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Strength Evaluation of Recycled Aggregate using Different Types of Curing Methods

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Abstract: : Due to the continuous demand for concrete to meet various requirements, extensive and wide spread research work is being carried out in the area of concrete technology. Construction activities generate a significant amount of concrete waste, posing environmental and economic challenges. Usage of recycled coarse aggregate (RCA) in concrete production offers a sustainable solution by reducing reliance on virgin resources and minimizing landfill waste. This project aims at assessing the strength characteristics of concrete incorporating 40% recycled aggregate while employing diverse curing techniques. The study has also been done to investigate the influence of different curing methods on the compressive and tensile strength of the concrete mix containing recycled aggregates. The study reveals that this kind of mixture with 40% recycled aggregate cured using water immersion method can successfully be used for construction of low-rise buildings and pavements. Thus, this project holds significance in sustainable construction practices.

Keywords: Recycled Coarse Aggregate, Concrete, Compressive and Tensile Strength.

1. Introduction

Concrete is composed of sand, aggregate, cement, and admixture. It is a structural material where sand and gravel are bonded together by cement and water. Concrete is the most common material used in construction and is highly inhomogeneous. The rapid development of the construction industry has significantly increased the consumption of natural resources.

However, the production of cement depletes natural resources and emits greenhouse gases. Concrete is the second most used substance in the world after water and is the most widely used building material. Advancements in construction technology have made the construction process easier and faster, drastically increasing the demand for building materials. Rapid urbanization and economic growth have improved living standards, leading to the demolition of older buildings and the construction of new structures. This rise in construction activity has increased the demand for concrete. Aggregate is a crucial component of concrete, and the demand for natural aggregate has risen sharply, leading to the extensive use of natural resources. The extraction of natural aggregates like gravel and sand has altered landscapes, river courses, and riverbeds, causing significant environmental damage.

Construction and demolition waste create major environmental issues, as a large quantity of this waste is sent to landfill sites. If this disposal rate continues, there will soon be a shortage of landfill sites and a depletion of natural aggregate sources. Studies show that approximately 75% of waste material in some countries are disposed of in landfills, despite their high recycling potential.

The high depletion of natural aggregates and the accumulation of construction and demolition waste (CDW) have driven the search for alternative uses for this waste. Recycling and reusing CDW is one of the best ways to utilize waste material. CDW can be crushed to the size of natural aggregate and treated with chemicals to remove the attached mortar layer, allowing it to be used as a substitute for natural aggregate. These substituted particles are known as recycled aggregate, and the concrete made from them is known as recycled aggregate concrete. Recycled aggregate consists of aggregate surrounded by mortar. The amount of mortar affects the durability and engineering properties of the concrete. RCA exhibits different characteristics compared

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to natural aggregate because it consists of both mortar (cement or lime mortar attached to aggregate) and natural aggregate. The attached cement mortar in RCA is responsible for its high-water absorption capacity, low density, and high Los Angeles abrasion.

The bonded mortar makes concrete more porous, thereby lowering the properties of recycled aggregate concrete compared to natural aggregate concrete. Recycled aggregate absorbs much more water than natural aggregate, which is a significant difference between the two. The major aim of this project is to evaluate the influence of different types of curing on RCA and normal concrete designed for M25 strength, prepared using RCA partially. The outcome of this project will help design structural elements under different curing methods and promote the use of demolished wastes in road and building construction.

2. Literature Survey

In this chapter the literature review on recycled coarse aggregate in concrete aims to provide an overview of the current state of research in this field. It discusses the growing demand for concrete globally and the environmental challenges associated with its production, such as resource depletion and waste generation. The introduction emphasizes the importance of sustainable construction practices and the potential of using recycled materials, particularly coarse aggregate, in concrete production to address these challenges. The objectives of the literature review are to examine the existing literature on the use of recycled coarse aggregate in concrete, identify the benefits and limitations of this practice, and analyze the factors influencing its performance in concrete mixtures. The introduction also outlines the structure of the subsequent sections, which will include a review of relevant literature, discussion of findings, and conclusions.

