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Evaluation of Properties of Concrete Made from Recycled Coarse Aggregates at Different Mix Proportions

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***Abstract*— With increasing urbanization, construction activities and demolition waste is generated in large quantity. Such waste contains unsafe material like protection, nails, electric wiring, shingle, digging materials, tree stumps and rubble. Development squander additionally contains lead, asbestos and other dangerous materials. The significant part of waste is comprised of blocks, cement, and wood. India produces 530 million tones of C&D squander yearly assessed by the service of climate and woods. This waste is unloaded in landfill destinations or set in side of the road or riversides which are the reason for decrease of regular assets and contamination like soil, air and water contamination. To diminish this danger for the future, we can reuse this loss to shield our current circumstance. This examination depends on substitution of regular coarse total (NCA) by reused coarse total (RCA). Concrete was collected from different sites and then was crushed to procure coarse aggregate of size 10 mm. Concrete of M20 grade was prepared and casted into 42 moulds of size 150mm×150mm×150 mm, different percentages of RCA were used to replace natural coarse aggregate viz. 0%, 25%, 50%, 75%, 90%, 100%. Seven cubes of each percentage were casted to get optimum results and were tested for compressive strength and density after 7, 14, and 28 days. The experimental analysis showed that compressive strength for 0%, 25%, 50%, 75%,90% and 100% replacement of NCA by RCA where recorded as 31.10N/mm^2, 30.40 N/mm^2, 28.35 N/mm^2, 25.95 N/mm^2 , 24.10 N/mm^2 and 21.11 N/mm^2 respectively after 28 days.**

***Index Terms*— concrete grade M20, RCA (RECYCLED COARSE AGGREGATES), compression test value, industrial by-product.**

I. INTRODUCTION

The request for development materials is expanding rapidly due to urbanization and industrialization, leading to a significant issue of Construction and Demolition (C&D) waste removal. This waste, generated massively, poses various environmental and health risks, including soil, water, and air pollution, as well as the spread of diseases like asthma and dengue. Traditional disposal methods like landfill sites and burning plants are costly and occupy valuable land, making recycling the most viable option.

The concept of recycling C&D waste emerged during World War II when there was a need to reuse demolished structures and roads. Recycling not only addresses waste management but also contributes to making construction more eco-friendly by conserving natural resources and reducing energy consumption and waste generation.

Despite the benefits, challenges exist in implementing recycling practices, including a lack of awareness, recycling processes, and infrastructure. Many countries have attempted to regulate C&D waste, but success in reducing waste and maximizing reuse has been limited.

Concrete production, a major contributor to environmental damage and CO2 emissions, faces challenges due to the increasing demand for natural aggregates. Reusing demolished concrete to produce recycled aggregate (RA) offers a potential solution. Recycled Aggregate Concrete (RAC) production involves crushing demolished concrete and removing impurities, offering a sustainable alternative to traditional concrete production.

However, using RAC may affect concrete quality, leading to decreased compressive strength and workability, and increased water absorption. Despite these drawbacks, the

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benefits of using recycled aggregate include cost savings, environmental preservation, and reduced landfill usage.

India has made efforts to address C&D waste processing, with the establishment of recycling plants. However, challenges remain, including waste mixing with municipal solid waste, inadequate facilities, and limited awareness.

The utilization of recycled aggregates in concrete offers environmental benefits and addresses the scarcity of natural aggregates. Research on the impact of recycled aggregate on concrete strength highlights challenges such as increased drying shrinkage and reduced compressive strength compared to conventional concrete.

Despite these challenges, the growing demand for recycled aggregates underscores the importance of sustainable construction practices. Recycling C&D waste not only conserves resources but also contributes to environmental protection and efficient waste management.

II. MATERIAL AND METHODOLOGY

The concrete prepared for the investigation consist of a conventional concrete design for M20 grade having a definite proportion i.e. ratio defined by IS code respectively and then replacement partial or wholly has been done as per requirement and depending upon the material availability.

