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Experimental Investigation of Recycled Concrete using Demolished Waste Materials

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ABSTRACT

The rapid growth of construction activities has increased the demand for natural aggregates and generated a large quantity of demolition waste. This study focuses on the utilization of recycled concrete aggregate (RCA) as a partial replacement of natural coarse aggregate in M30 grade concrete. Experimental investigation was carried out by replacing natural aggregate with RCA at 10%, 15%, and 20%. Compressive strength and split tensile strength tests were conducted at 7, 14, and 28 days. The results indicate that up to 30% replacement provides satisfactory performance with only a slight reduction in strength. The use of recycled aggregates helps in reducing environmental pollution and promotes sustainable construction practices.

1. INTRODUCTION

One of the most extensively used materials in construction is concrete because of its strength and resilience. But the extensive usage of natural aggregates results in the exhaustion of natural resources and environmental problems. On the other hand, demolition of the existing buildings gives rise to waste. Reusing the waste to form aggregates will be one way out of the problem. Recycled concrete aggregates (RCA) can act as a substitute to the natural aggregates in concrete. The current paper will try to analyze the strength characteristics of concrete that uses RCA in various replacement ratios.

2. LITERATURE REVIEW

Joseph (2023) conducted an extensive study on the utilization of recycled aggregates (RA) in concrete production. The research revealed that replacing natural aggregates with up to 30% recycled aggregates results in acceptable performance levels in concrete, maintaining strength and durability comparable to conventional concrete. The study also highlighted that the incorporation of chemical admixtures can significantly enhance the quality and workability of concrete containing recycled materials. These admixtures help mitigate issues related to water absorption and bonding, thereby improving overall concrete properties.

Marvila et al. (2022) investigated the structural performance of concrete with recycled concrete aggregates (RCA). Their research concluded that when RCA is used in limited quantities, there is only a minor reduction in compressive strength, which is acceptable for many structural applications. The findings advocate for the sustainable reuse of RCA, promoting environmentally responsible construction practices without significantly compromising structural integrity.

Alkhtbeeb (2025) analyzed the workability of concrete incorporating recycled aggregates. The study found that workability tends to decrease as the proportion of RCA increases, primarily due to the higher water absorption capacity of recycled materials. However, this issue can be effectively controlled by adjusting the water-cement ratio and incorporating superplasticizers or other admixtures into the mix design. Proper adjustments ensure that workability remains within desirable limits for practical applications.

Antunes (2025) highlighted the environmental advantages of using recycled aggregates, including the reduction of carbon emissions associated with the extraction and processing of virgin aggregates. The study also emphasized resource conservation, waste reduction, and landfill diversion as key benefits contributing to more sustainable construction practices.

Alibeigibeni (2025) addressed the challenges related to the quality and performance of recycled aggregates. The research recommended various pre-treatment methods, such as cleaning, crushing, and surface coating, to improve the physical and chemical properties of RCA. These treatments enhance the bond strength and durability of concrete made with recycled materials, ensuring long-term performance and compliance with standards.

Dafedar et al. (2024) extended the application of recycled aggregates beyond concrete, demonstrating that they can also be successfully used in masonry units. Their experiments showed that masonry blocks produced with recycled aggregates exhibit comparable compressive strength and durability to traditional fired clay bricks, suggesting that recycled aggregates can be a viable alternative in various construction components, thereby supporting sustainability and resource efficiency.

3. MATERIALS USED

The materials used in this experimental study were selected according to standard guidelines to achieve reliable and accurate results. All materials were tested before use.

A. Cement

The most widely used type of cement is Ordinary Portland Cement (OPC). Specifically, the 53-grade OPC, which complies with IS: 8112-1989 standards, is commonly employed. It acts as a fine adhesive and cohesive material that, when mixed with fine and coarse aggregates along with water, forms a paste. After curing for a designated period, this paste hardens into a solid mass of stone. Selecting the appropriate type of cement is crucial because the overall strength and durability of concrete largely depend on it. The properties of cement are shown in Table.

Table1: Properties of Cement

Property	Value
Grade	53 Grade
Specific Gravity	3.15
Initial Setting Time	30 minutes
Final Setting Time	600 minutes
Standard consistency	26%
Fineness Test	4%

B. Fine Aggregate

Fine aggregates primarily consist of sands obtained from land or marine sources. Typically, they are composed of natural sand or crushed stone, with the majority of particles passing through a 9.5mm sieve. Similar to coarse aggregates, fine aggregates can originate from primary, secondary, or recycled sources. The choice of fine aggregate is a crucial consideration, as it directly influences the concrete's strength and its water-cement ratio during mixing.

Table 2: Properties of Fine Aggregate.

Property	Value
Type	River Sand
Zone	Zone II
Specific Gravity	2.736%
Water Absorption	1.68%

C. Coarse Aggregate

Natural coarse aggregates of two sizes: 10 mm and 20 mm were used in this study. The aggregates were angular in shape and properly washed before use. A combination of both sizes was used to achieve better gradation and improved packing density.

Table 3: Properties of Coarse Aggregate.

