Partial Replacement of Natural Coarse Aggregates by Recycled Coarse Aggregates

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ABSTRACT :-

Concrete is a ubiquitous material in the construction industry, and its demand is escalating rapidly due to increasing urbanization. The subsequent rise in new building and infrastructure projects has led to a surge in demand for natural aggregates, resulting in excessive quarrying and depletion of natural resources. Concurrently, the demolition of existing structures generates vast amounts of construction and demolition waste, which are typically discarded in landfills. This project investigates the feasibility of replacing natural coarse aggregates (NCA) with recycled coarse aggregates (RCA) derived from demolished concrete in concrete production. The study evaluates the physical and mechanical properties of RCA, including water absorption, density, and compressive strength, compared to NCA. Various concrete mixes with partial and full replacement of NCA by RCA were prepared and tested to assess workability, strength, and durability. This not only requires substantial land areas, which are becoming increasingly scarce, but also poses significant environmental concerns. A viable solution to these dual challenges lies in recycling and reusing demolished concrete as aggregates in new concrete. The project also considers economic factors, such as the cost-effectiveness of RCA in regions with limited access to natural aggregates, and proposes guidelines for its adoption in local construction standards. This project investigates the feasibility of utilizing demolished concrete as a coarse aggregate, exploring its potential as a partial replacement for natural aggregates. The study examines the effects of replacing 0% to 40% of coarse aggregates with demolished concrete, assessing its suitability for use in new concrete applications.

1.INTRODUCTION

1.1 General:

Concrete is a crucial component in the construction industry, particularly in countries like India where infrastructure growth is rapid. The demand for construction materials is high, with massive quantities required to support ongoing development. Typically, concrete structures are designed to last for 50 years. However, as infrastructure expands, older constructions require increasing maintenance to remain economically viable. Maintaining aging constructions can be costly, leading to the demolition of old buildings and their disposal in open landfills. This not only reduces available land space but also incurs high dumping costs and contributes to environmental pollution. The construction of new buildings has increased, which, in turn, has reduced the reliance on non-renewable energy sources. According to a 2015 report by Niti Aayog, India consumed 48 billion metric tonnes of coarse aggregate, with consumption rates continuing to rise. This escalating demand threatens to deplete non-renewable energy sources, such as natural aggregates.

1.2 Recycled Aggregate:

Recycled coarse aggregates are produced by crushing and screening demolished concrete or other construction debris to obtain particles suitable for use in new concrete mixes or other applications. The adoption of RCA aligns with the principles of a circular economy, where materials are reused and recycled to minimize waste and reduce the demand for virgin resources. By replacing natural coarse aggregates with RCA, the construction industry can significantly lower its environmental footprint, conserve natural ecosystems, and reduce landfill dependency. Moreover, in regions where natural aggregates are scarce or expensive to transport, RCA can provide a cost-effective alternative, making construction projects more economically viable.

1.3 OBJECTIEVE

1.Environmental Sustainability

Reduce reliance on natural resources like gravel and sand.Minimize ecological damage from mining and quarrying activities.Lower carbon footprint by cutting down on transportation and energy consumption.

2. Enhanced Waste Management

Repurpose construction and demolition waste efficiently.

Reduce landfill accumulation and promote circular economy initiatives.

3.Economic Benefits

Lower costs associated with natural aggregate extraction and transportation.

Provide a cost-effective alternative for concrete production.

4.Conservation of Natural Resources

Protect ecosystems, including riverbeds and forests, by reducing aggregate mining.

Encourage sustainable construction and responsible material usage

5.Structural Performance and Durability

Assess and enhance the mechanical properties of recycled aggregate concrete.

Optimize mix designs to maintain strength, workability, and longevity

6.Regulatory Support and Industry Adoption

Align with policies promoting sustainable building materials.

2. LITERATURE REVIEW

[1] Abdul Samee M. Halahla [2019], "Utilization of demolished waste as coarse aggregate in concrete":

In this research, the old concrete was crushed and used as aggregates to obtain new concrete. Different mechanical tests were carried out to measure and characterize the new recycled aggregate concrete. All the mechanical tests showed that recycled aggregate concrete has slightly lower values than the natural aggregate concrete. The old crushed concrete can be a good alternative to be used as an aggregate in new concrete.

[2] Mbereyaho Leopold [2018], "Reuse of construction and demolished concrete waste in producing strong and affordable concrete blocks":

The objective of this study was to assess the strength characteristics of concrete blocks made from construction and demolished (C&D) concrete waste after recycling and reusing them in fresh concrete. After laboratory testing of recycled concrete blocks, the compressive strength fell within the accepted range thereby the blocks can be used easily in building construction as per the study.

