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An Experimental Study on the Mechanical Properties of Concrete Having Recycled Aggregates in Place of Natural Coarse Aggregates at Different Replacement Percentages

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Abstract*: With concrete being the most ubiquitous material used in the construction sector, rampant exploitation of natural resources has been observed in the form of plummeting availability of natural aggregates, which account to most of the volume of concrete. On the contrary construction and demolition waste obtained from the demolition of buildings end up accumulating space at landfills and contribute to environmental waste. To address the following problems, recycled aggregates serve as a solution. These aggregates have the advantage of reducing transportation costs as well as the amount of Carbon dioxide. But these aggregates aren't used on a large scale owing to the inferior quality of concrete produced. The research presents an experimental investigation to study the mechanical properties of concrete (compressive and split tensile strength) and compare the strength of conventional concrete with concrete having untreated as well as treated aggregates. The recycled aggregates were substituted with virgin aggregates in different percentages of 25, 50, 75 and 100. Treatment of the recycled aggregates was done to enhance its properties, thus utilizing its functionality. Concrete specimens were casted using recycled aggregates, untreated aggregates and treated recycled aggregates separately.

***Index Terms*: Recycled aggregates, Natural aggregates, Compression strength, Split tensile strength, Flexural strength**

I. INTRODUCTION

Recycled concrete has seen its use in the construction of pavements but aren't used on a large scale owing to the poor quality of concrete produced when compared to conventional concrete. With the amount of construction and demolition waste in India varying from 112 to 431 million tonnes in 2016, enormous potential is seen to reuse the aggregates, thus eliminating the need to extract the natural resources which constitute concrete. The study made investigates the use of recycled aggregates as a substitute to coarse aggregates in concrete by studying its mechanical properties. Concrete specimens consisting of cubes and cylinders were casted and tested at the age of 7, 14 and 28 days. Following the testing of the specimens, the replacement percentage producing ideal results was chosen in casting flexure beams and tested at 7, 14 and 28 days.

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II. MATERIALS USED AND METHODOLOGY

A. Cement

Ordinary Portland cement of grade 53 conforming to IS 8112-1989 was used in the experimental study with the basic tests carried to study its properties.

B. Fine aggregate

River sand is used as fine aggregate in the experimental study where the properties of sand were determined by conducting tests in accordance to IS: 2386 (Part – I). The Specific Gravity for sand is 2.6.

C. Coarse Aggregates

Coarse aggregates of size 20mm were used as a part of the experimental study where the properties were determined in accordance to IS: 2386 (Part – III). The following tests were done to study the basic properties which are shown in Table 1.

Table I Properties of Conventional Coarse Aggregates

Sl. No	Test Conducted	Result
1.	Specific Gravity	2.59
2.	Aggregate Crushing Value Strength	16.62
3.	Aggregate Impact Value	17.46
4.	Water Absorption	1.3
5.	Los Angeles Abrasion Value	2.6

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D. Recycled Aggregates

Recycled aggregates of size 20mm were used as a substitute to virgin aggregates in different replacement percentages. The following tests were done to study the basic properties which are shown in Table 2.

Table II Properties of Recycled Coarse Aggregates

Sl. No	Test Conducted	Result
1.	Specific Gravity	2.5
2.	Aggregate Crushing Strength	59.51
3.	Aggregate Impact Value	32.8
4.	Water Absorption	5.7
5.	Los Angeles Abrasion Test	8.2

E. Treated Recycled Aggregates

An appropriate treatment process was adopted in order to remove the mortar attached to the recycled aggregates. Aggregates of size 20mm was used in this experimental study. A test on the basic properties was done prior to its use in the casting of cube and cylindrical specimens. Table 3 shows the list of tests conducted.

Table III Properties of Treated recycled coarse Aggregates

Sl. No	Test Conducted	Result
1.	Specific Gravity	2.6
2.	Aggregate Crushing Strength	22.59
3.	Aggregate Impact Value	21.67
4.	Water Absorption	2.05
5.	Los Angeles Abrasion	4.24

F. Mix design Proportion

The concrete mix was proportioned for M-30 grade as per the guidelines of IS 10262:2009 constituting to a ratio of 1:1.3:2.5 for conventional concrete having a Water Cement ratio of 0.45.

Casting and Testing of Specimens

The cube and cylinder specimens were casted of M30 grade concrete. The recycled aggregates which were broken, were sieved to get aggregates of size 20mm which were used as both untreated and treated recycled aggregates separately in different replacement percentages of 25, 50, 75 and 100 in casting the specimens. The cubes, cylinder and flexural beam specimens which were cast had a dimension of 150×150×150 mm, 150×300 mm and 500x100x100mm respectively.

