Investigations on Concrete with Recycled Concrete as Coarse Aggregate

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Abstract: In India, a huge quantity of construction and demolition wastes are produced every year. These waste materials need a large place to dump and hence the disposal of these wastes has become a problem. Also the continuous use of natural resources for making conventional concrete leads to the reduction in their availability and results in the increase of the cost of the aggregates. When recycled coarse aggregate is used in structural concrete, the assessment of physical, mechanical and durable characteristics are very important. The physical and mechanical properties of natural aggregate and recycled aggregates are characterised. The experimental investigation was done on different grades of concrete (M25 and M35). A control specimen was created with 0% of recycled aggregates and this specimen was compared with different concrete mixes of different percentages of recycled aggregates. Recycled coarse aggregate is added in different amounts such as 20%, 40%, 60%, 80% and 100%. Cube compressive strength, cylinder compressive strength and split tensile strength of concrete made with recycled concrete aggregates are evaluated. A total of 72 cubes (150 mm), and 108 cylinders (150 mm diameter and 300 mm height) are used to determine the compressive strength and tensile strength. As the amount of RCA added is increased, the strength of the specimen decreased proportionally. Properties of materials used for the thesis were found out by doing several lab tests. The properties of recycled concrete aggregate are similar to the properties of natural aggregate. Thus, the possible use of RCA at this optimum amount helps to conserve natural resources and reduces the land needed for the disposal of waste aggregates.

Index Terms— ConstructionAnd Demolition Wastes, Experimental Tests, Mechanical Properties, Natural Resources, Optimum Percentage, Physical Properties, Recycled Concrete Aggregate.

1 Introduction

One of the major challenges of the present society is the protection of environment. Some of the important elements in this respect are the reduction in the consumption of energy, natural materials and extensive use of waste materials. Nowadays these are getting considerable attention under sustainable development. The use of recycled coarse aggregate from the construction and demolition wastes is showing prospective application in construction as an alternative to the natural aggregate. It conserves natural resources and reduces the space required for the landfill disposal.

India is presently generating construction and demolition (C &D) waste of 23.75 million tons annually and these figures are likely to double in the next 7 years. C&D waste, specifically concrete, has been seen as a resource in developed countries. Works on recycling have emphasized that if old concrete has to be used in second generation concrete, the product should adhere to the required compressive strength.

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Compressive strength primarily depends upon adhered mortar, water absorption, size of aggregate, strength of parent concrete, age of curing and ratio of replacement, interfacial transition zone, and moisture state, impurities present and controlled environmental condition.

The recycling and reuse of construction and demolition wastes seems to be a feasible solution in new constructions after the natural disasters or demolition of old structures. Due to shortage of aggregate and increasing transportation costs, there is continued pressure to use recycled materials in the construction industry as these materials can provide cost effective and environmentally friendly alternatives to the natural aggregate.

The 3R's

Recycled concrete aggregate (RCA) is often an economic alternative to new aggregates. In the construction sector, sustainable development is applicable on many levels, one of which is the production and the use of the recycled materials, especially concrete (as a percentage of the most commonly used construction material).

The term "recycling", in general, is defined as a single use or multiple usages of waste materials as an effective substitute for a commercial product or as raw material in further industrial process.

2 Literature Review

The current study deals with the effect of recycled concrete aggregate in conventional concrete, how the strength varying with different amount of RCA etc. Also to know the changes happens to strength values with different mix ratio. There are some literature which studies different areas of concrete waste and recycled concrete aggregate.

Hemalatha B.R.et.al (2008) highlighted the composition of Construction and Demolition waste [1], the need for its recycling and options that can be implemented for its efficient use in the field of concrete technology in general. The major components of construction and demolition waste are presented in this paper.

Ishtiyaq Gull (2011) gives results of studies undertaken to assess suitability of construction demolition as coarse aggregate in new concrete production [2]. this study recommends the recycling of waste concrete as an aggregate material in production of new concrete, provided the labor cost incurred in the extraction of waste aggregates from demolished buildings and also the cost incurred in using admixture to increase the strength of waste aggregates do not exceed the cost of fresh aggregates. The recycling of waste concrete helps us to conserve the natural aggregates and use them for more important constructional works.

