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Performance Of Recycled Aggregate Concrete With The Inclusion Of Industrial Waste As Additives

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Abstract: Urbanization and rapid growth in population has increased the quantum of waste generation. As per the reports of Central Pollution Control Boards (CPCB) [1] , India is producing about 23.75 million tons of construction and demolition waste (C & D) out of which only 5% is being processed. Hence large quantity goes as waste into dumping yards leading to environmental issues. Also globalization requires increased development of infrastructure to facilitate the needs of urbanization. The increase in development activities generates about 23% of concrete waste as per reports [1] that needs to be channelized and handled carefully. Industrialization has also led to the development of industrial waste such as fly ash, ground granulated blast furnace slag [GGBS], silica fume etc that are Industrial by products increasing the quantum of waste reaching dumping yards. Hence Industrialization requires sustainable solution that can be arrived by effective utilization of waste which reduces the burden on dumping yards and also fulfills the need of resources that are required for construction and development activities. Hence a pilot study is carried out by to arrive at recycled aggregate concrete (RAC) by using C & D waste as recycled coarse aggregates (RCA) and use industrial waste like silica fume and GGBS as partial replacement of cement to provide a sustainable solution for the alarming problem of Industrialization leading to global warming. In this work RAC was prepared for M40 grade with the inclusion of 10% of industrial waste for cement and partial replacement of coarse aggregate in the ratio of 0%, 10%, 20%, 30%, 40% and 50%. Mechanical behavior of RAC was studied to provide a sustainable solution for utilization of C & D waste and Industrial waste.

Keywords: Construction and demolition waste, compressive strength, split tensile strength, flexural strength.

1. Introduction

Economy of a nation is widely influenced by the increased infrastructure and development activity that is reflected in the gross domestic product (GDP) value. The value of GDP is affected by the waste being generated per capita per day. Industrialization has increased the requirement of natural resources that are required in enormous quantity for roads and housing sector. From the literature studies it has been understood that use of C & D waste is a useful material in arriving at constructional material concrete. One of the author [2] compiled study of concrete prepared with the inclusion of C & D waste which requires special attention if utilized as structural concrete. From the previous works that were carried out it is been understood that recycled coarse aggregates (RCA) experiences higher porosity that natural aggregates [3] and characteristics of grading curve are continuous for equivalent fraction. Code IS 383: 2016 also permits the use of C & D waste in the concrete with a replacement of 20% for M20 to M25 grade of concrete. In this work emphasize is laid to arrive at M40 grade of concrete with the inclusion of industrial waste such as silica fume and GGBS. From some of the literatures that were studied it's understood that [4, 5] while working with RAC on large scale is proposed to be an economical and eco-friendly material protecting the natural resources and facilitating the coexistence of human beings. Author [6] RCA can be used to prepare mass concrete and further studies are required to propose RCA for structural application. As per one of the author [7] the water absorption of RCA decreases with increase in size of aggregate, this helped in deciding the size of aggregate. As per one of the author [8**]** the adhered mortar content attached on the surface of RCA are inversely proportion to the size of aggregate and hence requires certain measures to be taken while working with RCA. As per Author [9**]** the strength of RAC are affected by the size of RCA considered. Strength achieved by 10mm and 14mm RCA are same compared to strength achieved using 20mmm size RCA. As per the study carried out by [10] cylindrical strength and shear strength of RAC were about 90% of normal concrete for strength ranging from 20 to 50 Mpa which suggested that while strength of RAC can be improved with the inclusion of additives. As per study carried out by [11**]** it was inferred that RAC prepared with 50% and 100% replacement ratio absorbed 22% and 44% more water absorption than control mix. It was also observed that RAC required 5% more cement than conventional concrete to arrive at the same strength. Author [12] studied the behaviour of RAC by using special mixing technique to arrive at improved strength and better bonding at interfacial transition zone, from which it was understood that treated aggregate behaved well compared to untreated RCA. From the research work carried out by one of the author [13] its inferred that strength achieved by aggregates smaller than 10mm are 12.5% less compared to 10mm, 20mm and 40mm size aggregates and from the research [14] suggested that strength achieved by concrete made with C & D waste with the inclusion of silica fume showed better performance. Hence, in this study an effort is made to arrive at recycled aggregate concrete (RAC) of M40 grade with the partial replacement of natural coarse aggregate by 0%, 10%, 20%, 30%, 40% and 50%. RAC prepared with partial replacement of C & D waste were also studied for the inclusion of supplementary cementitious material GGBS and silica fume by 10%. Initially characteristic of ingredients were studied and were suitably considered after their suitability in the acceptable range of IS code provisions. Fresh properties and hardened properties were studied by carrying careful experimental investigation and performance of RAC were studied with the inclusion of industrial waste as additives.