Curing was done where the concrete specimens were tested at ages of 7, 14 and 28 days.

Fig 1 Casting and curing of the concrete specimens

G. Treatment of Recycled Aggregates

Treatment of recycled aggregates is done to bring out the need to reuse recycled aggregates by adopting a suitable process to ameliorate its properties. In this study, Thermal Mechanical Abrasion process was used. The process constituted of heating the aggregates for 300ºC for 24 hours to make it brittle, followed by subjecting the aggregates to abrasion in the Los Angeles Abrasion machine with the drum rotating at a speed of 150 revolutions per minute (RPM) or a duration of 5 minutes. The abrasion process accounted to a loss in the overall weight of aggregates, which were then sieved to get aggregates of size 20mm and cast in the cube and cylinder specimens.

Fig 2 Stages involved in the treatment process

III. RESULTS AND DISCUSSION

A. Compressive Strength test

The Compressive Strength test is done to determine the maximum load carrying capacity a concrete specimen withstands under compression, with the test being done in compliance to IS 516 1959.

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The concrete specimens having natural aggregates, untreated recycled aggregates and treated recycled aggregates in separate mixes, are tested at 7th, 14th and 28th day. The results obtained are tabulated below.

Table IV Compressive Strength results of the concrete mixes

Mix type	Replacement % of Recycled Aggregates	Compressive strength N/mm^2		
		7th day	14th day	28th day
Control Concrete	Nil	25.3	29.5	37.15
Untreated Recycled Aggregates	25%	34.88	35.3	36.7
	50%	27.9	34.08	36.21
	75%	26.3	31.82	33.38
	100%	21.68	27.7	32.3
Treated Recycled Aggregates	25%	33.6	38.5	42.4
	50%	32.2	36.2	41.8
	75%	25.6	34.04	39.51
	100%	29.51	35.6	38.5

From the table, it is noticed that the compressive strength of concrete specimens having treated recycled aggregates is better than that of conventional aggregates. It can also be noted that in the case of untreated recycled aggregates, replacement percentages of 25 and 50 have comparable compressive strength values to that of conventional aggregates.

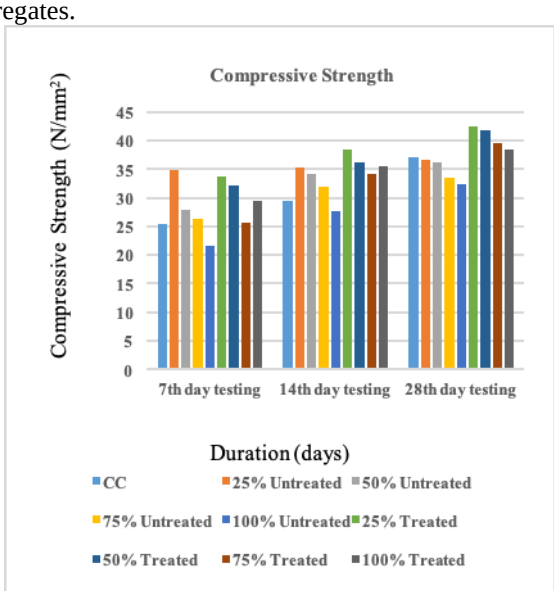

Fig 3 Graphical comparison of the compressive strength of concrete mixes consisting of conventional, untreated and treated aggregates

.Fig 4 Compressive Strength test indicating the failure of the specimen

B. Split tensile Strength Test

The Split tensile strength is done to determine the tensile strength as per the guidelines of IS 5816-1970. The concrete specimens having natural aggregates, untreated recycled aggregates and treated recycled aggregates in separate mixes are tested at 7, 14 and 28 days. The results obtained are tabulated below**.**

Table V Split tensile strength results of the concrete mixes

Mix type Of	Replacement % of Recycled Aggregates	Split Tensile Strength N/mm^2		
		7th day	14th day	28th day
Control Concrete	Nil	2.32	2.64	2.82
Untreated Recycled Aggregates	25%	2.15	2.57	2.97
	50%	2.4	2.7	2.95
	75%	2.29	2.50	2.88
	100%	1.79	2.32	2.78
Treated Recycled Aggregates	25%	2.59	2.74	3
	50%	2.40	2.53	2.98
	75%	2.16	2.46	2.95
	100%	1.79	2.12	2.79

From the table, an improvement of the split tensile strength of concrete specimens having treated recycled aggregates is observed, in comparison to conventional aggregates. It can also be noted that in the case of untreated recycled aggregates, replacement percentages of 25 has higher split tensile strength values than that of conventional aggregates.