[3] Jay Surya, Dr.I. Padmanabhan, [2018], "Strength Studies on Recycled Aggregate Concrete with Partial Replacement of Cement by Using Fly ash":

This paper reports the strength properties of recycled aggregate concrete with partial replacement of cement by using fly ash with various proportions (10%,20%,30%) Similarly concrete properties like compressive strength, flexural strength, etc are studied and compared with normal aggregate concrete. From the experimental work carried out on "Recycled aggregate concrete with partial replacement of cement by using fly ash". The compressive strength of recycled aggregate concrete with 20% of fly ash has higher strength when compared to normal concrete and split tensile test shows that concrete has good tensile strength when replace up to 20-30%. The water absorption of (RAC) recycled aggregate concrete is high when compared to ordinary coarse aggregate concrete, therefore usage of RAC with addition of proper admixture will reduce water content and increase strength also.

[4] Anagha Kalpavalli [2015], "Use of demolished concrete waste as coarse aggregate in high strength concrete production":

In this research, various tests were done on concrete with replacement of natural coarse aggregates and on conventional concrete. The demolished waste was crushed to required size manually by using rammers and thoroughly washed to remove adhere present in the aggregate. Then soaked in the water for 24 hrs. to reduce the water absorption in concrete. Due to this, no additional water is required while mixing. It shows that the concrete replaced with more recycled aggregates will develop the least strength compared to the lesser replacement ratio concrete. But it can be seen that up to 30% replacement gives better results. Beyond this replacement, the strength acquired reduces gradually and does not cross the required tensile strength. Further, this also concludes that split tensile strength follows same trend.

[5] Prof. Dharmesh K. Bhagat, Jigar P. Parmar, Yati R. Tank, Darpan H. Gadhiya, Jigar S. Goyani, [2014], "Experimental Study of Compressive Strength of Recycled Aggregate Concrete":

In the present work, attempts have been made to assess the effect of recycled concrete aggregate on the strength of ordinary concrete. The basic engineering properties of Recycled Concrete Aggregate (RCA) is evaluated and it is compared with the Normal Aggregate (NA). Similarly, the basic concrete properties like, compressive strength, workability etc. are studied for the different combinations of RCA with NA. The goal of this study is to develop the economical and sustainable concrete by using the concrete waste available on the site. The results of compressive strength show that, the use of RCA up to 40% affect the functional requirements of concrete structure. Also, the result of slump test shows there is continuous decrease in workability of concrete mix, as the cement mortar paste is attached to RCA.

[6] Mohd Monish [2013], "Demolished waste as coarse aggregate in concrete":

This project carries out a comparison between conventional concrete and concrete with demolished waste as partial replacement of coarse aggregate. In this, demolished waste is partially replaced with coarse aggregate as 10%, 20%, 30% and compared with conventional concrete. It is observed that more water is required for producing the same workability. Water usage increases with increase in percentage of demolished waste. In conventional concrete, up to 30% replacement of coarse aggregate with recycled aggregate is acceptable. The compressive strength retention is in the range of 86.84%-94.74% as compared to conventional concrete. The recycled aggregates have more crushing and impact value than normal aggregates.

3. METHODOLOGY

a) Materials

- Cement (opc)
- Fine aggregate
- Recycled coarse aggregate
- Coarse aggregate
- Water

Cement: The Ordinary Portland Cement (OPC) used for casting all specimens conforms to the 53 Grade specification. The physical and chemical properties of this cement adhere to the standards outlined in IS: 12269-1987, ensuring compliance with the requisite quality and performance criteria

Physical Properties of Cement

Different blends of cement used in construction are characterized by their physical properties Some key parameters control the quality of cement. The physical properties of good cement are based on:

- Fineness of Cement
- Soundness
- Bulk density
- Consistency
- Strength
- Setting Time
- Heat of Hydration
- Specific Gravity (Relative density)

These physical properties are discussed in detail in the following segment. Also, you will find the test names associated with these physical properties.

TESTS ON CEMENT:

1.Standard Consistency of Cement

The standard consistency of a cement paste is defined as the percentage of water added In 300gm weight of cement which will permit a Vicat plunger having 50 mm length and 10 mm diameter to penetrate in cement paste to a depth of 33-35 mm from the top of the mould.

2. Setting Time of Cement

Initial setting time gives an idea about how fast cement can start losing its plasticity and the **final setting time of cement** gives an idea about how much cement takes to lose its full plasticity and gain some strength to resist pressure.

3.Fineness of Cement

The fineness of cement is a measure of cement particle size and is denoted as terms of the specific surface area of cement. The fineness test of cement is done by sieving cement sample through standard IS sieve.

