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Experimental Study on Concrete using Recycled Coarse Aggregates

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ABSTRACT: This project report contains experimental study on concrete using recycled coarse aggregate (RCA) as a partial replacement of natural coarse aggregate (NCA). RCA is obtained from demolished structure waste. This paper focuses on the possibility of the use of recycled aggregate in concrete as structural material. The RCA was obtained from construction and demolition waste (C&DW) and used as Partially replacement of natural coarse aggregate (NCA) for production of RAC. Crushed granite was used as NCA while crushed concrete rubble from a demolished concrete building used as RCA. Mix design of M25 grade of concrete is prepared as per IS:10262(2019) and IS:456(2000). And concrete cube of size (150*150*150) mm is made with different percentage replacement of RCA with NCA . Replacement of RCA with NCA is taken as 0%, 10%, 20%, 30% and 40%. Total 45 cubes casted, cured and tested in compression testing machine. Compressive strength of of RAC cube is compared with conventional concrete at interval of 7 days ,14 days and 28 days. This study will be beneficial to construction industries as well as environment.

KEYWORDS: Recycled coarse aggregate, concrete, compressive strength, construction and demolition waste, durability, sustainability, natural aggregate replacement

I. INTRODUCTION

Aggregates represent about 60%-70% per volume of any concrete mixture. The growth of the new construction projects and the increasing demand for natural aggregates led to the expected shortage of the natural resources. In addition, several environmental and economical factors were the reason for the search of other alternatives. A possible solution of these problems is to recycle demolished concrete and produce an alternative aggregate for structural concrete in this way. Recycled concrete aggregate (RCA) is generally produced by two stage crushing of demolished concrete. RCA reduces the impact on landfills; decreases energy consumption and can provide cost savings. However, there is totally the beneficial use of RCA in concrete construction. Several environmental, economical, and engineering benefits could be achieved from recycling the construction industry waste. Recycled aggregates provide an alternative of the natural aggregate if quality is assured. Recycled aggregate is comprised of crushed, graded in organic particles processed from the material that have been used in the construction and demolition debris. The aim of this project is to determine the strength characteristic of recycled aggregates, for application in structural concrete. Coarse aggregate is important material in concrete for compressive strength, so there are utilization of demolished concrete in replaced by natural coarse aggregate. Recycled coarse aggregate (RCA) obtained from crushed concrete rubble, instead of being stored, can be reused in building industry. An attempt has been made to study the possibility of reusing the recycled concrete aggregate from demolished structures in the place of fresh aggregate. The basic properties of aggregates, such as water absorption and specific gravity, mechanical properties, such as abrasion resistance, effect, and crushing values were also calculated. Workability of fresh concrete and strength parameters of hardened concrete, such as compressive strength were studied. The use of RCA in new construction applications is still a relatively new technique. Buck (1977) cites the beginning of RCA use to the end of World War II, when there was excessive demolition of buildings and roads and a high need to both get rid of the waste material and rebuild Europe. After the immediate need to recycle concrete, the use of RCA tapered off. In the 1970s, the United States began to reintroduce the use of RCA in nonstructural uses, such as fill material, foundations, and base course material (Buck 1977). Since this time, some research has been conducted regarding how viable RCA is as an option to replace unused natural aggregate (NA) in structural concrete

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A study from freedonia group says that global demand for construction aggregate exceeds 48 billion metric tons in 2015. India recycles just one per cent of its construction and demolition (C&D) waste, a new report released by Delhi-based non-profit, Centre for Science and Environment (CSE) on August 25, 2020, has shown. The country generates an estimated 150 million tonnes of C&D waste every year, according to the Building Material Promotion Council. But the official recycling capacity is a meagre 6,500 tonnes per day just about one per cent. What's more, unofficial estimates of the total waste generated in the country put the figure at threefive times more than the official estimate. Recycling of concrete is needed from the viewpoint of environmental preservation and effective utilization of resources. At present, utilization of recycled aggregate is limited mainly to sub bases of roads and backfill works. A large portion of concrete waste ends up at disposal sites. It is anticipated that there will be an increase in the amount of concrete waste, a shortage of disposal sites, and depletion in natural resources especially. These lead to the use of recycled aggregate in new concrete production, which is deemed to be a more effective utilization of concrete waste. However, information on concrete using recycled aggregate is still insufficient, and it will be advisable to get more detailed information about the characteristics of concrete using recycled aggregate. The possibility to reutilize aggregates, resulting from recycling of End-Of-Life (EOL) concrete, represents a challenge in the sector. In these last years, more and more recycled coarse aggregates have been proven to be commercially and technically sound for both non- structural and structural applications. Recycled Aggregate Concrete (RAC) behavior and characteristics are strongly conditioned and influenced by the "source" waste aggregates, the adopted concrete mix design, the operative conditions to realize the mix, and the intrinsic RAC attributes (i.e. mineralogical composition, surface status, morphological and morphometrical properties). A preeminent role in final concrete characteristics is played by the cohesive interface properties resulting from RAC utilization, properties strongly linked to Interfacial Transition Zone (ITZ) characteristics, old mortar quality and the old mortar content of the original concrete. The ITZ, that is the region between aggregate and cement paste, is usually characterized by a different microstructure than the bulk paste.