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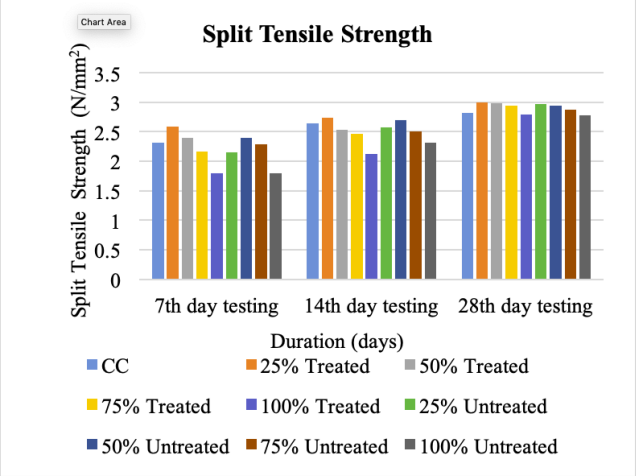

Fig 5 Graphical comparison of the split tensile strength of concrete mixes consisting of conventional, untreated and treated aggregates

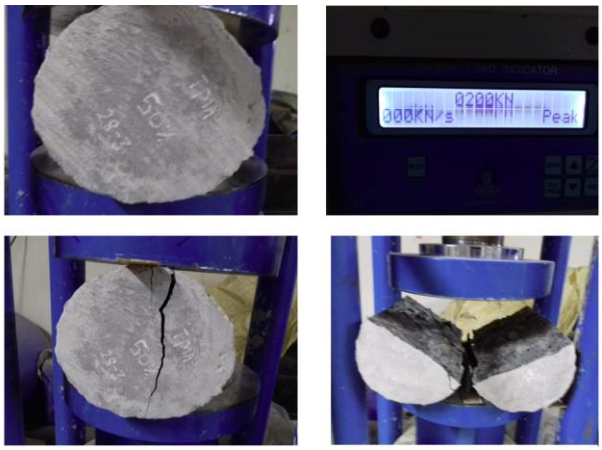

Fig 6 Split tensile strength test indicating the failure of the specimen

C. Flexural Strength Test

The flexure test on beams determines the maximum strength a specimen can resist without the emergence of cracks. The test is done in accordance to IS 516 1959 where the load acts at the center of the specimen. The dimensions of the mould are 100x100x500mm. After casting the cube and cylinder specimens, the replacement percentage giving better strength was opted and used in casting the unreinforced flexural beams. Concrete mixes consisting of conventional aggregates, untreated and conventional aggregates at 25 and 75 percentages respectively as well as treated and and conventional aggregates at 25 and 75, were casted separately and then tested at ages of 7, 14 and 28 days.

Table VI Flexural strength results of concrete mixes

Mix Type of	Replacement % of Recycled Aggregate	Flexural Strength N/mm²		
		7th day	14th day	28th day
Control Concrete	Nil	3	5.5	6.1
Untreated Recycled Aggregates	25%	5.2	6	6.3
Treated Recycled Aggregates	25%	5.5	6	7

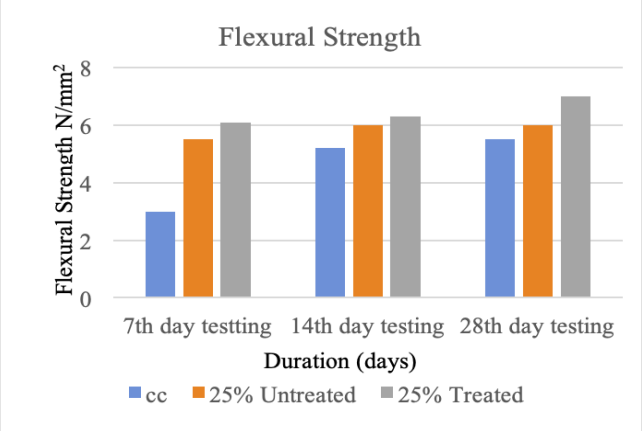

Fig 7 Graphical comparison of the flexural strength of concrete mixes consisting of conventional, untreated and treated aggregates

From the table, one can note that the beams consisting of treated aggregates produced better flexural strength value when compared to beams consisting of untreated and natural coarse aggregates

Fig 8 Flexural strength test indicating the failure of the specimen

IV.CONCLUSION

1. From the results obtained, it can be noted that replacement of treated aggregates at 25% can be used in place of natural coarse aggregates, as an increase in both the compressive, split tensile and flexural strength is observed.
2. Treated recycled aggregates showed higher values in the tests on properties in comparison with conventional aggregate.

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