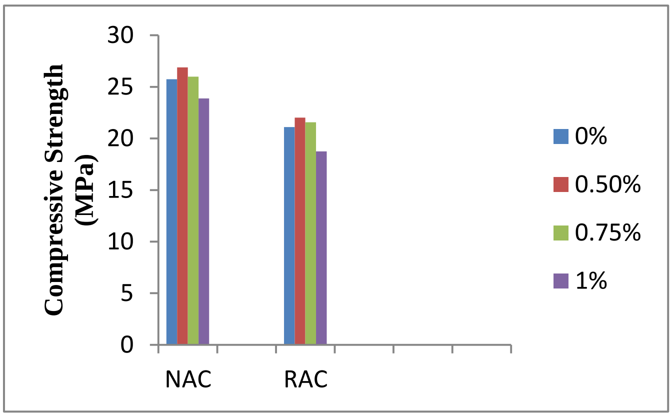
Graph **I:** Variation of workability of concrete with PP fiber volume fraction.

3.2 Properties of hardened concrete

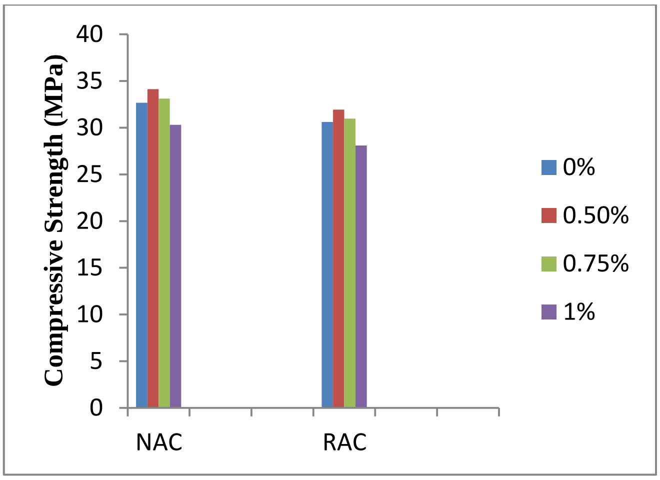
Compressive strength test

The compressive strength is determined using 2000 KN compression testing machine in accordance with BIS (IS: 516-1959). The compressive strength test was conducted on 150 mm size of cube after 7 and 28 days, adopting wet curing process. Three cube specimens were tested after each curing period of 7 and 28 days. A total of 6 cube specimens were tested for compressive strength for each mix [8].

The variation of compressive strength values with different polypropylene fiber content are presented in graphII&III. Variations in compressive strength values show similar trends in both RAC and NAC. The experimental results show an increase in compressive strength values with the addition of polypropylene fibers up to 0.5%. With further incorporation of PP fibers, a decrease is observed in compressive strength for both NAC and RAC and the minimum values being observed at 1% addition. The maximum compressive strength values were obtained at 0.5% PP fiber for both NAC and RAC. The maximum increment in compressive strength at 0.5% PP as observed in NAC is 4.46% and 4.25% in RAC.



Graph II Influence of polypropylene fiber volume fraction on compressive strength at 28 days



Graph III Influence of polypropylene fiber volume fraction on compressive strength at 28 days

This behavior of fiber reinforced concrete may be attributed to the high fineness and varying length of fibers in staple PP fibers which form a network that acts as a bridge and prevents the micro crack from propagating further. However, when the PP fiber content is more, the fiber is distributed non-uniformly in concrete and improper mixing. Hence, these fiber masses accumulated to form relatively weaker points which act as voids and therefore become more susceptible to cracking, hence the reduction in compressive strength. The reductions observed at 1% PP are 7.245% and 8.14% for NAC and RAC respectively.

Split tensile strength

The split tensile strength of concrete was determined after 7 days and 28 days of curing on cylindrical specimens of 150 mm diameter × 300 mm height using 1000 KN compression testing machine as per the procedure given in BIS (IS: 5816-1999).

A bar of square cross section of size 10 mm was placed along the centre of the base platen. The specimen is then placed in horizontal direction on this strip. Another strip of similar shape and size was placed on the cylinder exactly above and parallel to the lower strip. The machine was operated such that the upper platen just touches the top strip and then the load was applied at rate of 1.2 to 2.4 N/mm^2/min throughout the test.

Graph IV&V represents the variation of split tensile strength values with changes in fiber volume fraction for both RAC and NAC. Results show that PP fibers have effectively improved the splitting tensile strength values. Following figure suggests that the splitting tensile strength values tend to show an improvement with the addition of fibers up to 0.5% both in NAC and in RAC after which the splitting tensile strength values again start to decrease. The maximum value obtained in case of NAC is 3.68MPa for 0.5% fiber content, an increment of 18.01%. Similarly, the maximum value obtained in case of RAC is 3.12MPa for 0.5% fiber content, an increment of 10.25%. Once the splitting process has occurred, the fibers act as the bridging