2. Materials

Literatures revealed that while ingredients of RAC are to be considered with careful investigation as density of RCA are 3 to 10% lower than natural aggregates and water absorption of RCA are 3 to 5% higher than natural aggregates [15]. RAC were prepared by considering 43 grade ordinary Portland cement (OPC) suitably manufactured as per IS code [IS 8112-2013] and the Engineering properties tested for cement are represented in Table 2.1. Fine aggregate that were considered for the study are manufactured sand that free from silt and organic matter and passing through 4.75mm sieve confirming to zone 2 as per IS code 383[16] and Engineering properties tested for fine aggregate are represented in Table 2.2 . Coarse aggregates of maximum size 20mm and retained on 4.75mm were considered as per IS code 383. RCA were considered from the demolition work that was carried out from the MSRIT campus. These demolition wastes were rammed to arrive at RCA of 20mm size. The material so arrived were washed thoroughly to remove the possible adhered mortar and aerated to be further considered as a material in RAC. The Engineering properties tested for natural coarse aggregate (NCA) and RCA are represented in Table 2.3. Additives that were considered in the study are 10% of silica fume that is obtained by processing silicon metal. The specific gravity of silica fume is 2.2 and another additive material that was considered in the study was fly ash having a specific gravity of 2.8. Also to maintain the workability of RAC 2.5% of SPF430 Conplast super plasticizer of specific gravity of 1.1 were used. Characteristic studies of ingredients of RAC were tested as per the requirement of code [17-19] and further investigation of fresh and hardened properties were carried out. The above said ingredients were mixed to arrive at M40 grade of RAC in the presence of portable water.

Table 2.1- Engineering Properties of Cement

Sl. No.	Tests Conducted	Results Obtained
1	Specific Gravity	3.05
2	Normal Consistency	31%
3	Setting time (minutes)	Initial 40 minutes
		Final 345 minutes
4	Fineness (m^2/kg)	330
5	Soundness (mm)	2.5

Table 2.2- Engineering Properties of Fine aggregate

Sl. No.	Tests Conducted	Results Obtained
1	Specific Gravity	2.48
2	Fineness Modulus	3.94
3	Bulk Density kg/m^3	a. Dry Compacted 1646
		b. Loose Compacted 1532
4	Moisture content %	4

Table 2.3-Engineering Properties of Coarse Aggregate

	Engineering Properties		20mm NCA	20mm RCA
1.	Shape		Angular	Angular
2.	Bulk Density	a) Dry Compacted	1483	1589

	kg/m³	b) Loose Compacted	1310	1470
3.	Specific gravity		2.65	2.59
4.	Fineness Modulus		6.71	6.75
5.	Water Absorption%		1.8	10.6
6.	Impact Value%		28	35.1
7.	Crushing Value%		15.69	40.32
8.	Abrasion value%		26.72	30.72

3. Investigation of Fresh properties and Mix Design

3.1 Mix Design

RAC were prepared for M40 grade of concrete as per IS 10262-2019 code of practice considering manufactured sand as fine aggregates and NCA were partially replaced by RCA by 0%, 10%, 20%, 30%, 40% and 50% and are named as RACSF-0, RACSF-10, RACSF-20, RACSF-30, RACSF-40 and RACSF-50 for RAC prepared with the inclusion of 10% of silica fume and 10% of fly ash as supplementary cementitious material. Table 3.1 represents mix design considered for M40 grade of concrete.

Table 3.1-Mix Proportion of M40 Grade of RAC

Materials	Quantity	Per m^3
Cement	414.766	kg/m^3
Water	139.984	$liters/m^3$
FA	603.309	kg/m^3
NCA	1136.468	kg/m^3
RCA	0.000	kg/m^3
SP	3.111	kg/m^3
Silica Fume	51.846	kg/m^3
Fly ash	51.846	kg/m^3

3.2 Fresh Properties of RAC

Fresh properties of RAC for M40 grade were tested for fresh properties using compaction factor test and are found to achieve medium workability. The compaction factor of RAC prepared with the inclusion of Fly ash and silica fume are as shown in Table 3.2 and Fig 3.1.

Table 3.2-Fresh Properties of M40 Grade of RAC

% RCA Replacement Ratio	Compaction Factor
RACSF-0	0.811
RACSF -10	0.823
RACSF -20	0.835
RACSF -30	0.838

RACSF -40	0.841
RACSF -50	0.844

4. Experimental Investigation

4.1 Mechanical of M40 grade of RAC with the inclusion of additives

Mechanical properties of M40 grade of RAC were tested for compressive strength split tensile strength and flexural strength were checked and verified as per provision of code [20, 21] and are represented in Table 4.1. From the research work [22-24] gave inference for the inclusion of industrial waste in preparing RAC. Twenty eight day compressive strength of M40 grade of RAC cube specimens of 150mm size were tested in compressive testing machine (CTM) at a constant rate of 14N/mm^{2}for various replacement ratio of NCA varying from 0% to 50% with 10% increment of RCA. For conducting the split tensile strength cylindrical specimen of size 100mm diameter and 200mm length of M40 grade of RAC for replacement ratio of NCA varying from 0% to 50% with 10% increment of RCA were carried out for 28 days. The split tensile test was conducted by placing the cylindrical specimen in the CTM and applying uniform line load along the length of the specimen at a constant rate of 14N/mm^2. Flexural strength of M40 grade of RAC were tested on prism specimen of size 75 ×75 × 450 mm with the partial replacement of NCA by RCA for replacement ratio varying from 0% to 50% with an increment of 10% for 28 days strength using two point loading system.

