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"Experimental and Analytical Study on High Strength Concrete (M70) Using Recycled Concrete Aggregate"

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Abstract – *The results of the test programme to study the use of recycled concrete aggregate (RCA) in high-strength, 70 N/mm², concrete are described. The effect of coarse RCA content on strength of concrete, durability properties of such concretes have been established. The result showed that up to 30% coarse RCA had no effect on concrete strength, but thereafter there was a gradual reduction as the RCA content increases. It is shown that high-strength RCA concrete will have equivalent engineering and durability performance to concrete made with natural aggregates, for corresponding 7, 14 and 28 days design strength. The practical implications of the study for concrete construction are discussed.*

Key Words: Compressive strength, Split tensile strength, Particle size distribution, Crushing Strength, Impact Strength.

1. INTRODUCTION

Concrete is the most widely used man made construction material in the world and its second only to water as the most utilized substance in the planet. Seeking aggregates for concrete and to dispose of the waste from various commodities is the present concern. Today sustainability has got top priority in construction industry.

Any construction activity requires several materials such as concrete, steel, brick, stone, glass, clay, mud, wood, and so on. However, the cement concrete remains the main construction material used in construction industries. For its suitability and adaptability with respect to the changing environment, the concrete must be such that it can conserve resources, protect the environment, economize and lead to proper utilization of energy. To achieve this, major emphasis must be laid on the use of wastes and byproducts in cement and concrete used for new constructions. The utilization of recycled aggregate is particularly very promising as 75 per cent of concrete is made of aggregates. In that case, the aggregates considered are slag, power plant wastes, recycled concrete, mining and quarrying wastes, waste glass, incinerator residue, red mud, burnt clay, sawdust, combustor ash and foundry sand. The enormous quantities of demolished concrete are available at various construction sites, which are now posing a serious problem of disposal in urban areas. This can easily be recycled as aggregate and used in concrete. Research & Development activities have been taken up all over the world for proving its feasibility, economic viability and cost effectiveness.

An investigation conducted by the environmental resources ltd. (1979) for European Environmental commission (EEC) envisages that there will be enormous increase in the available quantities of construction and demolition concrete waste from 55 million tons in 1980 to 302 million tons by the year 2020 in the EEC member countries. As a whole, the safety and environment regulations are becoming stringent, demand for improvement in techniques & efficiency of the past demolition methods is getting pronounced. Special rules and regulations concerning the demolition have already been introduced in several countries like U.K., Holland and Japan.

A study considering high-strength concrete containing coarse RCA contents of 10, 20 and 30% indicated that the strength at given water/cement (w/c) ratio was similar to that containing natural aggregates. Similar results have been reported by other researchers.

This paper examines the influence of coarse RCA on high-strength, M70, concrete performance and addresses practical issues relating to its use. The work described is part of comprehensive research and development programme undertaken at the department of civil engineering, P.E.S.C.O.E., aimed at addressing the technical and practical aspects of the use of RCA in concrete construction.

1.1 Recycled Concrete Aggregate (RCA):

Recycled aggregate is a term used to describe crushed concrete or asphalt from construction debris that is reused in other building projects. This collection of construction refuse is mainly used for road base, cement concrete or other infrastructure projects.

The use of recycled materials for construction is a sustainable move in the construction industry. It prevents materials from having to be collected for building while also preventing more refuse from entering the landfill. This process can be easily done at the demolition site or even a permanent facility.

1.2 Benefits of RCA:

When structures made of concrete are demolished or renovated, concrete recycling is an increasingly common method of utilizing the rubble. Concrete was once routinely trucked to landfills for disposal, but recycling has a number of benefits that have made it a more attractive option in this age of greater environmental awareness, more environmental laws, and the desire to keep construction costs down.

Not only does concrete recycling help reduce new construction costs, it has a significant impact on the environment.

[1]Keeping concrete debris out of landfills saves landfill space. [2]Using recycled concrete can conserve natural resources by reducing the need for gravel mining, water, coal, oil and gas. [3]Using recycled concrete as the base material for roadways reduces the pollution involved in trucking material. [4]Recycling concrete can create more employment opportunities. [5]Recycling concrete drag down the cost for buying raw materials and transporting the waste to landfill sites. [6]Recycling one ton of cement could save 1,360 gallons water, 900 kg of CO2.