Sallehan Ismail and MahyuddinRamli (2013) investigated the engineering properties of treated recycled concrete aggregate (RCA) for structural applications [3]. This work studies the effect of using different molarities of acid solvent and age of treatment (soaking) on properties of RCA, as well as the influence of using this treated aggregate on the properties of concrete. The test results indicate marked improvements in density, water absorption, and mechanical strength of RCA after acid treatments as compared to untreated RCA. The results demonstrate that treated RCA produced concrete with higher compressive strength as compared to untreated RCA. The results indicate that incorporating concrete mix with treated RCA at a proportion of up to 45% achieves the optimum strength in the mix design of concrete compressive strength.

Praveen Mathew.et.al (2014) investigates a sustainable option for demolition concrete waste for recycled aggregate concrete [4]. The three percentage replacements were selected. However in these investigation maximum values of strength was obtained at 40% replacement. This may be because of better gradation of recycled aggregate.

Shivakumar.M.N.et.al (2014) investigates the experimental study for the utilization of building demolished waste in the manufacturing of Porous concrete as a replacement of coarse aggregate [5]. This paper concludes that Porous concrete may be an alternative to the conventional concrete because of low density and high porosity. The average 28 days cube compressive strength are satisfying the requirements of the values given in table-1 of IS 12727-1989. Hence porous concrete can be suggested for intentional use.

Manish Kumar Singh and Dilip Kumar (2014) investigated the utilization of demolished concrete and construction waste as coarse aggregate in concrete [6]. In research, it is shows that 0 to 15% replacements of recycled aggregate as natural aggregate gives a good comparatively result. Density of the concrete will be decreases as the percentage of replacement of demolished and construction waste aggregate increases from 0% to 25%.

3 METHODOLOGY

The aim of this investigation is to compare the basic properties of control concrete (concrete made with natural aggregate) and the properties of concrete made with different contents of recycled aggregate. Six concrete types were tested within the research program.

The type and quantity of coarse aggregate were varied in the following way: -

- The first concrete mix had 100% of natural aggregate (R0), control mixture,
- The second concrete mix had 80% of NCA and 20% of RCA (R20)
- The third concrete mix had 60% of NCA and 40% of RCA (R40),
- The fourth concrete mix had 40% of NCA and 60% of RCA (R60),
- The fifth concrete mix had 80% of NCA and 20% of RCA (R80),
- The sixth concrete mix had 100% of recycled coarse aggregate (R100).

As all the other variables were kept constant, this research enabled us to determine the influence of the coarse recycled aggregate amount (0%, 20%, 40%, 60%, 80% and 100%) on tested concrete properties. The experimental investigation was done on different grades of concrete (M25 and M35).

4 EXPERIMENTAL INVESTIGATIONS

Recycled concrete aggregate

Materials

- Cement: POZZOLANA PORTLAND CEMENT (PPC).
- Natural Coarse aggregate (NCA): Aggregates predominately retained on the No. 4 (4.75 mm) sieve. The maximum size of aggregate used in this thesis was 20 mm.
- Recycled Coarse Aggregate (RCA): Aggregates predominately retained on the No. 4 (4.75 mm) sieve. The maximum size of aggregate used in this thesis was 20 mm.
- Fine Aggregate (River Sand): Aggregates passing No.4 (4.75 mm) sieve and predominately retained on

the No. 200 (75 µm) sieve.

- Water: Portable water as per IS 456:2000

Mix design

Concrete mix proportions are designed as per IS 10262:2009, with a common target slump 70±10 mm. For this properties of materials used for the thesis were found out by doing several lab tests.

Grade	Cement	F.A	C.A	W/C
M25	1	1.789	3	0.5
M35	1	1.538	2.68	0.45

Compression test

This test was conducted as per IS 516-1959. The cubes of standard size 150x150x150mm and cylinders 150x300mm were used to find the compressive strength of concrete. Specimens were placed on the bearing surface of compression testing machine, of capacity 100tones without eccentricity and a uniform rate of loading of 550 Kg/cm2 per minute was applied till the failure of the cube. The maximum load was noted and the compressive strength was calculated.

Split tensile strength test

Mix were prepared according to the adopted mix design values. The cylinders of standard size 150 mm dia and 300mm height were used. After curing of 7 days and 28 days specimens were tested for split tensile test under compression testing machine.