Table 4.1-Mechanical Properties of M40 Grade of RAC at 28 days

% RCA Replacement Ratio	Compressive Strength in MPa	Split Tensile Strength in MPa	Flexural Strength in MPa
RACSF-0	50.86	5.15	7.49
RACSF -10	48.64	4.91	7.27
RACSF -20	47.27	4.66	7.12
RACSF -30	46.14	4.52	7.03
RACSF -40	45.80	4.28	6.87
RACSF -50	44.38	4.13	6.40

5. Results and Discussion

5.1Mechanical Strength of RAC

From the strength tests conducted on RAC we can observe that compressive strength of RAC for max replacement ratio considered that is 50% achieved the desired strength. However there is a strength decrement of 12.7% compared to M40 grade of concrete with 0% replacement. From the 28 days split tensile strength of M40 grade, it was observed that there was about 19.8% reduction in split tensile strength compared RAC with 0% replacement ratio. Whereas as per the code, the prediction pattern of split tensile strength is 10% of its compressive strength. Hence we can say that the behaviour of RAC with the inclusion of additives and RCA also behaves like normal concrete. From the flexural strength of M40 RAC it can be seen that 28 days strength 50% replacement ratio is about 14.55% less than RAC prepared with 0% replacement ratio. Mechanical strength of M40 RAC for various replacement ratios is represented in Fig5.1.

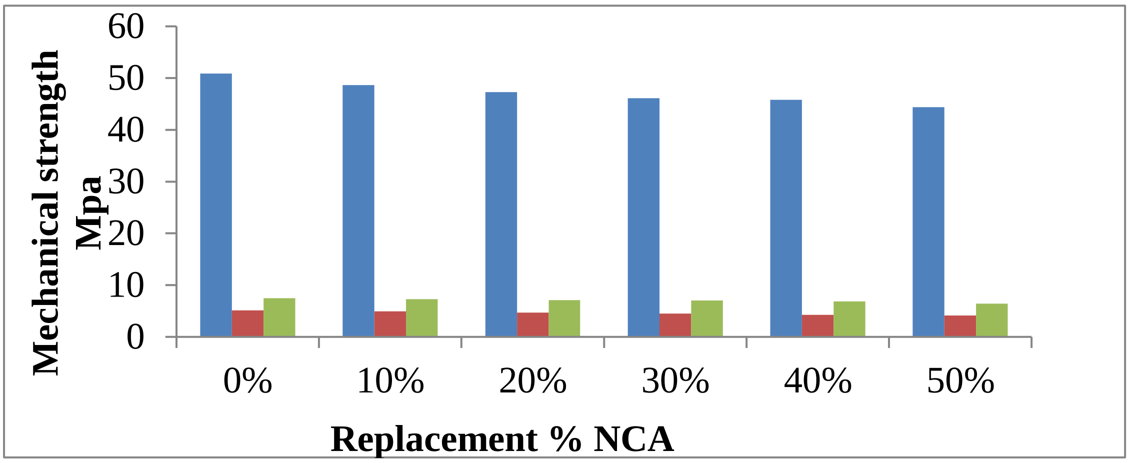

Fig 5.1- Mechanical Properties of M40 RAC at 28 days

6. Conclusions

From this research work carried out we can say that while working with C & D waste it is necessary to conduct characteristic study of ingredients of RAC to be suitably used as material in the concrete. While C & D waste materials are used as partial replacement of NCA it is necessary to wash the RCA to remove the adhered mortar and also by washing and aerating the aggregates the problem of water absorption of RCA gets reduced. Hence while RCA of 20mm size is considered it is required to wash and aerate the aggregates before being used in the concrete. Strength of M40 grade of concrete for 50% replacement ratio can be achieved with the inclusion of industrial waste as additives. Compressive strength of M40 grade of RAC was found to achieve the strength required at 28 days with a reduction of 12.7%. Split tensile strength variation is found to be 19.8% less compared to 0% replacement RAC even though the behaviour pattern of RACSF-50 behaved in similar pattern like normal strength concrete. Flexural behaviour of RACSF- 50 also performed 14.5 % less than 0% RAC which indicated that with further improvising the ingredients of RCA we can achieve a good structural concrete. Further to arrive at structural concrete intense study needs to be carried out in the area of shear, bond , short term and long term durability properties.

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Declaration of Conflicting Interests

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