2. Literature Survey:

[1]Katrina Mc Neil and Thomas H. Kang Et. Al. This paper discuss the properties of Recycled Concrete Aggregate (RCA), the effect of RCA use on concrete material properties and the large scale impact of RCA on structural members. Replacing natural aggregate with RCA decreases the compressive strength, but yields comparable splitting tensile strength. The modulus of rupture for RCA Concrete is slightly less. Modulus of elasticity is also lower, caused by the more ductile aggregate. As far as structural concerned, beam with RCA did experience greater midspan deflections under service load and smaller craking moment. Most of all, the ultimate moment was moderately affected by RCA content. It is confirmed that the use of RCA is likely a viable option for structural use. [2]Dr. Mark Snyder Et. Al. Using recycled concrete aggregate (RCA) can be successful if careful consideration is given to the properties and physical characteristics of the aggregate, the physical properties of the fresh and hardened concrete and the mechanical behavior of the pavement containing RCA as noted as recycled concrete aggregate is angular with rough surfaces, has higher water absorption capacity, lower specific gravity, higher Los Angeles abrasion loss. Hardened concrete made with recycled aggregate has slightly lower compressive strength and flexural strength, a lower stiffness (modulus of elasticity), higher resistance to freeze-thaw due to higher air contents. [3]M.C.Limbachiya et.al. The result of a test programme to study the use of recycled concrete aggregate (RCA) in high-strength, 50 of coarse RCA content on the ceiling strength, bulk engineering and durability properties of such concretes have been established. The results showed that up to 30% coarse RCA head no effect on concrete strength, but there after there was a gradual reduction as the RCA content increased. A method of accommodating the effect of high RCA content, involving simple adjustment to W/C ratio of the mix is given. It's shown that high-strength RCA concrete will have equivalent engineering and durability performance to concrete made with natural aggregates, for corresponding 28-day design strengths.

3. PERFORMANCE ANALYSIS:

3.1 PARTICAL SIZE DISTRIBUTION

Table -1: Particle size distribution

IS sieve size	Wt. of aggregate retained (g)	% of Wt. Retained	Cumulative % Retained	Cumulative % Passing
40mm	0	0	0	100
20mm	320	6.4	6.4	93.6
16mm	780	15.6	22	78
12.5mm	950	19	41	59
10mm	1200	24	65	35
4.75mm	1750	35	100	0

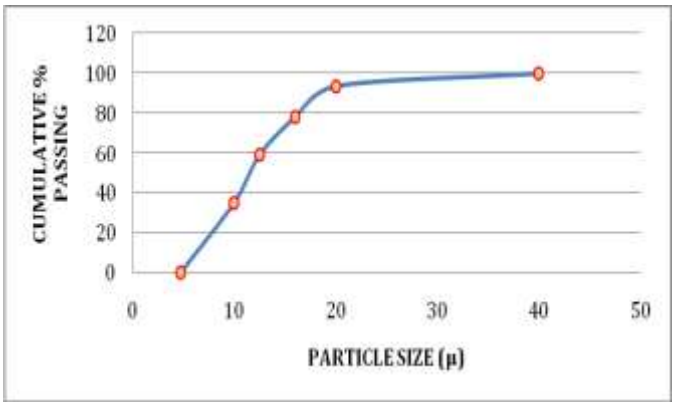

Chart -1: Particle Size Distribution

Fineness Modulus = Sum of Cumulative % Retained/100
= 365.6/100
= 3.656

3.2 Physical properties of RCA:

Table -2: Physical Properties of RCA

Sr. No.	Physical Properties	RCA
1	Water absorption (%)	6.38
2	Specific gravity	2.31
3	Bulk density (kg/m3)	1330.93

4	Crushing value (%)	20.5
5	Impact value (%)	8.9

3.3 Mix Proportion

Concrete mix proportion is designed as per IS-10262-2019. The compressive strength increased with a decrease in w/c ratio and directly proportional to strength of blended aggregate. However, when used at higher level of replacement the high water absorption ability of Recycled aggregate resulted in the higher total water demand. We know that, target strength for M70 mix Proportion is 70+(1.65*6)=79.9MPa and the ratio of cement : sand : aggregate was arrived at as 1:1.01:2.16. The results are tabulated under table,

Table -3: Mix Proportion

	Wt. (kg/m^3)	Proportion
Cement	581.48	1
Water	157	0.27
Fine Aggregate	587	1.01
Coarse Aggregate	1256	2.16
Superplasticizer	3.489	0.6%

3.4 Compressive Strength of Concrete:

A cube compression test performed on standard cubes for 10 combinations as per IS: 516-1959. To determine compressive strength of concrete at different level of coarse aggregate with R.C.A. of 15cm x15cm x15cm cement concrete Cubes of proportion 1 : 1.01 : 2.16 (M 70) mix is casted for 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, 100% R.C.A being replaced with N.A. and SPL as Super-plasticizer is used in proportion of 0.6% of cement weight and the results of the tests are tabulated in Table -4 below.