Natural coarse aggregate: The coarse aggregate used consists of crushed stone chips, with a particle size range of 4.75 mm to 20 mm, conforming to the specifications outlined in IS: 383-1970.

Advantages of course aggregate

Strength & Durability

Coarse aggregate enhances the compressive strength of concrete, making it more durable and resistant to wear and tear.

Reduced Shrinkage

It helps minimize shrinkage and cracking in concrete by reducing the amount of cement paste required.

Cost Efficiency

Since coarse aggregate is cheaper than cement, it reduces the overall cost of construction materials.

Improved Workability

Properly graded coarse aggregate improves the workability of concrete, making it easier to mix, pour, and finish.

Better Load-Bearing Capacity

It distributes loads more effectively, providing stability and strength in roads, bridges, and buildings.

Permeability Control

The size and shape of coarse aggregates influence the permeability of concrete, which can be adjusted to meet specific construction needs.

Disadvantages of coarse aggregate

Reduced Workability

Larger coarse aggregates can make concrete less workable, requiring more water or admixtures to maintain consistency.

Segregation Issues:

If not properly graded, coarse aggregates can cause segregation in concrete, leading to uneven strength distribution.

Increased Void Content:

Poorly shaped or excessive coarse aggregate can create more voids, reducing the density and strength of concrete.

Potential for Weak Bonding:

If the aggregate surface is too smooth or dusty, it may not bond well with cement, reducing overall concrete strength.

Higher Weight:

Coarse aggregates increase the weight of concrete structures, which may not be ideal for lightweight construction needs.

Alkali-Silica Reaction (ASR):

Some types of coarse aggregate can react with cement, causing expansion and cracking over time.

Difficulty in Pumping Concrete:

Large-sized coarse aggregate may cause blockages in concrete pumps, making placement more challenging.

Variability in Quality:

If sourced from unreliable suppliers, coarse aggregate may contain impurities or inconsistent sizes, affecting concrete performance.

Recycled coarse aggregate: Recycled Aggregates refer to the crushed and processed remnants of cement concrete from construction and demolition debris, which are repurposed for use in new building projects. These aggregates are produced by demolishing and removing aged concrete from foundations, pavements, bridges, and buildings, then crushing and processing it into various size fractions for reuse.

Laboratory Testing of Physical Properties of Recycled coarse aggregate And Natural Aggregates:

The physical properties of coarse aggregates significantly influence the performance of concrete, affecting its workability, strength, and durability. To evaluate the suitability of recycled coarse aggregates (RCA) as a replacement for natural coarse aggregates (NCA), laboratory testing is essential. These tests assess critical characteristics such as particle size distribution, specific gravity, water absorption, density, and abrasion resistance. By comparing the results of RCA derived from crushed construction and demolition waste with those of NCA, typically sourced from quarries or riverbeds, this study aims to quantify their differences and determine the feasibility of RCA in concrete production.

1. Particle Size Distribution (Sieve Analysis)
2. Specific Gravity and Water Absorption
3. Bulk Density
4. Los Angeles Abrasion Test
5. Shape and Texture

Fine aggregate: The fine aggregate used in the concrete is natural sand, which conforms to Zone-III specifications as per IS: 383-1970. According to this standard, the sand zones are classified based on their fineness, with Zone-I being the course, Zone-IV being the finest, and Zone-II and Zone-III representing moderate gradations.

Advantages of fine aggregate:

Improved Workability:

Enhances the ease of mixing, placing, and finishing concrete or mortar.

Better Bonding:

Helps create a strong bond between cement and coarse aggregates, improving overall strength.

Uniform Texture:

Provides a smooth and consistent finish in concrete and plastering applications.

Reduced Voids:

Fills gaps between coarse aggregates, reducing air pockets and increasing density.

Cost-Effective:

More affordable than other filling materials, reducing overall construction costs.

Increased Strength:

Contributes to the compressive and tensile strength of concrete structures.

Disadvantages of fine aggregate:

Increased Water Demand:

Requires more water for mixing, which can affect the water-cement ratio and strength of concrete.

Shrinkage and Cracking:

Excessive fine aggregates can lead to higher shrinkage, increasing the risk of cracks in concrete.

Reduced Permeability:

Fine aggregates can make concrete less porous, which may trap moisture and lead to durability issues.

Segregation:

If not properly graded, fine aggregates can cause segregation, leading to weak zones in concrete.

Lower Strength if Overused:

A high proportion of fine aggregates can reduce the overall strength of concrete.

Dust Generation:

Some fine aggregates, especially those with high silt content, can generate excessive dust, affecting the working environment.