Property	Value
Sizes Used	10 mm & 20 mm
Specific Gravity	2.865
Water Absorption	1.03%
Shape	Angular

Impact values test	8.7%

D. Recycled Concrete Aggregate (RCA)

Recycled concrete aggregate was obtained from demolished concrete waste. The waste material was crushed and sieved to obtain 10 mm and 20 mm sizes, similar to natural aggregates. RCA was used as a partial replacement of natural coarse aggregate in proportions of 20%, 30%, and 40%.

Table 4: Properties of RCA

Property	Value
Source	Demolished Concrete
Sizes Used	10 mm & 20 mm
Specific Gravity	2.40
Water Absorption	4.5%
Impact values test	9.3%

Figure 5: Recycled Concrete Aggregate

E. Water

Clean drinking water was used for mixing and curing of concrete. The water was free from harmful substances.Water is essential for hydration of cement and proper strength development.

4. MIX DESIGN

The concrete mix is designed as per IS: 10262 – 2009 and IS 456-2000 for the normal concrete. The grade of concrete adopted is M30 with a water cement ratio of 0.45. Replacement of NCA with RCA. The following points should be remembered before proportioning a concrete mix as per IS-10262-2009.

- This method of concrete mix proportioning is applicable only for ordinary and standard concrete grades.
- The air content in concrete is considered as nil.

The proportioning is carried out to achieve specified characteristic compressive strength at specified age, workability of fresh concrete and durability requirements.

Table 6: Mix Proportions Values

Ingredients	SSD Wt. (kg/m^3)	NMC	WA	Water Correction	Batch Weight After Correction	Batch Weight for 0.0343 m^3
Cementitious	380	—		—	—	—
Cement	380	—		—	380	12.92
20 mm	744	—		—	733	24.92
10 mm	476	—		—	476	16.18
River Sand	776	1.14	0.00	8.85	785	26.68
Free Water	158	1.44	0.00	2.28	160	5.45
Total Weight	2534	—		—	2534	86.16

Table7: Replacement Mix Proportions Values

Materials	Normal	10% Replacement + Demolished Waste		15% Replacement + Demolished Waste		20% Replacement + Demolished Waste	
Cement	12.92	12.92		12.92		12.92	
20 mm Aggregate	24.92	22.428	14.562	21.182	13.753	19.936	12.944
10 mm Aggregate	16.18	2.492	1.618	3.738	2.427	4.984	3.236
River Sand	26.68	26.68		26.68		26.68	
Free Water	5.45	5.45		5.45		5.45	
Total Water	5.37	5.37		5.37		5.37	
Total Weight	86.16	86.16		86.16		86.16	

5. EXPERIMENTAL METHODOLOGY

The study is carried out to investigate the use of demolished concrete waste as recycled aggregate in M30 grade concrete.

A. Material Collection

Cement (OPC 53 grade), sand, natural coarse aggregate, and demolished concrete waste are collected.

B. Processing of Waste

Demolished concrete is:

- Segregated (remove steel, impurities)
- Crushed
- Screened (10mm & 20 mm size)
- Cleaned and dried

C. Material Testing

All materials are tested for:

- Specific gravity
- Water absorption
- Sieve analysis, etc.

D. Mix Design

M30 concrete mix is prepared as per IS 10262. Recycled aggregate replaces natural aggregate at: 10%, 15%, 20%.

E. Mixing & Batching

Materials are weighed and mixed properly to get uniform concrete.

F. Workability Test

Slump test is conducted to check workability.

G. Casting of Specimens

- Cube moulds of size 150 mm × 150 mm × 150 mm were used for compressive strength.
- Cylindrical moulds of size 150 mm × 300 mm were used for Flexural strength.
- Concrete was placed in moulds in layers.
- Each layer was compacted using a tamping rod or vibrator.

Figure 8: Casting of Cube Specimens

H. Curing

After 24 hours of casting, specimens were removed from moulds and placed in a curing tank filled with water. Curing periods: 7 days, 14 days and 28 days

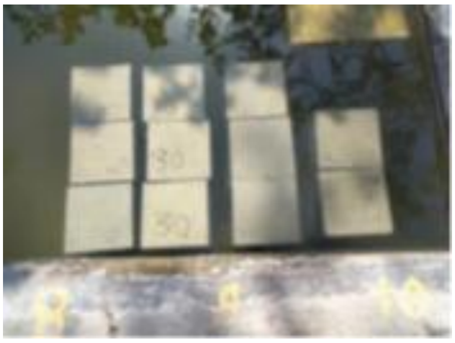

Figure 9: Curing of Cube Specimens

I. Testing

After curing, tests are conducted: Compressive strength and Flexural strength.

J. Analysis

Results are compared with normal concrete to find the best replacement percentage.

6. EXPERIMENTAL RESULTS

He results completed in the present investigation are reported in the form of tables and graphs for various percentage of recycled aggregate as a replacement to coarse aggregate. The Following are the percentages replacement of cement i.e. 10%, 15% and 20%.