Cylinder specimens are placed horizontally between the loading surface of compression testing machine and the load were applied until the failure of specimens. Split tensile strength = $2P/\pi DL$

Where P=Compressive load on cylinder,

D=Diameter of cylinder,

L= Length of cylinder.

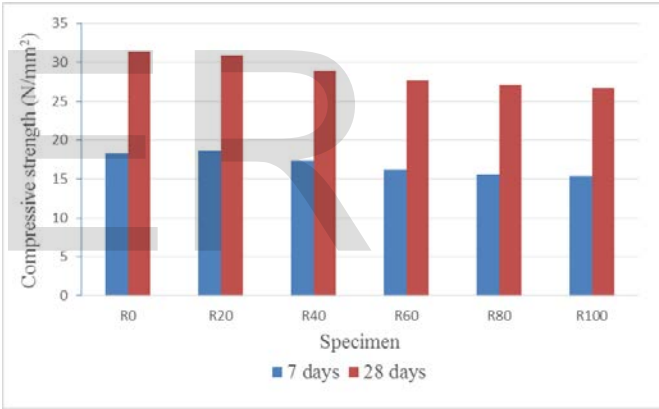
5 Results And Discussions

For recycled concrete aggregate, the result shown that the addition of recycled aggregate resulted in a significant reduction in concrete compressive strength with the control specimen. This reduction increased with increasing percentage of recycled aggregate. Reduction in M25 grade cube compressive strength of 2% (R20), 8% (R40), 12% (R60), 14% (R80) and 15% (R100) were observed when the natural coarse aggregate was replaced by recycled concrete aggregate.

TABLE 1
M25 grade concrete cube strength (MPa)

Specimen	7 days*	28 days*	Normalized strength values with respect to 28 days R0 specimen
R0	18.36	31.40	1.00
R20	18.66	30.91	0.98
R40	17.33	28.88	0.92
R60	16.24	27.63	0.88
R80	15.56	27.16	0.86
R100	15.42	26.72	0.85

*Average of 3 specimens



Reduction in M25 grade cylinder compressive strength of 4% (R20), 9% (R40), 14% (R60), 16% (R80) and 19% (R100) were observed when the natural coarse aggregate was replaced by recycled concrete aggregate.

TABLE 2
M25 grade concrete cylinder strength (MPa)

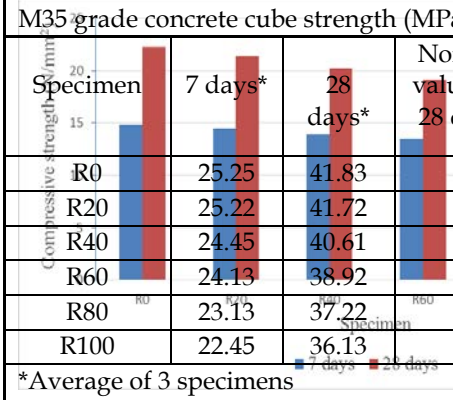
Specimen	7 days*	28 days*	Normalized strength values with respect to 28 days R0 specimen
R0	14.8	22.24	1.00
R20	14.43	21.37	0.96
R40	13.96	20.24	0.91
R60	13.47	19.15	0.86
R80	12.89	18.63	0.84
R100	12.73	17.98	0.81

*Average of 3 specimens

TABLE 4
M35 grade concrete cube strength (MPa)

Specimen	7 days*	28 days*	Normalized strength values with respect to 28 days R0 specimen
R0	25.25	41.83	1.00
R20	25.22	41.72	0.99
R40	24.45	40.61	0.97
R60	24.13	38.92	0.93
R80	23.13	37.22	0.89
R100	22.45	36.13	0.86