This study investigates the impact of substituting natural coarse aggregate (NCA) with recycled coarse aggregate (RCA) on concrete properties. Concrete samples were sourced from various locations, then crushed to obtain coarse aggregates with a size of 10 mm. M20 grade concrete mixes were prepared and cast into 42 molds sized at 150mm × 150mm × 150mm. Varying percentages of RCA were used as replacements for NCA: 0%, 25%, 50%, 75%, 90%, and 100%. Seven cubes were cast for each percentage to ensure reliability, and compressive strength and density were measured after 7, 14, and 28 days of curing.

Results revealed a progressive decline in compressive strength with increasing RCA content. After 28 days, compressive strengths for 0%, 25%, 50%, 75%, 90%, and 100% replacement were recorded as 31.10 N/mm², 30.40 N/mm², 28.35 N/mm², 25.95 N/mm², 24.10 N/mm², and 21.11 N/mm², respectively. This indicates that as the proportion of RCA increased, the compressive strength decreased, suggesting a potential compromise in structural integrity. Additionally, the density of the concrete samples was likely affected by the RCA substitution, although specific density measurements for each percentage were not provided in the summary.

The various type of material used in casting process of concrete are: fine aggregate, course aggregate, cement, water, admixture and RCA from various lab and dismantle site.

A) MIX DESIGN (M_{20})

Test data for materials

Table 2: Proportion of Material Used

SR NO.	MATERIAL	PROPORTION
1	Specific gravity of cement	3.15
2	Specific gravity of coarse aggregates	2.75
3	Specific gravity of recycled coarse aggregates	2.66
4	Specific gravity of fine aggregates	2.90
5	Zone of fine aggregates	II
6	Water absorption of recycled coarse aggregates	.598%
7	Water absorption of coarse aggregates	1.19%
8	Water absorption of fine aggregates	3.47%

After studying various properties of the used material for the preparation of the mix design M20 having defined proportion as per IS code. The design for M20 has achieved taking above mentioned material whose result is discussed below:

III. RESULT AND DISCUSSION

1. WORKABILITY

The ease with which one can work with concrete is called workability this can be measured using a simple test called slump test. The apparatus used were metallic mould of bottom dia 20cm, top dia 10 cm and 30 cm height.

Steel tamping rod 16 mm dia and 60 cm height were used for compaction of concrete.

The slump cone was placed on a smooth horizontal rigid surface then filled in 4 layers with the thickness of each layer being approximately one forth of height of mould each layer were tamped 25 times evenly using rounded end of tamping rod such that the strokes are uniformly distributed over cross section after the top layer were tamped the concrete was leveled with the trowel for checking the slump cone is filled exactly up to top.

The slump cone is then removed by raising it gradually for subsidence. The difference in level between height of slump cone and that of highest point of subside were measured.

The w/c ratio for 0%, 25% and 50% replacement was taken as 0.50 and for 75% and 90% replacement was taken as 0.55and for 100% replacement was taken as 0.60 to maintain the 75mm slump.

2. DENSITY

Density of concrete depends on ratio of Natural Coarse aggregate and recycled aggregate ratio. Density of concrete decreases as the percentage of recycled aggregate is

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increased i.e. density is inversely proportional to percentage of recycled aggregate.

