Experimental Studies on Concrete by Replacing Coarse Aggregates with Recycled Aggregates

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ABSTRACT

The huge concrete debris can be recycled and reused as an alternate source of raw material for concrete. Recycling of concrete and using it as aggregates has gained increasing interests. The recycling and reuse of concrete debris decreases solid waste pollution. The reuse of concrete is termed at recycled aggregate (RA).

This paper presents an experimental study on the properties of cement, fine aggregate, normal coarse aggregate (CA) and recycled aggregate (RA) The fresh and hardened concrete properties of concrete prepared with normal and recycled aggregates were studied. The influence of aggregates on concrete's compressive strength was also investigated. Concrete mixes with a target compressive strength of 25MPa were prepared by varying normal coarse aggregate and recycled aggregates in percentages of 10% to 100% from the total aggregate. W/C ratio was varied from 0.45 to 0.5. When normal aggregate was replaced by recycled aggregate up to 50%, the w/c ratio was 0.45 and for above percentages of replacement w/c ratio was 0.5, since the RA showed higher water absorption compared to CA. The compressive strength test of cubes and cylinder, split tensile strength test of cylinders and flexural strength test of beams were established during the experimental work. From the experimental studies, it was found that the compressive strength and tensile strength of concrete made with RA increased upto 60% replacement. The concrete of 50% to 60% replacement by RA showed an equivalent strength and with increase in percentage of RA above 60% the strength decreased.

Keywords: Normal coarse aggregate(CA), recycled aggregates(RA), compressive strength, split tensile strength, flexural strength

INTRODUCTION

Concrete is the premier construction material across the world and the most widely used material in all types of civil engineering works. Concrete is a manufactured product, essentially consisting of cement, aggregates, water and admixture. Among these, aggregates, i.e. inert granular materials such as sand, crushed stone or gravel form the major part. [Udhir P.Patil et.al.]Cement concrete is one of the seemingly simple but actually a complex material. Hence each and every property of materials in concrete that are being used is studied thoroughly. Mixing of concrete with cement, coarse aggregate and fine aggregate (river sand) is being practiced throughout everywhere and the strengths are being determined.

The amount of concrete debris collected from demolished structures is huge. The amount of construction and demolition waste has increased considerably over the last few decades. The solid waste management of this rubble collected from damaged and demolished structures has become an important issue in every country. The research works on the recycling of waste construction materials is very important since the materials waste is gradually increasing with the increase of population and increasing of urban development. The increasing cost of landfill, the scarcity of natural resources coupled with the increase in aggregate requirement for construction, has attracted increasing interests, from the construction industry, concerning the use of recycled aggregate (RA) to partially replace the virgin coarse aggregate[A.A. Tsoumani et.al]. Crushing, washing and drying this waste concrete could serve as recycled aggregate in another fresh concrete. Thus, recycling and reusing concrete debris can not only reduce the waste but also transform them into aggregate resources. In this paper the strength of concrete was determined by replacing the coarse aggregate with recycled aggregate in various percentages. The nominal mixes of M25 grade concrete was studied and was compared with the 10% to 100% replacement of Recycled aggregates.

EXPERIMENNTAL STUDY

Properties of Materials:

Properties of Cement (OPC 53-Grade): The Ordinary Portland Cement (OPC) of Grade 53 was used for the preparation of test specimens.

Fineness Test (By Air Permeability test):

Journal of Chemical and Pharmaceutical Sciences ISSN: 0974-2115

Specific Surface = 278m^2/kg

Setting Time (Using Vicat's Apparatus):

Initial setting time = 28 minutes
Final Setting Time = 158 minutes

Strength Test: Compressive Strength Test: Cement sand ratio of 1:3 was used and 12 cubes of size 70.5 mm x 70.5 mm x 70.5 mm were used to find the strength of cement mortar.

7 Days compressive Strength = 3.6 N/mm^2
14 Days compressive Strength = 18.4 N/mm^2
28 Days compressive Strength = 52.2 N/mm^2
Soundness test (Le-Chatelier method) = 0.48mm

Specific gravity of cement (By Density Bottle Method) = 3.10

Properties of Coarse Aggregate (CA): Crushed granite aggregates particles passing through 20mm and retained on 12.5mm I.S sieve was used as natural coarse aggregates.
Specific gravity of Coarse Aggregate = 2.605
Water absorption of Coarse Aggregate **(**Density Bucket) = 1.27 %
Bulking of Aggregate = 2%

Shape Factor:
Flakiness Index (Thickness Gauge) = 24.46%
Elongation Index (Length Gauge) =24.53%
Impact Value (Impact Testing Machine) =18.12%
Crushing Value (Compressive Testing Machine) =23.65%
Abrasion Value (Los Angeles Abrasion Testing Machine) =16.22%
Grading of aggregate Fineness Modulus = 6.89

Properties of Fine Aggregate (FA): The fine aggregate used in this experimental investigation was natural river sand confirming to zone II.