*Average of 3 specimens

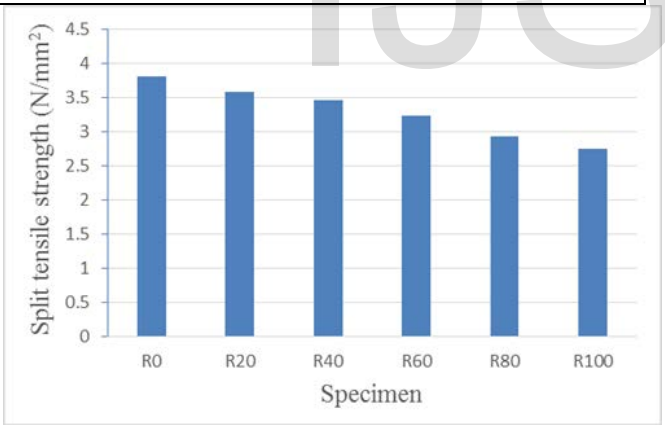


Reduction in M25 grade split tensile strength of 6% (R20), 9% (R40), 15% (R60), 23% (R80) and 28% (R100) were observed when the natural coarse aggregate was replaced by recycled concrete aggregate.

TABLE 3
M25 grade concrete split tensile strength (MPa)

Specimen	28 days*	Normalized strength values with respect to 28 days R0 specimen
R0	3.81	1.00
R20	3.59	0.94
R40	3.46	0.91
R60	3.24	0.85
R80	2.93	0.77
R100	2.75	0.72

*Average of 3 specimens



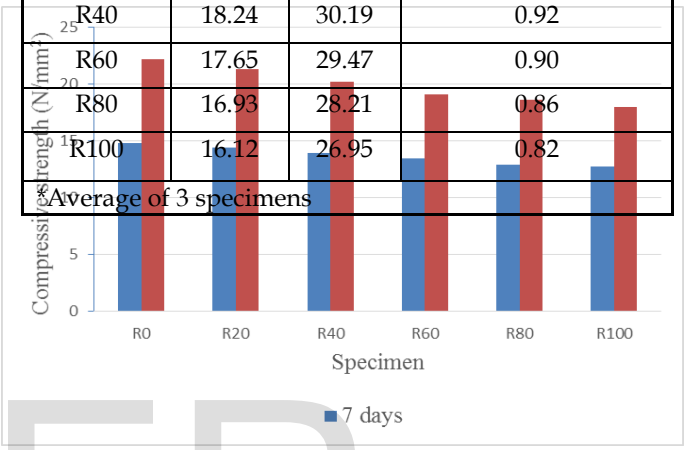
Reduction in M35 grade cube compressive strength of 1% (R20), 3% (R40), 7% (R60), 11% (R80) and 14% (R100) were observed when the natural coarse aggregate was replaced by recycled concrete aggregate.

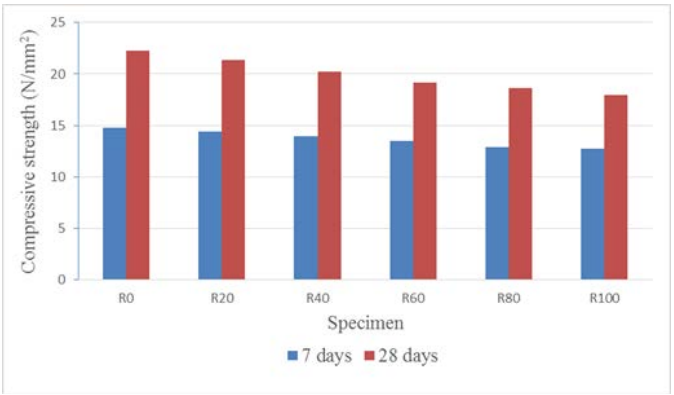
Reduction in M35 grade cylinder compressive strength of 3% (R20), 8% (R40), 10% (R60), 14% (R80) and 18% (R100) were observed when the natural coarse aggregate was replaced by recycled concrete aggregate.

TABLE 5
M35 grade concrete cylinder strength (MPa)

Specimen	7 days*	28 days*	Normalized strength values with respect to 28 days R0 specimen
R0	19.44	32.63	1.00
R20	19.04	31.83	0.97
R40	18.24	30.19	0.92
R60	17.65	29.47	0.90
R80	16.93	28.21	0.86
R100	16.12	26.95	0.82