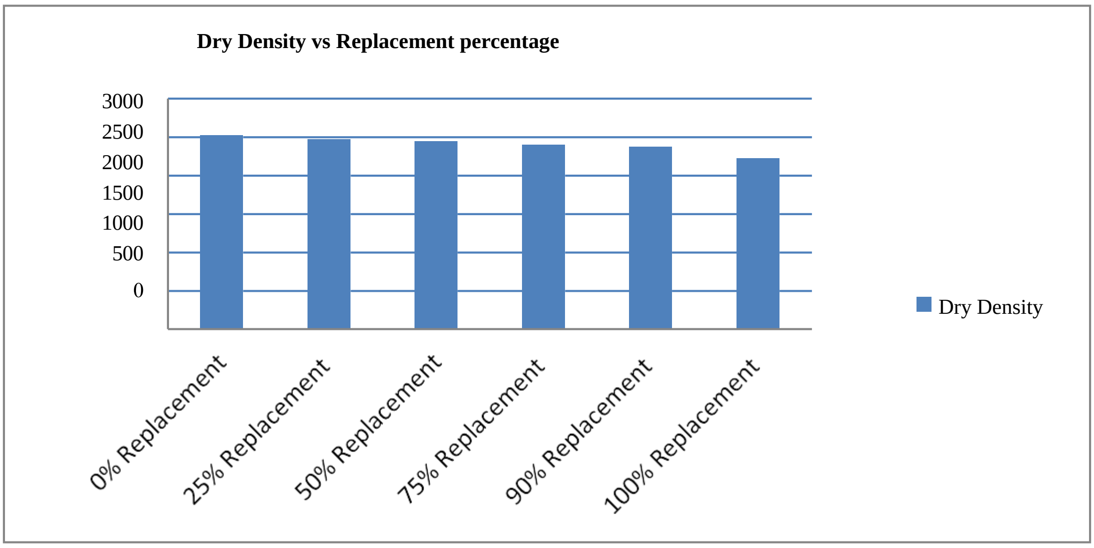

Fig. 1: Dry density vs Replacement percentages

3. COMPRESSIVE STRENGTH TEST

Compressive strength is one of the main properties of concrete it is determined by cube test. The characteristic compressive strength of concrete is defined as the compressive strength of 15 cm cubes at 28 days in N/mm^2, below which not more than 5% of the test results are expected to fall. It is addressed as fck .

Concrete cube samples are taken to batching plant and cured for 27 days. The compressive strength and tensile strength in bending and modulus of elasticity of concrete can be correlated with the characteristic compressive strength.

The strength is affected by water cemented ratio. Higher the water cement ratio lower is the strength.

As per Abram's law, the compressive strength of concrete is inversely proportional to the water-cement, provided the mix is of workable consistency.

The water content in mix also influences the workability of the mix therefore; an optimum water cement ratio is required to give a mix of desired workability and maximum strength.

The specimens after 28 days were tested for compression and the compressive load for different mix proportions (0%, 25%,50%,75%,90%,100%) are given in table below

Compressive strength is calculated by using formula fck= P/A, where P= Load in KN and A= area of cube(150mm×150mm)