Specific gravity of Fine Aggregate = 2.63
Water absorption of Coarse Aggregate (Density Bucket) = 3.25%
Bulking of Aggregate =5%
Grading of aggregate Fineness Modulus = 2.6

Properties of Recycled Coarse Aggregate (RA): Crushed concrete aggregate waste passing through 20mm and retained on 12mm IS sieve were used as recycled coarse aggregate. Recycled aggregate used in this research was crushed concrete, i.e. RA obtained from site near Schemmencherry, Tamil Nadu, India. The recycled aggregates were crushed and soaked in water for 24 hours for water treatment then kept for drying.
Specific gravity of Coarse Aggregate = 2.89
Water absorption of Coarse Aggregate (Density Bucket) = 5.78 %
Bulking of Aggregate = 6%
Shape Factor
Flakiness Index (Thickness Gauge) = 25.62%
Elongation Index (Length Gauge) =28.72%
Impact Value (Impact Testing Machine) =16.42%
Crushing Value (Compressive Testing Machine) =22.85%
Abrasion Value (Los Angeles Abrasion Testing Machine) =19.72%
Grading of aggregate Fineness Modulus = 7.03

Water*:* Portable water available in laboratory was used.

Test Specimen: Various combinations of specimens made with M25 Grade of concrete by varying the percentages of aggregates both normal and recycled aggregate are listed in Table 1. The variation in w/c ratio is 0.45% for 0% - 50% replacement of natural aggregate by recycled aggregate and the variation increase to 0.5% from 50% - 100% replacement, due to the increase in the water absorption properties of recycled aggregates.

Journal of Chemical and Pharmaceutical Sciences ISSN: 0974-2115

Table.1.Description of Specimens

Specimen	Coarse Aggregate		Number of Specimens			Water Cement Ratio
	Normal Coarse Aggregate (CA)	Recycled Aggregate (RA)	Cube	Cylinder	Prism	
RA - 0% (Control Specimen)	100%	0%	9	18	9	0.45%
RA - 10%	90%	10%	6	12	6	0.45 %
RA - 20%	80%	20%	6	12	6	0.45 %
RA - 30%	70%	30%	6	12	6	0.45 %
RA - 40%	60%	40%	6	12	6	0.45 %
RA - 50%	50%	50%	6	12	6	0.45 %
RA - 60%	40%	60%	6	12	6	0.5 %
RA - 70%	30%	70%	6	12	6	0.5 %
RA - 80%	20%	80%	6	12	6	0.5 %
RA - 90%	10%	90%	6	12	6	0.5 %
RA - 100%	0%	100%	6	12	6	0.5 %

Fresh Concrete Test: Workability, flow property and compaction factor of M25 grade of concrete for various test specimen were studied.

Table.2.Fresh Concrete Properties

SPECIMEN		RA0%	RA10%	RA20%	RA30%	RA40%	RA 50%	RA60%	RA70%	RA80%	RA90%	RA100%
w/c ratio		0.45	0.45	0.45	0.45	0.45	0.45	0.50	0.50	0.50	0.50	0.50
Slump Test	Slump Value	22mm	17mm	14mm	9mm	3mm	2mm	68mm	53mm	47mm	33mm	21mm
Flow Table	Flow %	16%	13%	11%	10%	9%	6%	31%	28%	20%	18%	12%
Compaction Factor	Compaction Factor	0.78	0.78	0.77	0.76	0.74	0.73	0.88	0.82	0.79	0.77	0.76

Hardened concrete test: Concrete mixes prepared for different specimen were casted in cube moulds of size 150 mm x 150 mm x 150 mm, cylinder moulds of diameter 150mm and height 300mm and prism moulds of cross section 100mm x 100mm and length 500mm by proper compaction using tamping rods and keeping in a vibrating table. After proper compaction the concrete in the mould is leveled and allowed to set. After 24 hours the moulds were removed and the specimen were cured in the curing tank for the required or specified days. Specimens stored in water were tested immediately on removal from the water and while they were still in the wet condition. Surface water and grit were wiped off from the specimens and any projecting fins were removed. The testing was done in CTM for compression test or Flexural Testing Machine for bending test. The loads were applied smoothly and gradually. The crushing loads were noted and average compressive and flexural strength of specimens was determined.