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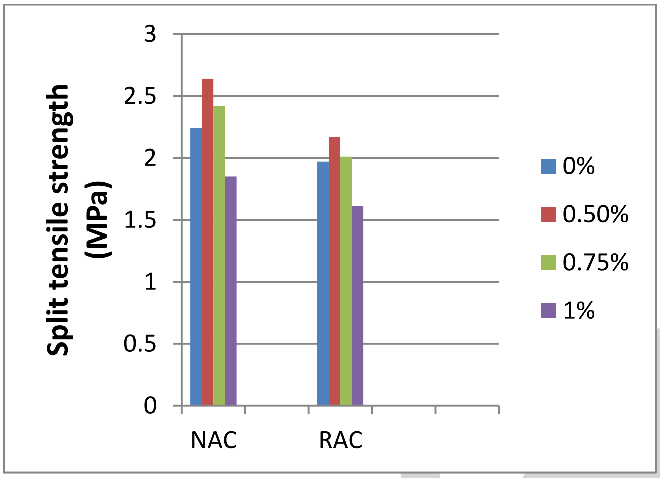
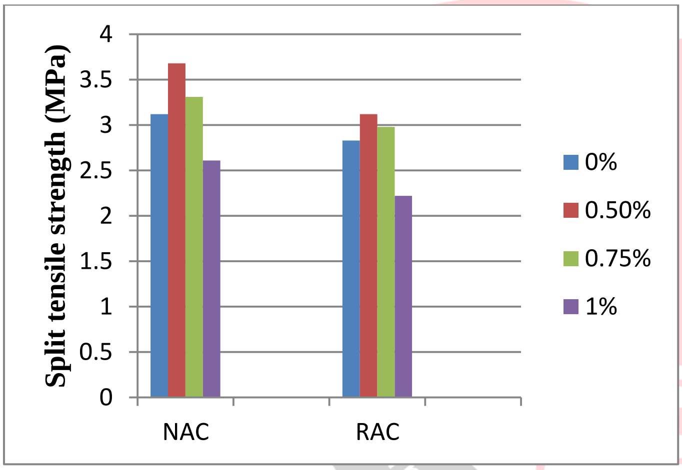
element effectively transferring the load from the matrix to the fibers, thereby taking the additional load leading to an improvement of split tensile value. The increase in split tensile strength of concrete is also depends on the size and shape of the polypropylene fibers.



Graph IV: Influence of polypropylene fiber volume fraction on split tensile strength at 7 days

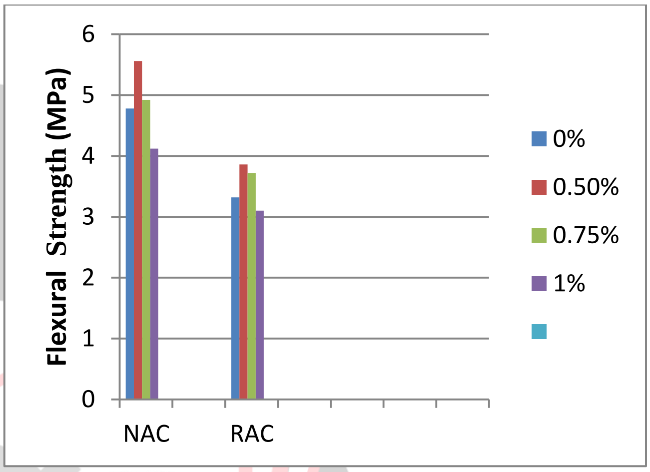


Graph v: Influence of polypropylene fiber volume fraction on split tensile strength at 28 days

Flexural strength test

This test was performed in accordance with BIS (IS: 516-1959) on prisms of size 100 × 100 × 500 mm after 28 days of water curing using 200 KN universal testing machine. The specimen was supported on two roller support spaced at 400 mm centre to centre. The load was then applied at rate of 0.7 N/mm^2/min through two similar rollers mounted at third point of the span till the failure occurred. The flexural strength is expressed as modulus of rupture and it is calculated based on the appropriate expression in code. Three samples are used for each mix of concrete and the average result is reported [7].

The influence of PP fiber volume fraction on the flexural strength of both NAC as well as RAC is depicted in Graph VI&VII. The flexural strength also follow the same pattern for NAC and RAC, an increase up to 0.5% PP fiber content and then decrease with further increase in fibers. Unlike the compressive strength values, significant improvements are observed in flexural strength with the addition of fibers. The maximum value obtained for NAC is 5.56MPa which is 17.15% increase. Similarly, for RAC, the maximum value obtained is 3.86MPa, an increase of 12.26 %. As obtained in the case of compressive strength and splitting tensile strength values, the flexural strength values for NAC are slightly greater than that of RAC. The decrease in flexural strength values with further increase in fiber content can be attributed to the fact that voids increase in the matrix with the increase in PP fibers.



Graph VI: Influence of polypropylene fiber volume fraction on flexural strength at 28 days.

IV. CONCLUSIONS

Based on the experimental work the following conclusion is drawn:-

Due to the higher porosity of adhered mortar on to the recycled aggregates, the workability of RAC is much lower than NAC It is observed that the workability further decreases with the increase in the incorporation amount of polypropylene fibers. This is due to increase in frictional resistance between ingredients of concrete and polypropylene. The addition of polypropylene fiber has significant effect on compressive strength of the both NAC and RAC. Compressive strength initially increases with fiber content up to 0.5% and then decreases with further use of fibers. This is because the stress concentration is not the same along entire length of fiber in a dispersed fiber cement matrix and stresses are higher at the ends of the fibers. Since, the length of fibers considered in the present investigation is small (12 mm) in size, there may be more numbers of critical points exist which become susceptible to cracking. The maximum value obtained in case of NAC is 3.68MPa for 0.5% fiber content, an increment of 18.01%. Similarly, the maximum value obtained in case of RAC is 3.12MPa for 0.5% fiber content, an increment of 10.25% for split tensile strength. The maximum value obtained for NAC is 5.56MPa which is 17.15% increase. Similarly, for

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RAC, the maximum value obtained is 3.86MPa, an increase of 12.26 % for flexural strength.

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