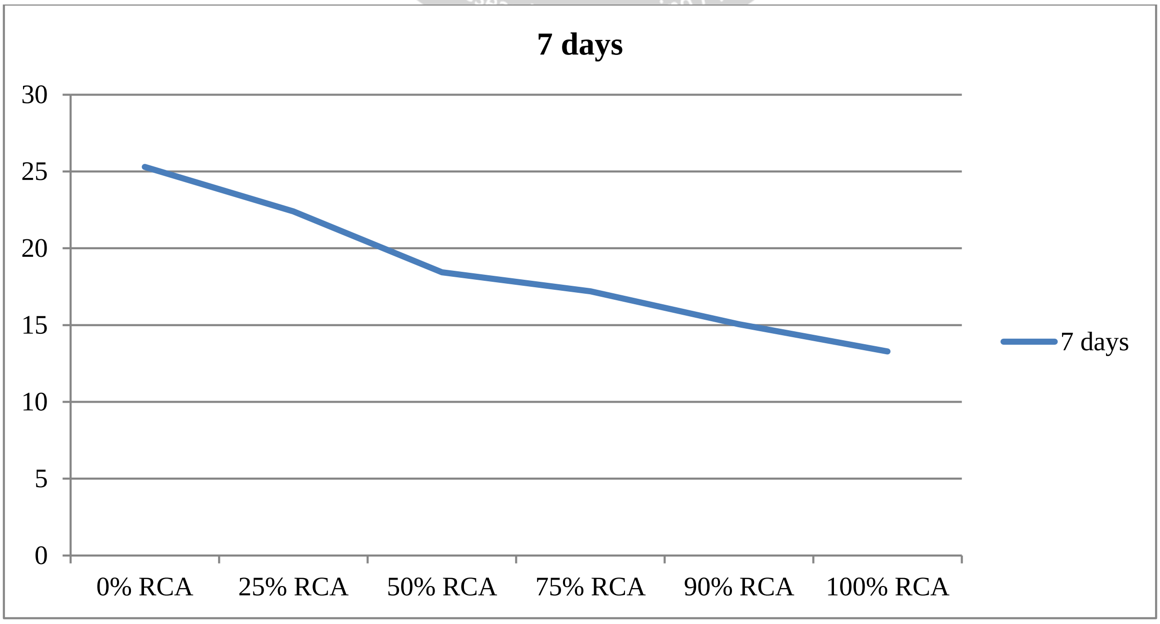

Fig 2: Compressive Strength (N/mm^2) after 7 Days

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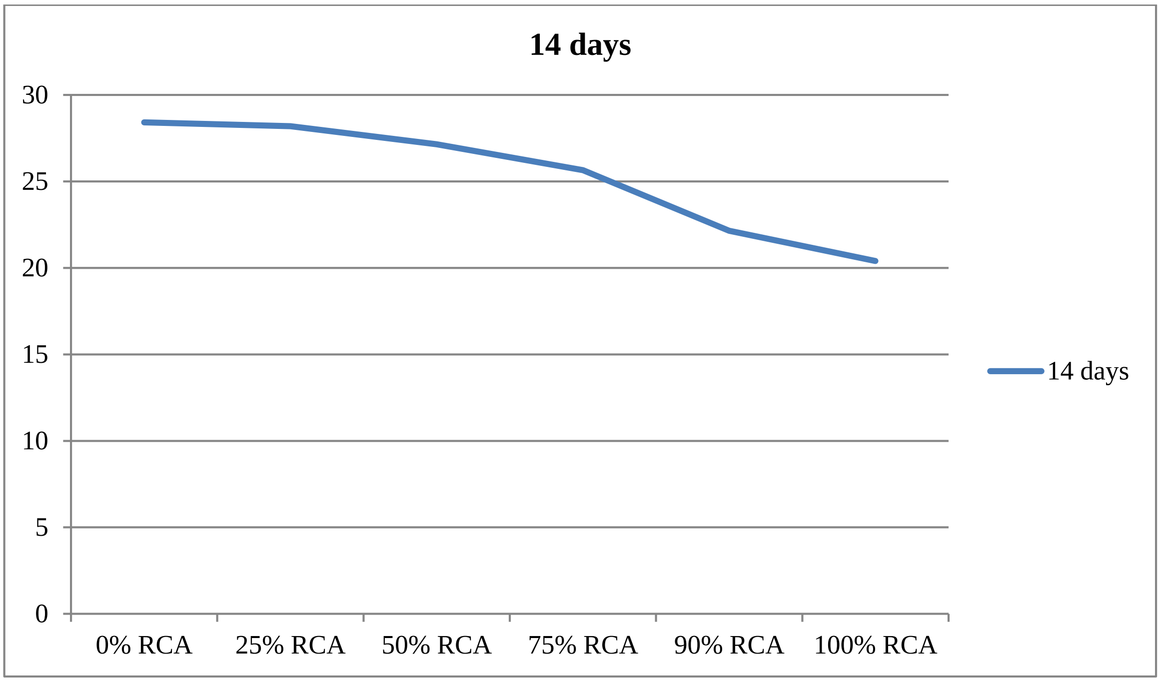