Fig.1.Mixing of Concrete

Fig.2.Batching of Concrete

Fig.3.Vibrating Table

Journal of Chemical and Pharmaceutical Sciences ISSN: 0974-2115

Compressive Strength Test: Compressive strength for hardened concrete was determined by using CTM of 1000kN capacity. The specimens were loaded up to failure and the collapse load was noted. From collapse load and area of cross section of the specimen the Compressive Strength were calculated in the corresponding specimen for 3, 7 and 28 days. The compressive strength of cube and cylinder were calculated from the collapse load.

Split Tensile Strength Test: The splitting tests are well known indirect tests used for determining the tensile strength of concrete and referred to as split tensile strength of concrete. The test consists of applying a compressive line load along the opposite generators of a concrete cylinder placed with its axis horizontal between the compressive platens. Due to the compression loading a fairly uniform tensile stress is developed over nearly 2/3 of the loaded diameter. Split Tensile strength for hardened concrete was determined by using CTM of 1000kN capacity. The specimens were loaded up to failure and the collapse load was noted. From collapse load and area of cross section of the loading the Split Tensile Strength were calculated in the corresponding specimen for 3, 7 and 28 days.

Flexural Strength Test: Flexural strength measures the tensile strength of concrete. It is a measure of an unreinforced concrete beam or slab to resist failure in bending. It is measured by loading 100mmx100mm concrete beams with a span length of at least three times the depth. The flexural strength is expressed as Modulus of Rupture (MPa) and is determined by standard third-point loading.

Fig.4.Cube Tested in CTM

Fig.5.Cylinder Tested in CTM

Fig.6.Split Tensile Test in CTM

Fig.7.Split Tensile Test in CTM

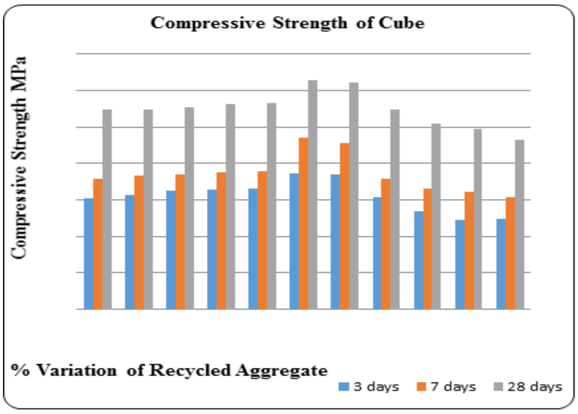
Fig.8.Flexural Test of Beams

Fig.9.Flexural Test of Beams

RESULTS

The compressive strength of cube and cylinder were calculated based on the collapse load. The figure shows the compressive strength of cube for various percentages of normal coarse aggregate (CA) and recycled aggregates (RA). The compressive strength at 28 days increases rapidly for 10 percentage replacement to 50% replacement and thereafter decreases. There is a significant change between 50% to 60% replacement of CA with RA. When plotted in a smooth graph it shows a significant peak increase around equal percentage variation.

Journal of Chemical and Pharmaceutical Sciences ISSN: 0974-2115



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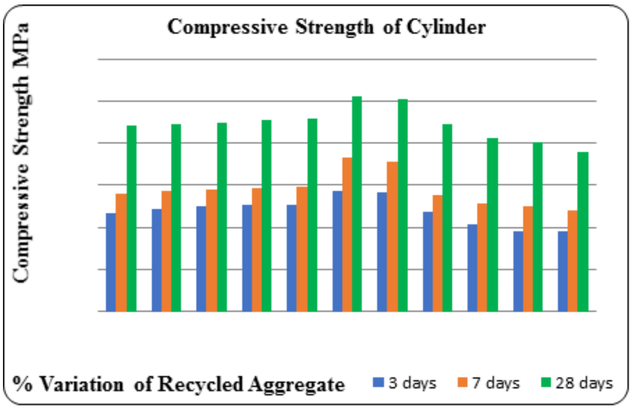

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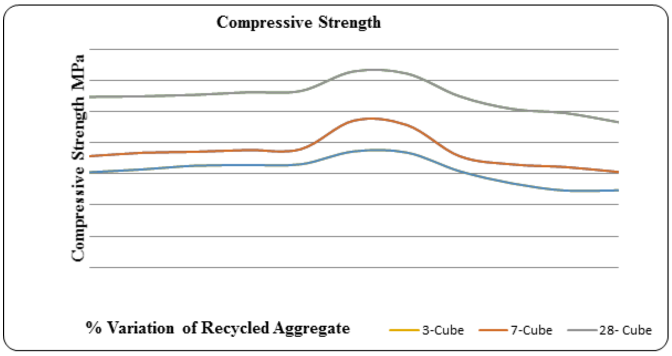

