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DEVELOPMENT OF M20 AND M30 GRADE OF RECYCLED AGGREGATE CONCRETE BY REPLACING 100% VIRGIN AGGREGATES WITH RECYCLED AGGREGATES

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Abstract-*The increasing difficulty in securing natural coarse and fine aggregates for the production of concrete coupled with the environmental issue and depletion of natural aggregates makes the usage of recycled coarse aggregate. Hence, the recycled aggregate concrete (RAC) is very much required to preserve the natural resources for future generation. Study on recycled aggregate is having high significance as the concrete contains 60 to 80% with coarse aggregates. However, the full use of the material can be justified only through structural applications. Engineers are reluctant to use RAC in structural elements due to lack of established design guidelines. Strength and durability studies pertaining to Recycled Aggregate Concrete (RAC) of M20 and M30 grades made by replacing 100 % virgin aggregates with recycled aggregates are presented. The results of compressive strength test, split tensile strength, flexural strength and permeability tests are presented in this paper.*

Keywords*-Construction and Demolition waste, Environmental issues, Structural Engineering Applications, 100% recycled aggregate, Compressive strength, flexural strength, splitting tensile strength and permeability.*

I. INTRODUCTION

The idea of recycling 'construction and demolition waste' was conceived after World War II, due to bombarding during the period 1939-45. The cities have become heaps of construction and demolition waste. Also due to rapid urbanization the demolition of concrete buildings has been increased. The difficulty for disposing of concrete rubble and scarcity of aggregate has prompted an interest in the possibility of using it as aggregate in concrete. Due to continuous extraction of natural resources, there will be depletion of them which will have severe impact on the environment.

As per the World Bank's survey made in the year 2015, some important cities like Delhi and Mumbai in India, are generating a daily waste of about 58,750 kN and 53,900 kN respectively. These two cities are ranked 9th and 10th among top ten cities in the World in generating daily 'construction and demolition waste'. Generation of daily waste material over the entire India stood at 4th place in the world. It is worth to mention that about 50% of the daily waste is the building rubble. In this context, investigation on strength and durability of recycled aggregate concrete has significant role. After the World War II, extensive research has been carried out by substitution of recycled aggregate with virgin aggregate but little attention has been paid on usage of 100 % recycled aggregate for production of RAC for structural concrete. This paper presents usage of 100 % recycled aggregate for an ordinary grade concrete (M20) and a standard grade of concrete (M30). Extensive research is required to study the durability of RAC. Mechanical properties such as compressive strength, flexural strength, splitting tensile strength and permeability of RAC for M20 and M30 grades of concrete are presented in this paper.

II. AIM OF THE WORK

To achieve Target Mean Strength of Recycled Aggregate Concrete of grade M20 and M30 by replacing 100% virgin aggregates with Recycled Aggregates for production of RAC for structural engineering applications.

III. NEED OF THIS WORK

a) To conserve natural resources
b) To resolve environmental issues
c) To reduce the construction cost
d) To save the land fill space

IV. SCOPE OF THIS WORK

In this experimental investigation 24 cubes, 24 cylinders, 12 prisms are cast for Compressive, Split and Flexural Strengths and permeability test results are compared NAC(Natural Aggregate Concrete) with RAC(Recycled Aggregate Concrete) by *replacing 100 % virgin aggregates with recycled aggregates* for production of an ordinary grade concrete (M20) and a standard grade of concrete (M30).

V. RESEARCH SIGNIFICANCE

So far maximum research has been done by replacing virgin aggregate with recycled aggregate at *various percentages*.
In this present investigation, the Target Mean Strength of M20 and M30 achieved by *replacing 100% virgin aggregates with Recycled Aggregates*.

