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UTILIZATION OF DEMOLISHED CONCRETE WASTE FOR NEW CONSTRUCTION

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ABSTRACT

Large quantities of new construction for infrastructure development and significant amounts of concrete demolition waste are generated in India every year. The disposal of demolition waste is a serious issue as it requires substantial space. In current construction practices, only a small portion of demolished waste is reused or recycled, typically using traditional methods. Numerous structures worldwide need to be demolished for various reasons, such as reaching the end of their expected lifespan, being replaced by new investments, or failing to meet local and international standards.

This paper focuses on the feasibility of using construction waste aggregate to produce new green concrete. For making an M-25 grade mix, IS Code 10262-2019 was followed. The scope of the study extends to exploring engineering applications. Various standard tests were conducted on recycled aggregate, including water absorption, sieve analysis, impact value, abrasion value, crushing value, workability, and compressive strength of mixes using 150 mm standard cubes.

The study suggests the use of alternative materials, such as demolished or recycled waste, for new construction to address challenges associated with debris, dust, and rubbish. Tests were conducted with 0%, 25%, 50%, 75%, and 100% replacement of fresh aggregate with recycled aggregate to determine physical and mechanical properties. The introduction of sustainable practices in the construction industry aims to better manage natural resources, addressing the growing demands of modern construction and minimizing waste. Construction industries, being significant consumers of natural resources, must adopt sustainable concepts to ensure a better future.

Keywords: Demolition Concrete, Concrete, Solid Waste Application, Slump Value, Compression Strength, Flexural Strength.

1. INTRODUCTION

The growing concern for environmental protection and the promotion of sustainable development principles have prompted some governments to introduce legislation encouraging the use of recycled aggregates. One approach is to lower the selling price of recycled aggregates compared to natural aggregates, often achieved by increasing landfill costs.

Demolition sites and restoration projects generate large amounts of solid waste, which is often used as mere landfill. Additionally, building practices frequently mix reusable materials with rubble, stone, and soil, reducing their value and making recycling difficult or uneconomical. Consequently, this waste material is often relegated to use as infill for construction work or as landfill.

Recycling building waste as aggregates is a modern approach to preventing environmental pollution by reducing waste stocks and decreasing reliance on natural aggregates. This practice not only helps manage solid waste more effectively but also supports sustainable construction practices by addressing the environmental and economic challenges associated with the use of natural resources.

On the other hand, it is possible to selectively demolish a building if it is an intentional act, allowing for the reuse of most building materials and components and the recycling of a significant portion of the rubble. According to [1], investigations on the composition of demolition waste in the Netherlands revealed that 20% of the wood, 90% of the steel, and 100% of other metals like zinc, lead, and copper can be removed from the structure, leaving behind the following composition of building waste:

- Brickwork: 62%
- Concrete rubble: 24%
- Brick rubble: 6.1%
- Tiles: 2.3%
- Bituminous materials: 0.2%
- Wood: 4.7%
- Scrap steel: 0.1%
- Other: 0.6%
- **Total:** 100%
-

Although the volume of demolition waste is enormous, much of it is inert and can be crushed, processed, and reused as aggregate in building works. However, significant amounts still end up as landfill rather than being recycled. Waste containing half-used paint pots, discarded solutions, solvents, and chemicals are potentially hazardous. Additionally, building waste likely contaminated with asbestos must also be treated as dangerous.

It has been established that materials and components recovered from demolished buildings are reused for new construction works and renovation projects, especially by low-income communities in developing countries. Interestingly, materials that were previously considered unsuitable for reuse have gained prominence in the market following the recent global economic crisis. For instance, steel reinforcement from demolished buildings, which was traditionally recycled back into steel, is now being directly reused as a building material. Demolition contractors have also started prioritizing the recovery and sorting of materials for new construction, with an emphasis on proper storage and display of recovered materials.

Rapid industrial development has introduced global challenges, such as the depletion of natural aggregates and the generation of enormous amounts of waste materials from construction and demolition activities. One effective solution to these problems is to utilize recycled aggregates in new construction concrete components.

Literature Review

Over recent years, the recycling potential of construction and demolition waste (CDW) has become a focal point of waste management policies, emphasizing minimization. The development of recycled aggregate concrete (RAC) has been recognized as an efficient way of recycling waste concrete, significantly contributing to sustainable development in the construction industry [1, 2]. To make RAC a widely accepted structural material, comprehensive experimental research has been conducted.

Regarding RAC strength, the experimental results of Bairagi et al. [3] and Olorunsogo [4] show that the compressive strength of RAC decreases as the percentage of recycled aggregate (RA) increases. Comprehensive analyses of test results from various scholars, including Wesche and Schulz [5], confirm these findings.

Reports indicate that the amount of concrete demolished annually in European countries and the United States is about 50–60 million tons, respectively [6, 7]. However, very little demolished concrete is currently recycled in these countries. In India, demolished concrete is not even used as a stabilized base or sub-base in highway construction and is instead discarded as fill material. It is high time to seriously consider reusing demolished concrete for producing recycled concrete in countries like India and Saudi Arabia [8]. Recycling would not only conserve resources but also promote the safe and economic use of such materials, which is urgently needed in developing economies.

It has been established that materials and components recovered from demolished buildings are being reused for new construction works as well as renovation projects, particularly by low-income communities in developing countries. Materials that were previously considered unsuitable for reuse have gained market prominence after the recent global economic crisis. For instance, steel reinforcement from demolished buildings, which was traditionally recycled back into steel, is now being reused directly as a building material. Demolition contractors are increasingly recognizing the feasibility of recovering as much material as possible for new construction. As a result, they are placing significant emphasis on the proper sorting, storage, and display of salvaged materials.