A. K. Padmini, S. Ramasubramani (2017) Explored in their study on “A Review on Recycled Aggregate Concrete: From Laboratory to Field Applications” offers a comprehensive overview of the transition of recycled aggregate concrete (RAC) from laboratory research to practical field applications. The paper examines various studies focusing on the mechanical properties, durability, and sustainability aspects of RAC. Additionally, it discusses the challenges and opportunities associated with the implementation of RAC in real-world construction project.

R. Gupta, A. Kumar, And S. Sharma (2020) Experimented on “Recent development in Recycle Aggregates Concrete: A State-of-the-Art Review” it synthesizes finding from research articles conference proceedings and technical reports to highlight progress in material characterization techniques, durability, assessment methods, and sustainable construction practices related to RAC. Durability, assessment methods and sustainable construction practices reviews critically examines the influence of various factors such as aggregates quality, mixed design parameters and curing conditions on the performance of RAC.

K. S. Pablojohn Et Al (2019) Worked on RCA can potentially to impact the durability of concrete negatively. This is preliminary due to recycle aggregate tendency to increase permeability and sustainability to factors such as freeze-thaw cycle or chemical attacks. To address this durability concerns by researchers, propose implementation of proper mixed design methodology and surface treatment techniques for carefully optimizing the mixed proportions and incorporating suitable additives, as well as applying surface treatments, durability of concrete containing recycle was a little can be enhanced thus ensuring it long time performance in various environmental conditions.

N. Singh Et Al (2018) Modified the mix design by adjusting the water-cement ratio, using supplementary cementitious materials (SCMs) like fly ash or slag, and optimizing the aggregate size distribution can improve the strength and workability of RCA concrete.

K. E. Daouadji, N. Benachour (2019) As in researched on “Recycled Coarse Aggregates: A Review” it provides a compressive overview of recycled coarse aggregate in concrete the paper examines various studies on mechanical property, durability and environmental impact of concrete containing RCA. It discusses the challenges and approaches associated with use of RCA in concrete production offering insight into its potential application in sustainable construction.

S. S. B. Aziz, H. Mahmud (2018) As in pondered on “Influence of Recycled Aggregates on Mechanical Properties of Concrete” they provided a compressive analysis on how recycle aggregate impact the mechanical properties of concrete they synthesize findings from previous research to assess the effects of incorporating recycle aggregates in concrete properties such as compressive strength, tensile strength and modulus of elasticity. They identify a key pattern influencing the mechanical performance of concrete with recycled aggregates and purposes strategies for optimizing concrete mixture the utilization of recycle aggregates in concrete production.

N. S. Poon And E. E. Chan (2006) As in learned on "Influence of Recycled Aggregate on the Properties of Concrete”. The studies have focused on the influence of recycled aggregate (RA) on concrete properties.

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Mechanical properties such as compressive and tensile strength, as well as durability factors like resistance to chloride ion penetration and sulfate attack, have been scrutinized. While some findings suggest comparable or enhanced mechanical performance, others note potential reductions due to weaker recycled aggregates. Workability is also affected by RA's water absorption and angularity. Despite environmental benefits, technical challenges remain, necessitating further research to optimize RA's use in concrete production.

A. M. Neville And J. J. Brooks (2010) Reviewed on "Sustainable Construction: Use of Recycled Concrete Aggregate". The literature on recycled concrete aggregate (RCA) highlights its potential for sustainable construction. Studies have examined its mechanical properties, durability, environmental impact, and economic feasibility. While RCA shows promise in reducing landfill waste and environmental impact.