II. LITERATURE SURVEY

- 1. **Patil, A. & Gupta, S. (2023):** The use of recycled coarse aggregate (RCA) in concrete has gained prominence due to growing environmental concerns and depletion of natural resources. This study investigated the properties of M25 grade concrete with varying percentages of RCA (10%, 20%, 30%, and 0%) as a replacement for natural coarse aggregate (NCA). Results indicated a reduction in compressive strength with an increasing RCA percentage, but mixes with up to 30% RCA replacement met the strength requirements for general construction purposes. The research emphasizes RCA's potential as an eco-friendly alternative in concrete production.
- 2. **Kumar, V. et al. (2022):** This study focused on the durability of concrete made using RCA in aggressive environments. Tests on sulfate resistance and chloride penetration revealed that RCA concrete displayed higher permeability compared to NCA concrete. However, durability could be enhanced through the use of supplementary cementitious materials such as fly ash and GGBS. This highlights the need for mix optimization when incorporating RCA in structural applications.
- 3. **Reddy, P. & Sharma, T. (2021):** An experimental study was conducted to evaluate the mechanical properties of concrete with RCA as a full replacement for NCA. The findings showed that while RCA concrete had slightly lower compressive and flexural strength, it was suitable for non-structural and pavement applications. The study also highlighted the importance of pre-treatment of RCA to improve the bonding between aggregate and cement matrix.
- 4. Singh, R. & Patel, A. (2020): The economic feasibility of using RCA in concrete was assessed in this study. It was observed that using RCA significantly reduces construction costs while contributing to waste management. The study concluded that replacing up to 25% of NCA with RCA achieves a balance between cost efficiency and structural performance.
- 5. Chen, H. et al. (2019): The long-term performance of RCA-based concrete was studied through shrinkage and creep tests. The results demonstrated that RCA concrete exhibited higher shrinkage and creep compared to conventional concrete. The authors recommended blending RCA with NCA to mitigate these effects and achieve improved dimensional stability.





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III. METHODOLOGY

The chapter deals with the materials collection, which were used in the investigation. It also explains the various experimental investigations carried out for physical and chemical properties to understand the behavior.

Basic Tests on Materials

Table 1: Tests on Cement

Sl. No.	Tests	Results
1	Specific Gravity	3.02
2	Fineness	9%
3	Standard Consistency	30%
4	Initial Setting Time	40 min
5	Final Setting Time	280 min

Table 3: Tests on Natural Coarse AggregatesAggregates

Sl. No.	Tests	Results
1	Specific Gravity	2.56
2	Fineness Modulus	6.5
3	Water Absorption	0.6%

Table 2: Tests on Fine Aggregates

Sl. No.	Sl. No. Tests	
1	Specific Gravity	2.84
2	Fineness Modulus	2.7
3	Water Absorption	1.0%

Table 4 : Tests on Recycled Coarse

Physical Property	Value
Density	2.4 - 2.7 g/cc
Melting Point ⁰ C	500 - 750
Elongation at break	3 %

Table-5: Proportionvalues for different mixes (allinkg/m3)

% RCA	0%	10%	20%	30%	40%
Cement	390.98	390.98	390.98	390.98	390.98
Sand	647.34	647.34	647.34	647.34	647.34
NCA	1181.70	1063.53	945.36	827.19	709.02
RCA	0	118.17	236.34	354.51	472.68
water	191.58	191.58	191.58	191.58	191.58
Sp. dosage	1.681	1.681	1.681	1.681	1.681