*Average of 3 specimens



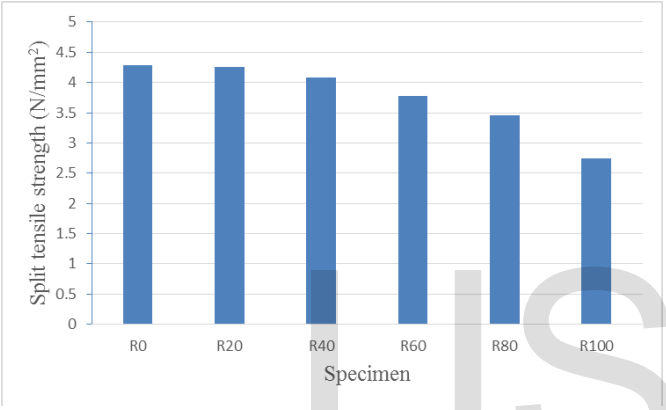


Reduction in M35 grade split tensile strength of 1% (R20), 5% (R40), 12% (R60), 20% (R80) and 23% (R100) were observed when the natural coarse aggregate was replaced by recycled concrete aggregate.

TABLE 6
M35 grade concrete split tensile strength (MPa)

Specimen	28 days*	Normalized strength values with respect to 28 days R0 specimen
R0	4.29	1.00
R20	4.25	0.99
R40	4.08	0.95
R60	3.78	0.88
R80	3.45	0.80
R100	3.29	0.77

*Average of 3 specimens



6 Summary AndConclusions

From this study, it can be inferred that the recycled concrete aggregate is an ideal substitute for structural and non-structural concrete. Accordingly the six percentage replacement were selected. Here, two different grade of concrete were used for the study. However in these investigation the strength values reduce by increase in percentage of replacement. First of all, the difference in strength between R0 and R100 concrete are less than 16% for cubes and less than 20% for cylinders. The strength between R0 and R40 less than 10% for cubes and cylinders. The difference in tensile strength between R0 and R100 concrete are less than 30%. The strength between R0 and R40 less than 10%. Such difference in compressive strength and tensile strength are very small and will not have a considerable effect on concrete applications. From the results, it shows that grade of concrete have no major role in the strength variation. That is, change in the grade of concrete is not a factor which affects the properties of concrete with recycled concrete as coarse aggregate. Hence, this study recommends Construction and Demolished waste is used as the coarse aggregate in new concrete. It is shows that 0 to 40% replacements of recycled aggregate as natural aggregate gives a good comparatively result. Construction and Demolished waste concrete may be an alternative to the conventional concrete. Use of the waste aggregate in the new concrete as the recycled concrete aggregate reduces the environmental pollution as well as providing an economic value for the waste material. Usage of recycled aggregates can not only preserve the finite raw materials, but also reduce energy consumption and overall construction costs.

7. Future Scope Of The Study

This study is very much useful in the area of sustainable development, especially the reduction in the consumption of energy, natural materials and extensive use of waste materials. There is significant potential for growth of recycled and secondary aggregates as an appropriate and "green" solution to the anticipated increased world-wide construction activity. Major research has shown that recycled concrete waste can be used in concrete and that there are few applications issues related to its use. However, further work is needed to gradually develop the much wanted knowledge base and the necessary tools for the industry to be able to use these resources routinely and with confidence. Significant steps and researches are being taken to improve the quality of recycled aggregates and new standards are easing its use in higher value applications.
This study, evaluated cube compressive test, cylinder compressive strength and split tensile strength of concrete with different proportions of natural and recycled aggregate. There is a lot of advanced studies to be carried out beyond this. More specimens with different admixtures and treatments can be used to do more studies and experiments. Let it be a good start to do more findings.

Acknowledgement

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Reference

[1] Hemalatha B.R.et.al, "Construction and demolition waste recycling for sustainable growth and development", Journal of Environmental research and development, 2008.
[2] Ishtiyaq Gull, "Testing of strength of recycled waste concrete and its applicability",ASCE,2011
[3] Sallehan Ismail and MahyuddinRamli., "Engineering properties of treated recycled aggregates (RCA) for structural applications", Construction and building materials, 2013.
[4] Praveen Mathew.et.al., "Recycled Aggregate Concrete, a Sustainable Option from Demolition Concrete Waste-A Percentage Replacement Method", IJIRSET, 2014.
[5] Shivakumar.M.N.et.al, "Use of building demolished waste as coarse aggregate in porous concrete", IJRET, 2014.

[6] Manish Kumar Singh and Dilip Kumar, "Utilization of Demolished Concrete and Construction Waste as Coarse Aggregate in Concrete", IJESRT, 2014.