S. P. Singh And S. K. Dhiman (2017) Analyzed on "Effect of Recycled Coarse Aggregate on Concrete Properties". The study investigates the impact of incorporating recycled coarse aggregate (RCA) on concrete properties. It examines factors such as compressive strength, flexural strength, and durability of concrete. While some findings suggest comparable or improved properties with RCA, others note potential reductions due to factors like aggregate quality and mix design. Proper adjustments to the mix design and surface treatment techniques are recommended to optimize the performance of RCA concrete.

P. K. Mehta And P. J. Monteiro (2019) Studied on "Mechanical Properties of Recycled Aggregate Concrete". The study explores the mechanical properties of recycled aggregate concrete (RAC). It discusses how factors such as aggregate quality, water-cement ratio, and curing conditions influence concrete performance. While some studies demonstrate satisfactory mechanical properties of RAC, others highlight challenges such as reduced compressive and tensile strength. The review provides insights for optimizing RAC mixtures to enhance mechanical performance in construction applications.

3. Theory / Calculation

3.1 Cement

Cement is the most important material in concrete, acting as the binding agent. In this investigation, Ordinary Portland Cement (53 grade) manufactured by Ramco is used. Various properties of the cement have been tested according to IS 12269-1987 and IS 4031-1988, as result has been tabulated given below:

Table. 1 Test Values of Cement

S.No	Test Name	Obtained Value
1	Fineness Of Cement	4.5%
2	Initial Setting Time	29 Mins 38 Sec
3	Final Setting Time	8 Hours 26 Mins
4	Specific Gravity	3.10
5	Normal Consistency	32%
6	Soundness	3 Mm
7	Compressive Strength	40.7 N/Mm2

3.2. Fine Aggregate

Fine aggregate helps fill the voids present between coarse aggregates and mixes with cementitious materials to form a paste that coats the aggregate particles, affecting the compatibility of the mix. The properties of the fine aggregates have been tested according to IS 383 and IS 2386: Part-3, as result has been tabulated given below:

Table. 2 Test Values of Fine Aggregate

S.No	Test Name	Obtained Value
1	Specific Gravity	2.66
2	Water Absorption	3%
3	Silt Content	5.5%
4	Grading Curve	Zone-2

3.3. Coarse Aggregate

Selection of the maximum size of aggregate mainly depends on the project application, workability, segregation, strength, and availability. The maximum size of the aggregate varied between 4.75 mm and 20 mm. The properties of the coarse aggregates have been tested according to IS 383-1970, IS 2386 Part A, IS 2386-1963 Part 3, and IS 2386-1963 Part 4 as result has been tabulated given below:

Table 3: Test Values of Coarse Aggregate

S.NO	TEST NAME	OBTAINED VALUE	
		NORMAL	RECYCLED
1	Specific Gravity	2.52	2.32
2	Water Absorption	1.2%	3.6%
3	Impact Test	19.61%	24%
4	Crushing Test	28.77%	32.52%
5	Grading Curve	20 MM	-

3.4. Concrete

Concrete is a versatile construction material made from cement, water, and aggregates like sand and gravel. It begins as a fluid mixture that can be molded into various shapes. As it hardens, it becomes a strong and durable

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solid, suitable for a wide range of construction projects. Its adaptability makes it essential in modern construction.

3.5 Test Performed On Concrete:

Slump Cone:

Table. 4 Test Values of Slump Cone

S.NO	W/C RATIO	SLUMP IN MM	
		NORMAL	RECYCLED
1	0.45	0	-
2	0.5	65	-
3	0.6	180	0
4	0.7	220	63
5	0.8	280	173

Compaction Factor:

Table 5: Test Values of Compaction Factor

S.NO	W/C RATIO	COMPACTION FACTOR	
		NORMAL	RECYCLED
1	0.5	0.846	0.692
2	0.6	0.999	0.901
3	0.7	1.038	0.932
4	0.8	1.049	0.969

The workability of compaction factor for normal and recycled coarse aggregates at 0.5 W/C values are 0.846,0.692**.**

3.6 Mix Design

Based on the mix design guidelines in IS 10262:2019, the obtained mix design proportions for M25 concrete are 1 part of cement: 1.62 parts of fine aggregate (FA): 2.53 parts of coarse aggregate (CA).