VI. LITERATURE REVIEW

Bhikshma et al[1] investigated on strength characteristics of the bacterial concrete with recycled coarse aggregate concrete with bacteria observed to be 10% more compared with RCA concrete without bacteria culture for M20, 6% more for M25 grade concrete and concluded that, workability of recycled aggregate bacteria concrete increases by 10% ore when compared to without bacteria concrete. Lokesh et al[2] reported that, the torsion decreases with increase in the percentage of recycled aggregates and also found that uo to 50% replacement of aggregates the strength reduction isles and not even 10% in case of torsion strength and concluded the usage of recycled aggregates up to 50% can be acceptable. Neville[3] reviewed the properties of aggregates that highly affect the behavior of both fresh and hardened concrete, namely strength, hardness, toughness, durability, porosity, volume change, grain shapes and texture, chemical reactivity, and relative density. Sastry[4] investigated on fibrous recycled aggregate triple blended high strength concrete and concluded that the 28 days compressive strength of the triple blending , the strength is reduced by 20% with addition of 100% recycled aggregates used as replacement to virgin aggregates. The addition of steel fibres is helpful in increasing the flexural strength, splitting tensile and young's modulus with and without recycled aggregate. Kumar[5] stated that the deposit of coarse-grained soil are a good source of natural sand and gravel. Since soil deposits usually contain varying quantities of silt and clay, which adversely affect the properties of both fresh and hardened concrete, these contaminants must be removed by washing or dry screening. Prasad[6] investigated on bamboo reinforced concrete and concluded that the mechanical properties of bamboo had been found, that the bamboo having the same properties as steel used to prepare the test specimens. Stress verses strain curve of bamboo splint in tension shows that bamboo is viscous elastic material having both viscous and elastic properties and exhibits time dependent strain elasticity. The ultimate tensile strength of bamboo splints is as high as 182 MPa which is comparable to the yield strength of structural steel i.e 250 MPa. Hence bamboo splints can resist sufficient tensile loads in a concrete flexural element. Also, reported that the even the modulus of elasticity of 50% bamboo replaced case gives 15% variation as compared to 100% steel reinforcement.
After literature review, it is concluded that, the little attention has been paid for production of 'recycled aggregate concrete' by replacing 100% virgin aggregates with recycled aggregates.

VII. EXPERIMENTAL PROGRAMMES

The recycled aggregates have extracted by using Jaw Crusher. The materials that are used for the present research work are cement, fine aggregate, virgin aggregates, recycled coarse aggregate and water. Physical properties of coarse and fine aggregates were studied as per IS 2386:1963[7] and IS 383:2016[8]. The properties of coarse aggregate are presented in Tables 1 to 3. Potable water which is free from chemicals and organic materials was used for the study.

Table 1 Physical property of Cement (OPC 53 grade)

Sl. No.	Property of Cement	Test Results	IS: 12269-1987[9] Specifications
1	Specific gravity	3.14	---
2	Normal Consistency	35%	---
3	Initial setting time	48 min.	Not less than 30 minutes
4	Final setting time	260 min.	Not more than 600 minutes
5	Fineness	3100 cm^2/gm	Should not be less than 2250 cm^2 / gm
6	Compressive strength	61.5 MPa	53 MPa

Table 2 Physical properties of Aggregates

Property		Natural Aggregate	Recycled Aggregate	Fine Aggregate
Bulk Density	Loose	1498 kg/m^3	1487 kg/m^3	1740 kg/m^3
	Compacted	1711 kg/m^3	1708 kg/m^3	
Aggregate impact value		17.30%	16.78%	-
Crushing strength (MPa)		22.06	21.11	-
Fineness modulus		7.04	7.06	2.95
Specific gravity		2.75	2.66	2.75
Water Absorption (%)		0.27%	3.05%	0.82
Water content (%)		-	-	3.21
Percentage Voids (%)		-	-	38.71

VIII. MIX PROPORTIONING

The mix design was carried out as per IS 10262 (2009) [10] for M20 and M30. Extra water of 3.05% (by weight of cement) was added to produce 'recycled aggregate concrete' as the recycled aggregates absorb relatively higher water compared to virgin aggregates. Properties of cement, fine aggregate, natural and recycled aggregates were investigated. For both M20 and M30 grades of concrete considered in this paper, *100% recycled aggregate* was used instead of virgin aggregates. The quantities of materials required for natural aggregate concrete (NAC) and recycled aggregate concrete (RAC) are shown in the Table 3.

Table 3. Quantity of materials

Material	Quantity(kg/m^3) for NAC		Quantity(kg/m^3) for RAC	
Grade	M20	M30	M20	M30
Cement	325.00	350.00	370.00	424.00
Fine aggregate	725.83	750.00	673.83	656.00
Coarse aggregates (20mm)	1104.20	1125.00	666.00	649.2
Coarse aggregates (20mm)	-	-	444.08	432.80
Water	176.60	170.00	186.60	185.00

IX. RESULTS AND DISCUSSIONS

9.1 Workability of Concrete

Workability of concrete was assessed using slump cone and compaction factor test. It is observed that the slump of recycled aggregate concrete (RAC) is 75 and 80 mm for M20 and M30 concrete mixes. Also it is found that compaction factor values of the RAC are 0.91 and 0.89 for M20 and M30 mixes. It is observed that, the workability of RAC has been improved by change of fraction of coarse aggregates. Test results are compared and evaluated and presented in table 4 and 5.