A. Slump Cone Test

Slump test is used to determine the workability of fresh concrete. Slump test as per IS: 1199 – 1959 is followed. The apparatus used for doing slump test are Slump cone and tamping rod. The internal surface of the mould is thoroughly cleaned and applied with a light coat of oil. The mould is placed on a smooth, horizontal, rigid and non-absorbent surface. The mould is then filled in four layers with freshly mixed concrete, each approximately to one-fourth of the height of the mould. Each layer is tamped 25 times by the rounded end of the tamping rod. After the top layer is rodded, the concrete is struck off the level with a trowel.

Table10: SLUMP CONE TEST RESULT %

Replacement of Demolished Aggregate	Slump Value (mm)	Types of Slump	Workability
Normal Concrete	80	True slump	Medium
10%	75	True slump	Medium
15%	60	True slump	Medium
20%	40	True slump	Low

Figure11: Slump Cone Test

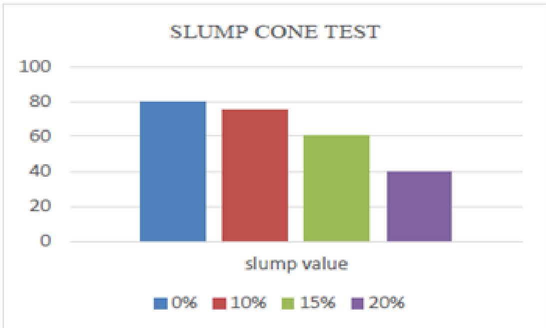

Figure 12: Slump Cone Test Results

B. Compressive Strength Test

Concrete cubes of 150mm size are tested for crushing strength using a compression testing machine after 7, 14, or 28 days of curing. The strength depends on factors like water-cement ratio, cement quality, material quality, and construction practices. During testing, load is applied gradually at 140 kg/cm^2 per minute until the specimen fails. The compressive strength is calculated by dividing the maximum load at failure by the area of the cube. The recorded maximum load and any unusual observations are included in the test report.

Table13: Compressive Strength Test Result

Mix Type	7 Days	14 Days	28 Days
0% (Normal)	22.5	27.8	33.5
10% RCA	21.8	26.9	32.8
15% RCA	20.9	25.7	31.6
20% RCA	19.5	24.2	29.8

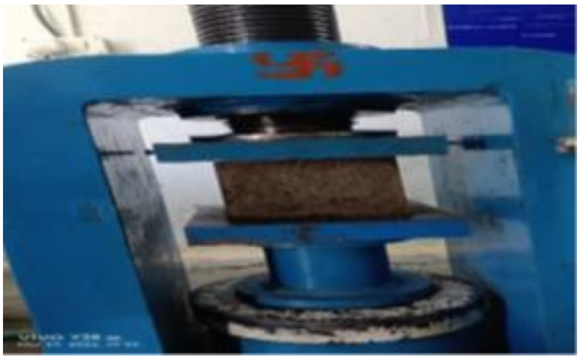

Figure14: Compressive Strength Test

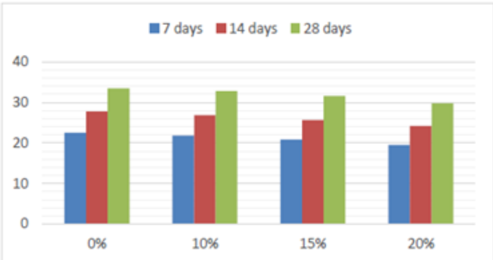

Figure15: Compressive Strength test results

C. Split Tensile Strength Test

Split tensile strength of concrete is a measure of its ability to resist tensile stresses, which are critical since concrete is weak in tension. It is determined by applying a load along the length of a cylindrical specimen placed horizontally until it cracks and splits. The split tensile strength is calculated usingthe formula:

$$Ft = \frac{2P}{\pi DL}$$

Where P is the ultimate load in kilonewtons (kN), D is the diameter of the cylinder and L is its length. This test helps assess the tensile capacity of concrete and its tendency to crack under tensile forces.

Table16: SPLIT TENSILE STRENGTH TEST RESULT

Mix Type	7 Days	14 Days	28 Days
0%	2.2	2.8	3.5
10%	2.1	2.7	3.3
15%	2.0	2.5	3.1
20%	1.8	2.3	2.9

Figure 17: Split Tensile Strength Testing Machine.

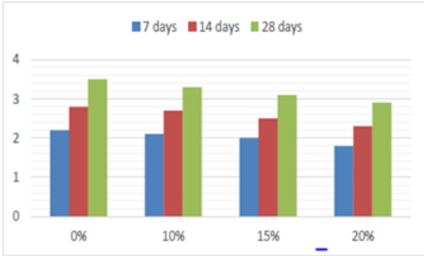

Figure18: Split Tensile Strength test results

CONCLUSIONS

- Reccled concrete aggregate can be used up to 30% replacement.
- Strength reduction is minimal up to this level.
- 20% replacement gives best performance.
- RCA helps in:
- Reducing construction waste.
- Saving natural resources.
- Promoting sustainable construction.

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