Fig 3: Compressive strength in N/mm^2 after 14 days

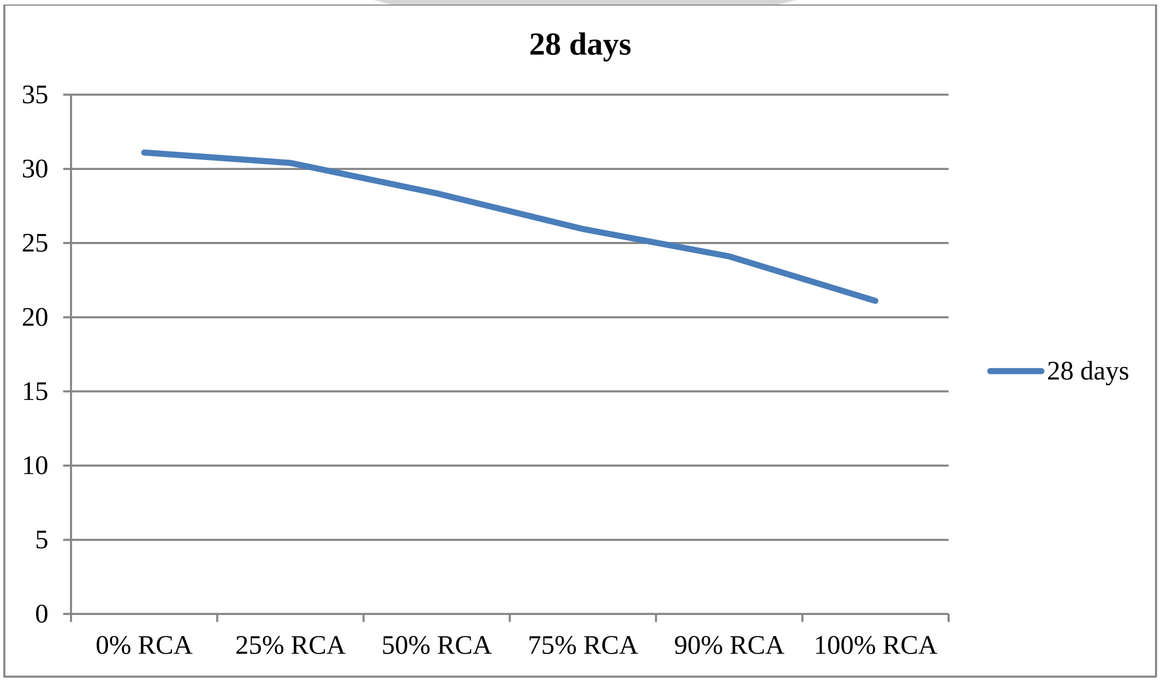

Fig 4: Compressive strength in N/mm^2 after 28 days

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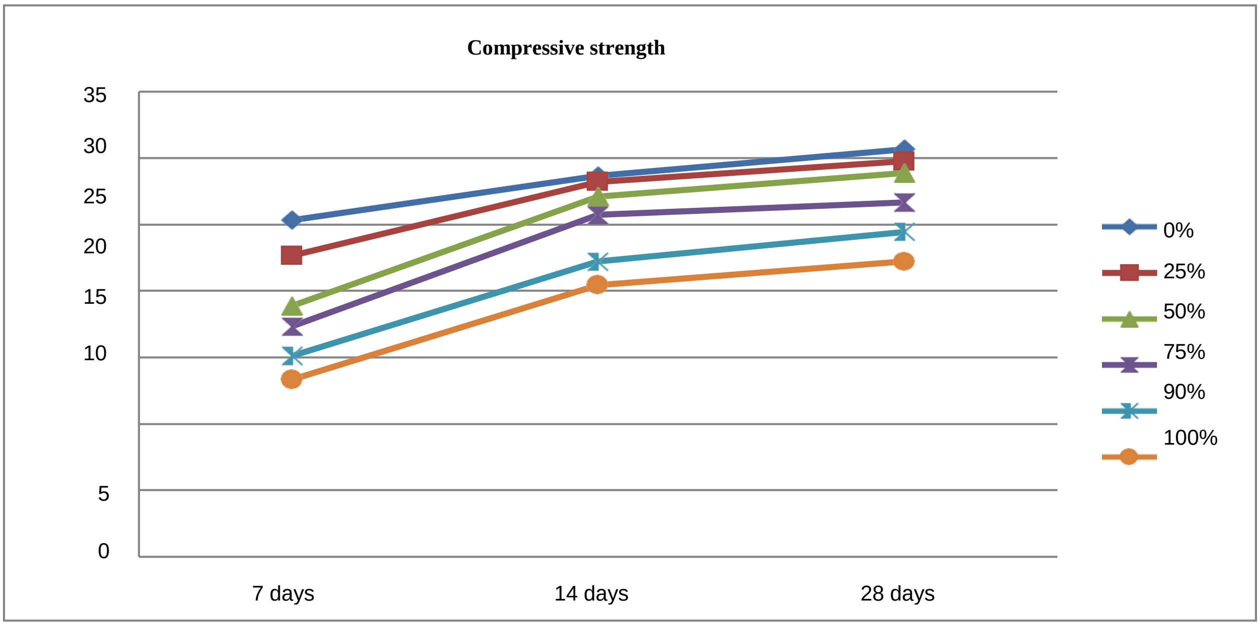