Table 4 Test results of NAC

Design Mix	Compressive strength (MPa)		Flexural strength (MPa)	Splitting Tensile strength(MPa)	Permeability of coefficient(m/s)
	7days	28days	28 days	28-days	Uniform pressure applied @ 78.40N for 100 hours
M20	21.78	29.01	3.70	1.951	1.26 x10^{-10}
M30	31.02	41.73	4.32	2.412	1.78 x10^{-10}

Table 5 Test results of RAC

Design Mix	Compressive strength (MPa)		Flexural strength (MPa)	Splitting Tensile strength(MPa)	Permeability of coefficient(m/s)
	7days	28days	28 days	28-days	Uniform pressure applied @ 78.40N for 100 hours
M20	22.41	32.10	3.180	1.791	$1.26\ x10^{-5}$
M30	28.29	40.73	3.035	2.164	$9.2\ \ 10^{-5}$

Compressive strength

The concrete cubes of 150 mm size are cast and tested to study the compressive strength under axial compression on completion of 7 and 28 days as per IS: 516-1999[11]. As per Table 4 & 5, the test results of compressive strength for both M20 and M30 grade of NAC and RAC are achieved their target strengths. The test results are very satisfactory and encouraging for production of M20 and M30 grade *RAC with 100 % replacement of natural aggregates with the recycled aggregates.* Production of M20 and M30 grade RAC is possible as per the procedures are vogue for conventional concrete. Extra water required for recycled aggregaes can be mitigated by adding superplasticisers(HRWR-High Range Water Reducers) in the recycled aggregate concrete. The 7 and 28 days test results of RAC and NAC are compared in the following graphs.