4. Experimental Method

This chapter presents the study of recycled aggregate concrete, focusing on the effects of different curing methods on its properties. Experiments were conducted to evaluate the modulus of elasticity, permeability, compressive strength, and split tensile strength of the concrete. The influence of recycled aggregate on these properties, particularly compressive and split tensile strength, was analyzed based on the experimental data.

4.1 Casting of Specimens

Concrete mix of M25 grade was designed using the IS method, resulting in a mix proportion of 1:1.62:2.53 with a water-cement ratio of 0.45. To proceed with the experimental program, steel molds of size 150x150x150 mm for cubes and molds of 300x150 mm (height x diameter) for cylinders were cleaned and brushed with machine oil on all inner surfaces to facilitate easy removal of specimens afterward.

First, recycled aggregate and cement were thoroughly mixed, followed by the addition of conventional coarse aggregates. This mixture was thoroughly combined by hand. Each batch consisted of nine cubes for normal concrete, nine cubes for 40% recycled coarse aggregate (RCA) concrete, and six cylinders. The molds were placed on a platform, and concrete was poured into the molds in three layers, each layer being compacted thoroughly with a tamping rod to avoid honeycombing. Finally, the filled molds were vibrated on a table vibrator for 7 seconds to ensure consistency across all specimens. The specimens were demolded 24 hours after casting and then immersed in a clean water tank for curing. After 28 days of curing, the specimens were removed from the water and allowed to dry under shade for a few hours.

4.2 Curing Procedure

After casting, the specimens were left for 24 hours before demolding. The specimens were then subjected to different curing methods: immersion curing, hot water curing, and adiabatic curing. For immersion curing, the specimens were kept in normal water until the testing age. In hot water curing, specimens were immersed in hot water at a controlled temperature. Adiabatic curing involved enclosing the specimens to retain the heat generated during hydration. These curing methods were applied consistently to assess their impact on the strength characteristics of recycled aggregate concrete.

4.3 Testing and Evaluation

The specimens were tested for modulus of elasticity, permeability, compressive strength, and split tensile strength after 28 days of curing to determine the influence of different curing methods on these properties. Compressive strength tests were performed on the cubic specimens to determine the maximum load the concrete could withstand. The split tensile strength test was conducted on cylindrical specimens of 300 mm height and 150 mm diameter to evaluate the tensile strength of the concrete, a crucial indicator of its durability and resistance to cracking. The data collected from these tests were analyzed to evaluate the effect of recycled aggregate and curing methods on the concrete's performance, focusing particularly on compressive strength and split tensile strength. By analyzing the results, insights into the optimal curing methods for achieving desired strength properties in recycled aggregate concrete were obtained.

5. Result and Discussion

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Due to increase in demand of building material in construction industry, search for the alternative material is the need of hour to preserve our natural resources. Hence, using recycled concrete aggregate solves two major problems of safeguarding the natural resources and utilization of construction demolished waste (CDW). Hence, the study was conducted to check the strength of concrete manufactured with RCA. The results for the test conducted are graphical represented below:

5.1 Compressive Strength

The standard cubes of size 150x150x150 mm were cast for M25 concrete with 40% recycled coarse aggregate and tested for compressive strength as per IS 516:1959. The samples were tested after 28 days of curing.