Fig.4.5. Compressive Strength Vs Age

IV. DISCUSSION

Based on the findings of the aforementioned study, the following observations were made regarding the properties and behavior of concrete when partially replacing Natural Coarse Aggregate (NCA) with Recycled Coarse Aggregate (RCA):

- The strength of concrete after 28 days of curing was highest at 0% replacement, reaching a maximum of 31.10 N/mm2, exceeding all other replacement proportions.
- At 25% replacement, the strength after 28 days was recorded at 30.40 N/mm2, nearly equivalent to that of conventional concrete (31.10 N/mm2).
- For 50% replacement, the strength after 28 days decreased slightly to 28.35 N/mm2, being slightly lower than both conventional concrete and 25% replacement concrete.
- Strength gradually decreased with increasing replacement proportions, reaching its lowest point at 100% replacement.
- Workability decreased as the percentage of recycled aggregate increased due to higher water absorption in recycled aggregate compared to natural aggregate. To maintain consistency, the water-cement ratio was adjusted to 0.5 for 0%, 25%, and 50% replacements, 0.55 for 75% and 90% replacements, and 0.60 for 100% replacement.
- The density of recycled coarse aggregate was lower than that of natural aggregate due to porous and less dense residual mortar adhering to the surfaces. An increase in particle size led to a higher volume percentage of residual mortar.
- Dry density of concrete decreased as the percentage of replacement increased after 28 days of curing.
- Recycled coarse aggregate had rough textured and elongated particles, while natural aggregate had smooth and rounded compact particles.
- The properties of freshly mixed concrete were influenced by the particle shape and surface texture of the aggregate. RCA required more water than NCA to produce workable concrete. Angular aggregate increased void content, whereas larger sizes of well-graded aggregate reduced void content.

V. CONCLUSION

Reusing and recycling building wastes has emerged as a viable solution to the challenges of disposing of large quantities of waste while facing a shortage of natural

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aggregates. The incorporation of recycled aggregates in concrete proves to be a valuable construction material in technical, environmental, and economic aspects. There are numerous practical applications for utilizing recycled coarse aggregate in construction. However, further research and implementation of initiatives for the utilization of Recycled Aggregate Concrete (RCA) are necessary to revise our design codes, specifications, and methods for the use of recycled aggregates.

The issue of incorporating RCA into construction projects in India should be prioritized, especially considering the large-scale infrastructural projects scheduled for the coming years. Utilizing rubble waste reduces waste production in the construction industry, making it an environmentally friendly construction material. The use of recycled aggregate in concrete conserves energy, protects the environment, and reduces the cost of transporting and excavating natural resources.

Construction practices involving the replacement of natural coarse aggregate with recycled coarse aggregate at rates of 25% and 50% are suitable for various construction purposes, including lightly reinforced beams, slabs, walls, columns, floors, canal linings, strip footings, and mass concreting. These practices demonstrate minimal differences in strength parameters, indicating their feasibility and effectiveness in construction applications.

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