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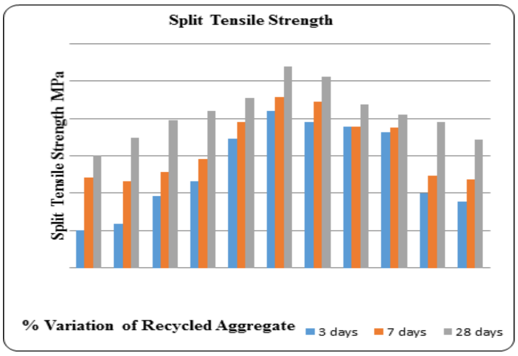

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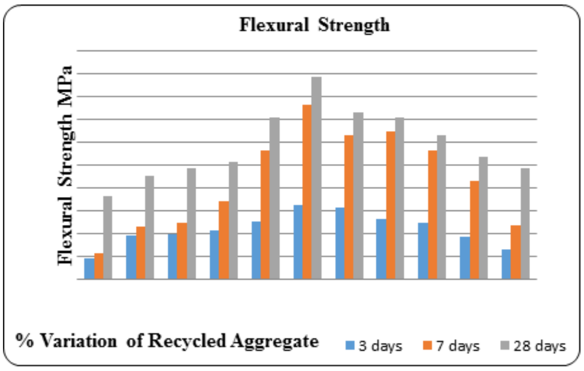

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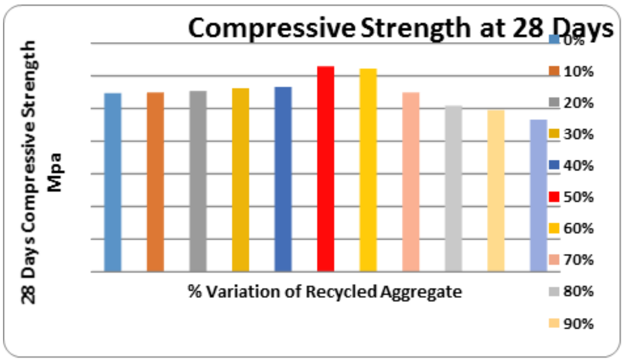

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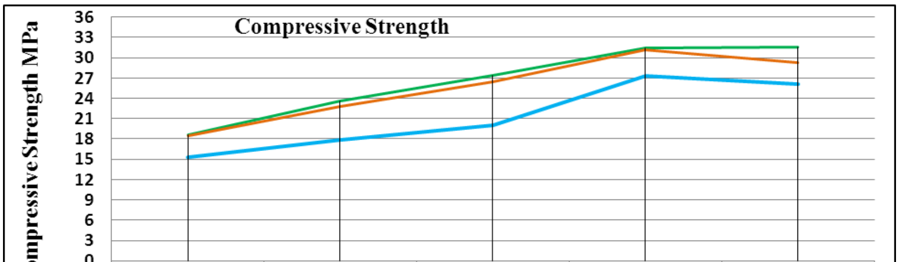

	3 Days	7 Days	14 Days	28 Days	60 Days
0%	15.26	17.85	20.01	27.36	26.11
50%	18.62	23.56	27.33	31.47	31.52
60%	18.43	22.85	26.42	31.11	29.33

Figure.16.

Journal of Chemical and Pharmaceutical Sciences ISSN: 0974-2115

CONCLUSION

This paper has discussed properties of RA, the effects of RA use on concrete material properties, and the large scale impact of RA on member properties and strength. Specific gravity of RA was high when compared with specific gravity CA. Water absorption was high for RA and hence the w/c ratio of 0.05% was increased for increase in RA content above 50% replacement with CA. Although recycled aggregate can be applied in the high strength structure, one issue must not be neglected that increase in recycled aggregate with reduce water content would have low workability. Whenever recycled aggregate is applied, water content in the concrete mix has to be monitored carefully as the water absorption capacity of recycled aggregate will vary.

1. With the same w/c ratio, the slump value decreases if percentage of RA was increased.
2. With the same w/c ratio, the flow percentage decreases when percentage of RA was increased.
3. With the same w/c ratio, the compaction factor increases when percentage of RA was increased.
4. The effect of the use of recycled aggregate on the compressive strength depends on the percentage of coarse aggregate substituted. For low percentages of substitution (less than 50%) it can be said that this influence is practically negligible. The compressive strength of concrete gradually increased form 10% to 50%.
5. When CA was replaced by RA the compressive strength decreases gradually form 60%. For higher percentages of substitution the compressive strength of concrete decreased with an increase in the recycled aggregate content. Replacing CA in concrete with RA decreases the compressive strength above 60% replacement.
6. When the replacement was between 50% - 60% the compressive strength remains almost equal or the percentage variation was less. The maximum compressive strength was achieved in this variation.
7. Split tensile strength was equivalent and at times superior. Split tensile strength was marginal for 3 and 7 days test but gradually varied for 28 days test.

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