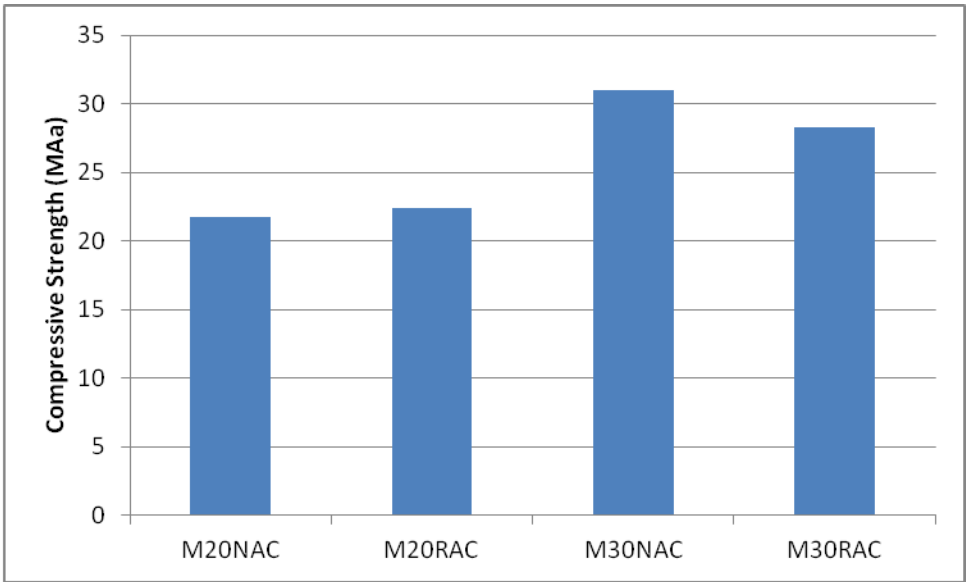

Fig. ***1 Comparison of 7 days Compressive Strength for NAC and RAC***

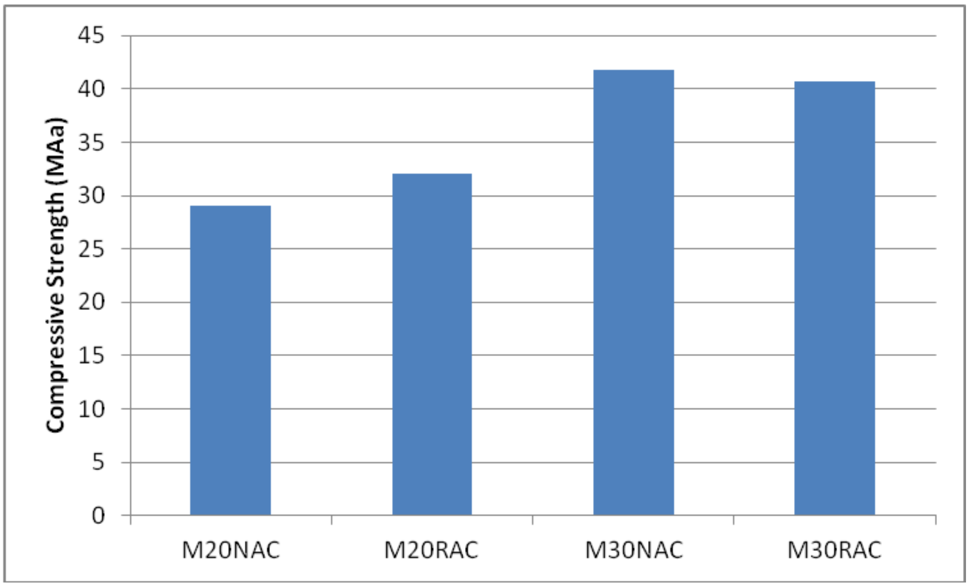

Fig. 2 Comparison of 28 days Compressive Strength for NAC and RAC

9.2 Flexural strength

This investigation was carried out to study the flexural strength of ordinary grade of M20 and standard grade of M30 grade concrete (RAC) at 28 days. NAC and RAC prisms of size 100 × 100 × 500 mm are cast and tested at 28days age as per IS: 519 -1959[11]. As per the test results shown in Table 4 & 5, the flexural strength of M20 and M30 NAC is 14.05% and 29.75% greater than RAC which attributes to weak Interfacial Transition Zone (ITZ) of RAC. This can be improved by adding mineral admixtures and fibers to plain concrete. The lesser flexural strength RAC could be the reason which attributes to inconsistency in the source, age, shape, and grade and attached mortar of recycled aggregates. The 28 days test results of RAC and NAC are compared in following graph.

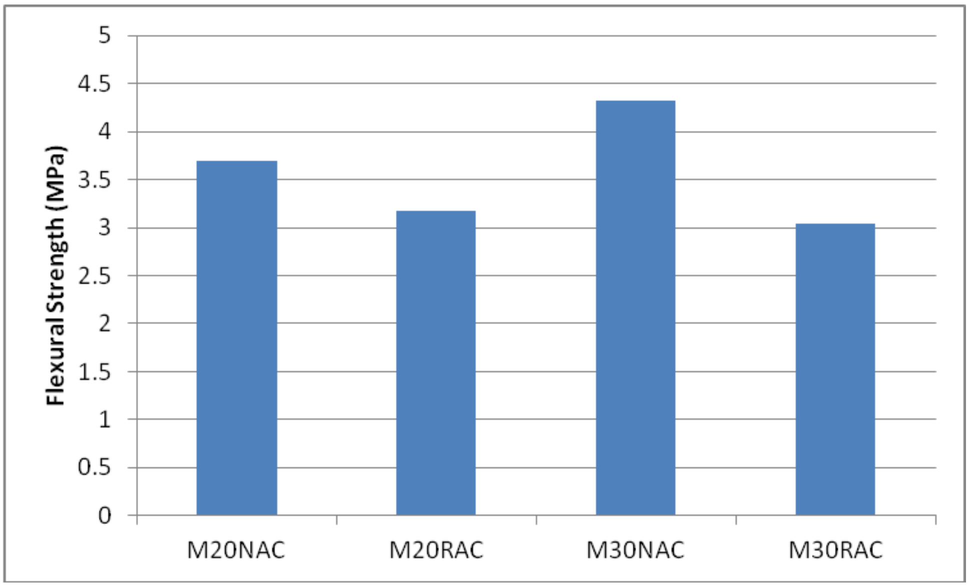

Fig. 3 Comparison of 28days flexural Strength for NAC and RAC

9.3 Splitting tensile strength

This investigation was carried out to study the split tensile strength of M20 and M30 grades of concrete (NAC & RAC) at 28 days. The cylinders of size 150 mm diameter and 300 mm height are cast and tested to study the splitting tensile strength of concrete(NAC & RAC) at 28days as per IS: 5816-1970[12]. Splitting tensile strength of NAC is greater than RAC due to weak Interfacial Transition Zone (ITZ). Weak ITZ attributes to inconsistency in source, shape, age, grade of recycled aggregates and attached mortar. As per the test results shown in Table 4 & 5, the splitting tensile strength for M20 and M30 NAC is 8.20% and 10.28% greater than RAC which attributes to weak Interfacial Transition Zone (ITZ) of RAC. This can be improved by adding mineral admixtures and fibers to plain concrete. The 28 days test results of RAC and NAC are compared and shown in following graph.