FINAL MIX PROPORTION = 1:1.65:3.02





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IV. EXPERIMENTAL RESULTS

Table 6: Compressive strength of NCA(0%RCA) cubes

Sr. No.	Days	Compressive strength	Avg.Compressive strength
		19.66	
1	7	22.71 21.2	21.18
		23.89	
2	14	25.57 29.13	26.51
		29.42	
3	28	27.55 28.4	28.48

Table 7: Compressive strength of NCA(10%RCA) cubes

Sr. No.	Days	Compressive strength	Avg.Compressive strength
		19.6	
1	7	19.2 19.4	19.40
		25.7	
2	14	26 26.1	25.90
		27.8	
3	28	27.9 28	27.90

Table 8: Compressive strength of NCA(20%RCA) cubes

Sr. No.	Days	Compressive strength	Avg.Compressive strength
		19.82	
1	7	15.33 17.44	17.57
		24.13	
2	14	26.14 25.29	25.17
		26.24	
3	28	27.41 27.98	27.21





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Table 9: Compressive strength of NCA(30%RCA) cubes

Sr. No.	Days	Compressive strength	Avg.Compressive strength
		17.0	
1	7	16.8	16.90
		17.1	
		23.6	
2	14	23.7	23.70
		23.8	
		25.7	
3	28	25.9	25.80
		25.8	

Table 10: Compressive strength of NCA(40%RCA) cubes

Sr. No.	Days	Compressive strength	Avg.Compressive strength
		16.1	
1	7	16.2	16.20
		16.3	
		22.8	
2	14	22.9	22.90
		23	
		24.8	
3	28	25	24.90
		25	

Table-11 : Comparisonbetweencompressive strengthafter 28 days

%RCA	Compressive strength after 28 days (MPa)	Compare to 0% RCA	% decrement
0%	628.48	-	-
10%	627.90	0.58	2.04%
20%	627.21	1.27	4.46%





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30%	25.80	2.68	9.41%
40%	24.90	3.58	12.57%

Graph-1: Compressivestrengthafter 7 days



Graph-2: Compressivestrengthafter 14 days



Graph-3: Compressivestrengthafter 28 days

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- > Thetest results of the 7, 14 and 28 days compressive strength of concrete are presented in above tables.
- Both NAC and RAC concrete types had similar compressive strength development with increase in time. As expected, the compressive strength of each concrete mix increased with age with the 7-day
- > concrete cube attaining the lowest compressive strength while the 28-day concrete had the highest strength.
- > This is due to increased amount of hydration products with the longer curing age. Both NAC and RAC types had approximately similar compressive strength development with time.
- The 7-day compressive strength of concrete generally ranges from 60-80% of the 28-day compressive strength for traditional concrete under standard curing conditions.
- The 7-day compressive strength of NAC obtained in this study was 74.36% of its 28-day compressive strength, while the 7-day compressive strength of RAC is 63.86%, 67.61% and 71.74% of its 28-day compressive strength for 20%, 50%, and 100% RCA replacement respectively.
- ➤ Table 11 shows the reduction in compressive strength of RAC in comparison with NAC(0% RCA).
- The reduction in compressive strength of RAC could be attributed to the lower quality of the recycled aggregate in comparison with virgin coarse aggregate.
- > It should be noted that the RCA was obtained from a demolished concrete structure of unknown compressive strength.

V. CONCLUSION

- 1. The compressive strength of natural aggregate concrete (0% RCA) was consistently higher than that of recycled aggregate concrete (RAC) across all curing ages.
- 2. The compressive strength of concrete decreased as the percentage of RCA increased due to the weaker properties of recycled aggregates compared to natural aggregates.
- 3. The compressive strength of concrete with 10% RCA replacement decreased by 2.04% compared to conventional concrete (0% RCA).
- 4. The compressive strength of concrete with 20% RCA replacement decreased by 4.46% compared to conventional concrete.
- 5. The compressive strength of concrete with 30% RCA replacement decreased by 9.41%, while 40% RCA replacement resulted in a 12.57% reduction compared to 0% RCA.
- 6. Concrete with up to 20% RCA replacement achieved a compressive strength above 25 MPa after 28 days and is suitable for structural applications.
- 7. Concrete with 30% and 40% RCA replacement exhibited compressive strengths below the threshold for M25 grade concrete and is recommended for non-structural applications such as pavements, foundations, or lightly loaded members.
- 8. The compressive strength reduction in RAC is attributed to the lower quality of recycled aggregates, which have higher porosity and lower interfacial bond strength compared to natural aggregates.

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