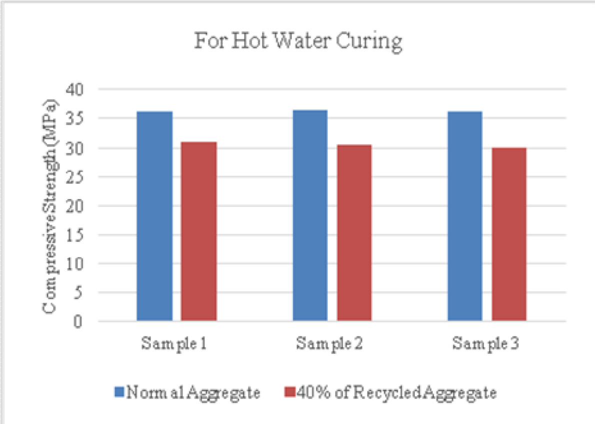

Figure. 1 Shows the Compressive Strength Comparison between Concrete with Normal Aggregate and Concrete with 40% Recycled Aggregate using Hot Water Curing

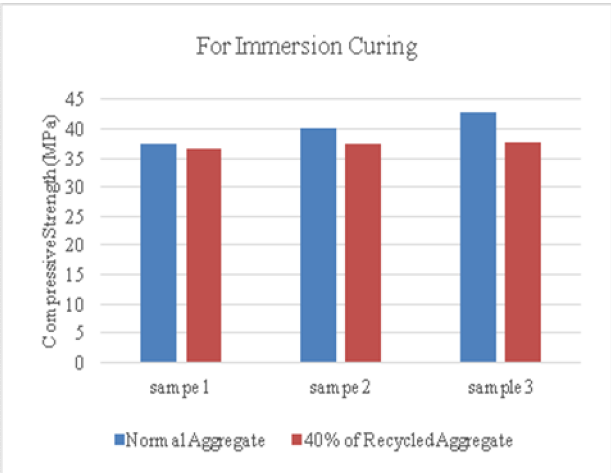

Figure. 2 Shows the Compressive Strength Comparison between Concrete with Normal Aggregate and Concrete with 40% Recycled Aggregate using Immersion Curing

It was found that the compressive strength of these cubes was lower compared to those made with fresh aggregate. Different curing methods, including hot water curing, immersion curing, and adiabatic curing, were used. The results indicated variations in compressive strength depending on the curing method applied.

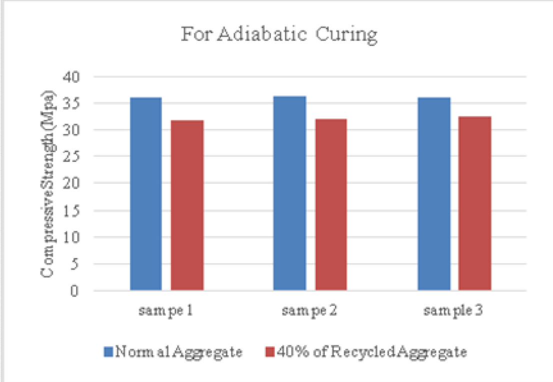

Figure 3: Shows the Compressive Strength Comparison between Concrete with Normal Aggregate and Concrete with 40% Recycled Aggregate using Adiabatic Curing

5.2 Spilt Tensile Strength

The standard cylinders of size 150x300 mm were cast for M25 concrete with 40% recycled coarse aggregate and tested for spilt strength as per IS 5816:1999. The samples were tested after 28 days of curing. It was found that the spilt tensile strength of these cylinders was lower compared to those made with fresh aggregate. Different curing methods, including hot water curing, immersion curing, and adiabatic curing, were used. The results indicated variations in compressive strength depending on the curing method applied.

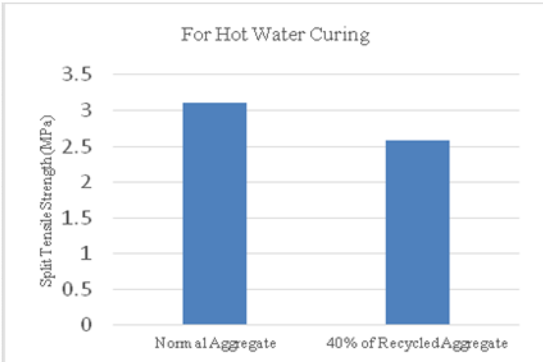

Figure 4: Shows the Spilt Tensile Strength Comparison between Concrete with Normal Aggregate and Concrete with 40% Recycled Aggregate using Hot Water Curing