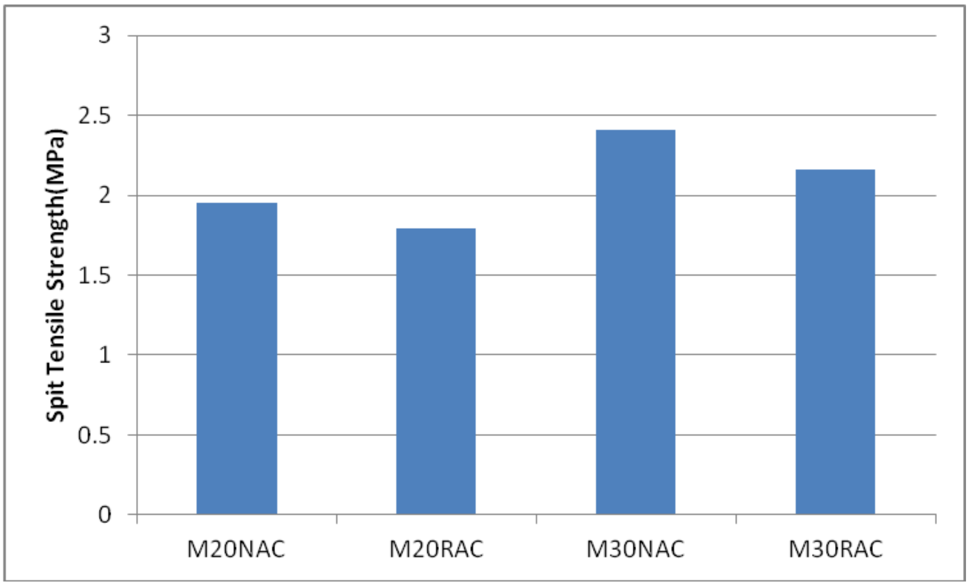

Fig. 4 Comparison of 28days splitting tensile Strength for NAC and RAC

9.4 Permeability of concrete

Permeability of concrete test procedure carried out as per the IS: 3085 – 1965[13]. The continuous uniform pressure is applied @ 78.40 N for 100 hours. As per the test results shown in table 4 & 5, the permeability of recycled aggregate concrete is more compared to the natural aggregate concrete. Further; the change in fraction of aggregates addition of mineral admixtures may improve the Interfacial Transition Zone (ITZ) of the RAC attributes to improvement in permeability coefficient (k).

X. CONCLUSIONS

- When workability of recycled coarse aggregates was tested using slump test and compaction factor test, the mix shows medium workability.
- Compressive strength for both M20 and M30 grade of NAC and RAC are achieved their target strengths.
- Flexural strength of M20 and M30 NAC is 14.05% and 29.75% greater than RAC which attributes to weak Interfacial Transition Zone (ITZ) of RAC. This can be improved by adding mineral admixtures and fibers to plain concrete.
- Splitting tensile strength for M20 and M30 NAC is 8.20% and 10.28% greater than RAC which attributes to weak Interfacial Transition Zone (ITZ) of RAC. This can be improved by adding mineral admixtures and fibers to plain concrete.
- The lesser flexural and split tensile strength of RAC could be the reason which attributes to inconsistency in the source, age, shape, and grade and attached mortar of recycled aggregates.
- Water absorption in recycled aggregates is more than virgin aggregates which affect the durability of concrete. Additional water required for production of RAC shall be mitigated by adding mineral admixtures.
- The coefficient of permeability of RAC is more than NAC, this can be improved by adding different fraction of aggregates and mineral admixtures to obtain durable 'recycled aggregate concrete'.
- The study shows that 100% replacement of natural aggregate with recycled coarse aggregates gives satisfactory results for M20&M30. So the replacement is of much benefit and shall be encouraged to achieve higher grades of concrete.

Future work

Extensive research is required on durability of M20 and M30 grade of Recycled Aggregate Concrete by replacing 100% virgin aggregates with recycled aggregates for structural application.

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