Table -4: Compressive Strength of Concrete

% RCA Replacement	Weight of Cube (kg)	Compressive Strength of Concrete (N/mm2)		
		7 days	14 days	28 days
0%	8.63	62.68	73.604	79.560
10%	8.55	62.02	73.046	79.50
20%	8.58	61.79	72.84	79.36
30%	8.47	61.13	72.52	79.29
40%	8.44	60.24	71.63	78.38
50%	8.55	59.57	71.01	77.85
60%	8.51	58.09	69.99	75.76
70%	8.45	57.76	69.49	74.68
80%	8.57	57.19	68.89	73.50
90%	8.42	56.60	68.01	72.94
100%	8.49	56.07	67.39	72.37

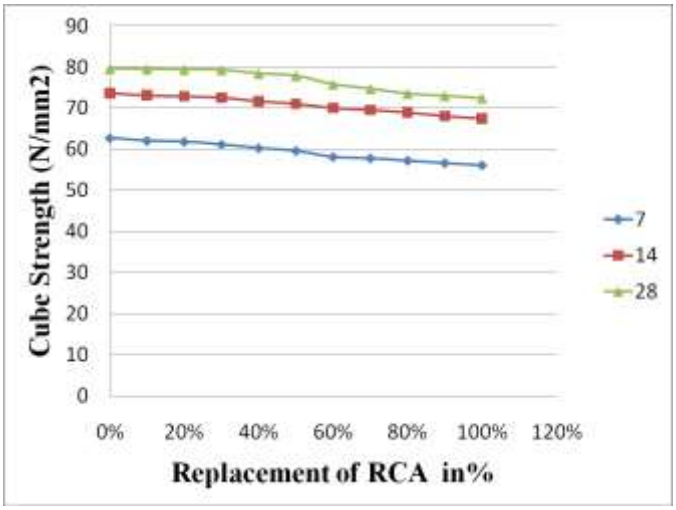

Chart -2: Compressive Strength of Concrete

3.5 Split Tensile Strength:

The split tensile strength at which failure occurs is the tensile strength of concrete. In this investigation the test is carried out on cylinder by splitting along its middle plane parallel to the edge by applying compressive load to opposite edge as per IS: 516-1959. To carry out this test 10 combinations are prepared. To determine split-tensilt strength of concrete at different level of coarse aggregate with R.C.A. of 30cm height and 15cm diameter cement concrete Cubes of proportion 1 : 1.01 : 2.16 (M 70) mix is casted for 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, 100% R.C.A being replaced with N.A. and SPL as Super-plasticizer is used in proportion of 0.6% of cement weight and the results of the tests are tabulated in Table -5 below.

Table -5: Split-tensile Strength of Concrete

% RCA Replacement	Wt. of Cylinder (kg)	Split Tensile Strength of Concrete (N/mm2)		
		7 days	14 days	28 days
0%	13.53	4.61	5.57	6.15
10%	13.59	4.53	5.41	6.01
20%	13.55	4.24	5.15	5.79
30%	13.58	4.17	5.00	5.56
40%	13.53	4.05	4.85	5.39
50%	13.36	3.86	4.62	5.10
60%	13.55	3.69	4.40	4.89
70%	13.51	3.48	4.19	4.63
80%	13.45	3.32	3.99	4.42
90%	13.57	3.26	3.84	4.27
100%	13.42	3.15	3.65	4.05

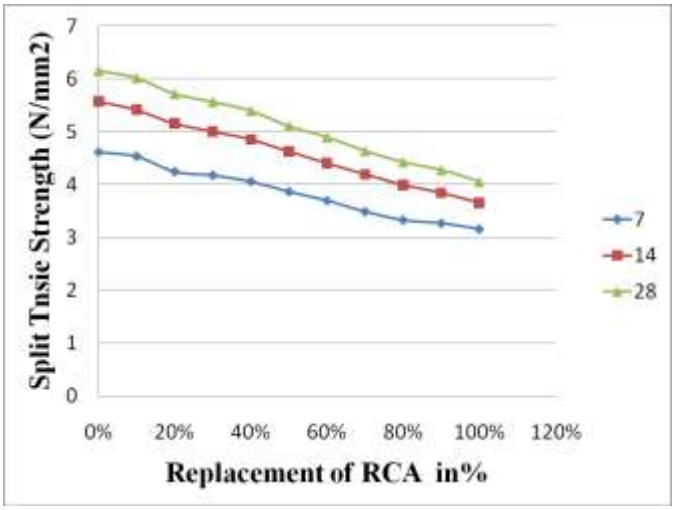

Chart -2: Split-tensile Strength of Concrete

4. CONCLUSIONS

i. Recycled concrete aggregate had 7 to 9% lower relative density and 2 times higher water absorption than natural aggregate in saturated surface dry state. The mechanical properties of RCA were also found to be somewhat lower than the natural aggregate used, But within the IS requirement.

ii. The Specific gravity of NA and RCA is 2.75 and 2.23 respectively which is responsible for compressive strength of concrete.

iii. According to the test results it is noted that the compressive strength of high strength concrete of grade M70 is equal to the limiting strength up to 30% replacement of RCA. Thereafter as percentage of RCA increases the compressive strength reduces gradually. This was observed consistently for concrete mix tested at 7, 14 & 28 days.

iv. The split tensile strength of concrete with RCA is also less than the limiting split tensile strength of concrete with natural aggregate.

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