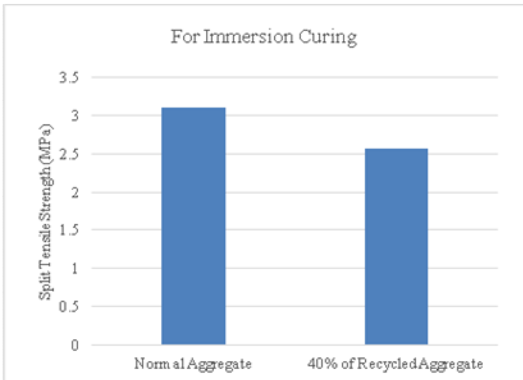

Figure 5: Shows the Spilt Tensile Strength Comparison between Concrete with Normal Aggregate and Concrete

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with 40% Recycled Aggregate using Immersion Curing

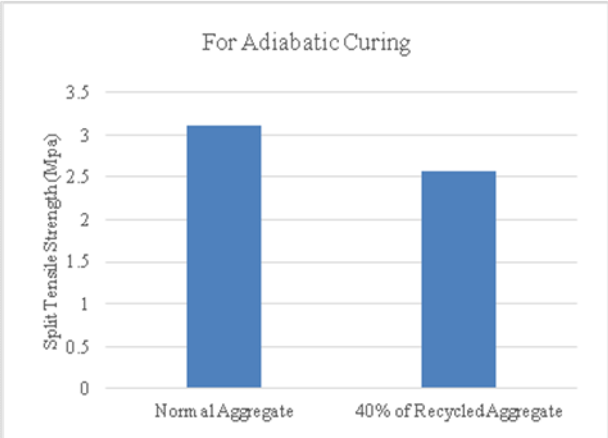

Figure. 6 Shows the Spilt Tensile Strength Comparison between Concrete with Normal Aggregate and Concrete with 40% Recycled Aggregate using Adiabatic Curing

6. Conclusion and Future Scope

Artificial In this study, experimental investigations have been carried out on Normal Coarse Aggregate (NCA) and Recycled Coarse Aggregate (RCA) for determination of compressive strength, split tensile strength and permeability of M25 concrete mix which was casted according to mixed design IS 10262-2019. Further, different samples of RCA were taken and cured using different types of curing methods. The following conclusions has been drawn from the results of the present study. The compressive strength results indicate that water immersion curing method is the most effective method compared to hot water curing and adiabatic curing. For normal M25 concrete, immersion curing resulted in an average compressive strength of 40.133 MPa, for over hot water curing (20.33 MPa) and adiabatic curing (36.28 MPa). Similarly, in the case of M25 concrete with 40% partial replacement of RCA, the immersion curing demonstrated notable strength at 37.27 MPa, surpassing both hot water curing (17.76 MPa) and adiabatic curing (32.23 MPa).

Split tensile strength results do reveal that water immersion curing has exhibited favorable outcomes compared to that of other methods. For normal M25 concrete, immersion curing produced a split tensile strength of 3.36 MPa, outperforming hot water curing (2.872 MPa) and adiabatic curing (3.103 MPa). Likewise, in M25 concrete with 40% partial replacement of RCA, the immersion curing achieved a split tensile strength of 3.08 MPa, surpassing hot water curing (2.364 MPa) and adiabatic curing (2.574 MPa). For the following reasons, the recommended RCA can be used for construction of low-rise buildings and pavements. The decrease in compressive and split tensile strength of concrete with 40% RCA has visually been observed being with inhomogeneity, higher water absorption, presence of impurities, lack of particle grading, and reduced mechanical properties.

Declaration

We Declare with our best of Knowledge that this research work is purely Original Work and No third-party material Not used in this article drafting. If any such kind material found in further online publication, we are responsible only for any judicial and copyright issues.

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