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Quality Variability:

Natural fine aggregates may contain impurities like clay, organic matter, or salts, which can weaken concrete.

Water potable: Tap water, which was examined and confirmed to be clean, particle-free, and fit for drinking, was used for mixing the concrete.

b) Mix Design

Mix Design is carried out in B.I.S Method (Bureau of Indian Standards) As per IS 10262:2009

MIX DESIGN PROCEDURE FOR THE CONCRETE OF GRADE M30:

1. Target strength:

f'ck = (fck+ks) or (fck+x)

fck = Target mean compressive strength at 28 days

K = 1.65

S = 5 N/mm2 standard deviation (IS-10262-2019, table-2 P. No:3)

X = factor based on grade of concrete as per table-1

X = 6.5 (IS-10262-209, Table -2 P. No:3)

f'ck1= 30+(1.65×5)

f'ck1= 38.25 N/mm^2

f'ck2= 30+6.5

f'ck= 36.5 N/mm^2

f'ck1 > f'ck2

38.25 > 36.5 N/mm2

f'ck= 38.25 N/mm2

Table: 3.1 Quantity of Material in Different Proportions per m3

M20 grade concrete	% Replacement				
	0%	**10%**	**20%**	**30%**	**40%**
Cement	437.78	437.78	437.78	437.78	437.78
Fine Aggregate	604	604	604	604	604
Coarse aggregate	1142	1027.8	913.6	799.4	685.2
Recycled concrete	0	114.2	228.4	342.6	456.8
Water	194	194	194	194	194

The ratio of the mix is 1:1.38:2.60 (Cement: fine aggregate: coarse aggregate).

4. RESULTS AND ANALYSIS

Tests on Concrete (before casting)

• Slump Test:

The most commonly used method for determining the workability of the concrete is slump cone test which can be done either in the field or in the laboratory. This method is not suitable if the concrete is very wet or very dry.

Table: 4.1 Slump value for different percentage replacements in M30 grade concrete

% Replacement	Slump Value
0%	110
10%	105
20%	98
30%	95
40%	84

Tests on Hardened Concrete

• COMPRESSION TEST

In order to determine the compressive strength of the hardened concrete one of the most commonly used test is compression test. This test is conducted on the hardened concrete blocks by applying the loads gradually.

Table: 4.2 Compressive strength of M30 grade concrete cubes after 7 days

Recycled coarse aggregate	grade	Compressive strength (N/mm^2)
0%	M30	20.38 N/mm^2
10%	M30	19.50 N/mm^2
20%	M30	18.73 N/mm^2
30%	M30	16.40 N/mm^2
40%	M30	12.43 N/mm^2

Table: 4.3 Compressive strength of M30 grade concrete cubes after 28 days

Recycled coarse aggregate	grade	Compressive strength (N/mm^2)
0%	M30	37.16 N/mm^2
10%	M30	36.63 N/mm^2
20%	M30	35.80 N/mm^2
30%	M30	34.43 N/mm^2
40%	M30	25.47N/mm^2

Figure: 4.1 collection of recycled aggregate

5. CONCLUSIONS

Based on the experimental work conducted, the following conclusions can be drawn:

The material testing revealed that Recycled Concrete Aggregates (RCA) exhibit:

- Lower specific gravity compared to Natural Aggregates (NA)
- Higher water absorption due to the presence of adhering mortar and cement paste, necessitating compensation during mix design
- Comparable bulk density to NA
- Lower impact and crushing values compared to NA

Additionally, the slump test results showed a significant decrease in workability with increasing percentages of RCA replacement. The compressive strength results indicate that the use of Recycled Concrete Aggregates (RCA) up to 40% replacement level does not significantly compromise the functional requirements of concrete structures. The slump test results, however, reveal a continuous decrease in workability of the concrete mix as the RCA replacement percentage increases, likely due to the attachment of cement mortar paste to the RCA. The study demonstrates that recycling and reusing building wastes is a viable solution to the environmental and economic challenges posed by the disposal of massive amounts of construction debris, particularly in the face of dwindling natural aggregate resources. The incorporation of RCA in concrete has been shown to be a technically, environmentally, and economically valuable approach, offering numerous benefits, including:

- Reduced disposal and landfilling costs
- Conservation of natural resources
- Production of sustainable concrete for construction applications

Overall, the use of RCA in concrete presents a promising strategy for promoting sustainability in the construction industry.

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2. IS-383-2016 (specification for materials)

3. IS-10262-2009 (concrete mix design)

4. IS-4031-1988 (Methods of Physical Tests for Hydraulic Cement)

5. IS-2386-1963 (Methods of Tests for Aggregates)