Rapid industrial development poses serious challenges globally, including the depletion of natural aggregates and the generation of enormous amounts of waste materials from construction and demolition activities. One effective solution to these challenges is the utilization of recycled aggregates in new concrete components.

In recent years, the recycling potential of construction and demolition waste (CDW) has become a key focus of waste management policies aimed at minimizing waste. The development of recycled aggregate concrete (RAC) has been identified as an efficient way to recycle waste concrete and significantly contribute to sustainable development in the construction industry [1, 2]. Comprehensive experimental research has been conducted to make RAC a widely accepted structural material.

Research indicates that the compressive strength of RAC decreases with an increase in recycled aggregate (RA) content, as demonstrated by Bairagi et al. [3] and Olorunsogo [4]. A review of test results by Wesche and Schulz [5] supports these findings. Reports also reveal that approximately 50–60 million tons of concrete are demolished annually in European countries and the United States, respectively [6, 7]. However, very little of this demolished concrete is recycled. In India, for example, demolished concrete is not even used as a stabilized base or sub-base in highway construction and is instead dumped as fill. It is high time to consider reusing demolished concrete for the production of recycled concrete, especially in countries like India and Saudi Arabia, where this could conserve resources and promote safe, economic practices.

Research indicates promising results for using recycled concrete in pavement construction, although limitations remain for its use in structural applications. Comprehensive research is ongoing to address these limitations and establish guidelines for the safe and economical use of recycled concrete in the future. Experimental studies from the 1980s [9, 10] and more recent research in the United States [11] highlight the extensive use of aggregates, with 60–70% being used in structural concrete, 10–15% in pavements, and 20–30% in road construction and maintenance. Recycled aggregate production in the U.S. is carried out by natural aggregate producers (50%), contractors (36%), and debris recycling centers (14%).

Recycling Technologies and Practices

In several countries, advanced technologies for recycling concrete waste have been developed, and recycling specifications have been established [12, 13, 14]. Practical recycling of waste concrete requires further breaking and crushing of demolished concrete. Typically, two grades of crushed concrete aggregates are produced and classified by size gradation:

1. **Coarse Recycled Concrete Aggregates:** These can be used in new concrete or as road base materials.
2. **Fine Recycled Concrete Aggregates or Recycled Mortar:** These are smaller than 5 mm in size and are discussed in various studies for valuation and application [15, 16, 17, 18, 19].

In India, very little demolished concrete is currently recycled, and it is often discarded as fill. There is an urgent need to rethink this practice and adopt recycling methods for producing recycled concrete. Recycling not only conserves resources but also ensures safe and economical use of concrete, which is critical for countries like India and Saudi Arabia.

2. Remark Based on Literature Survey

Concrete recycling is emerging as one of the most critical components for construction sustainability. Concrete composed of binders, additives, and aggregates can be reused as raw materials for cement after hardening. Concrete incorporating waste products as aggregate is often referred to as "Green" concrete. This study focuses on the feasibility of using construction waste aggregate for producing new green concrete.

Various standard tests were performed on recycled aggregates, including water absorption, sieve

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analysis, impact value, abrasion value, crushing value, workability, and compressive strength using 150 mm standard cubes. The study highlights the potential use of alternative materials (demolished or recycled waste) in new construction, replacing conventional materials plagued with debris, dust, and rubbish.

Tests were conducted with 0%, 25%, 50%, 75%, and 100% replacement of fresh aggregate with recycled aggregate to evaluate physical and mechanical properties. Key findings include:

- **Water Absorption:** Water absorption increases from 1.5% (100% fresh aggregate) to 4.6% (100% dismantled aggregate), indicating a higher water-cement ratio requirement for mixes with large percentages of recycled aggregates.
- **Crushing Value:** The crushing value increases with higher recycled aggregate content. According to Indian Roads Congress and IS standards, the crushing value should not exceed 30% for concrete pavements and 45% for other types of concrete.
- **Impact Value:** Impact value tests permit only 20% replacement by dismantled aggregate for roller-compacted concrete pavements.
- **Abrasion Value:** Replacement up to 30% is permitted for roller-compacted concrete pavements based on abrasion tests.
- **Compressive Strength:** At a water-cement ratio of 0.6, replacing 75% of fresh aggregate with recycled aggregate improves compressive strength by 26.75%, although slump decreases to two-thirds of its original value. Increasing the water-cement ratio to 0.625 boosts slump from 21 mm to 60 mm while enhancing compressive strength by 12.68%.
- For M15 and M20 mixes at a water-cement ratio of 0.65, replacing 75% fresh aggregate with recycled aggregate increases compressive strength by 40%, although slump decreases by half (from 20 mm to 10 mm).

The use of dismantled aggregate in fresh concrete production reduces solid waste and landfill usage. Reusing demolished concrete also improves the environmental quality of regions by reducing mining activity and air pollution.

3. Materials and Experiment

Portland Pozzolana Cement (PPC) conforming to IS 1489 (Part 1), with an apparent density of 395 kg/m³, was used for this investigation. Natural river sand with a fineness modulus suitable for M25 mix, maximum grain size of 20 mm, and an apparent density of 1239 kg/m³ was utilized. According to IS 10262:2019:

- **Minimum Cement Content:** 300 kg/m³.
- **Water-Cement Ratio:** The free water-cement ratio for a target strength of 31.60 N/mm² is 0.4 for PPC 43 Grade. This value is lower than the maximum permissible value of 0.5 for reinforced concrete as prescribed by IS 456:2000 (Table 5).
- **Free Water Content:** 158 kg/m³.
- **Fine Aggregate Density:** 158 kg/m³.

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These parameters were adopted for the experimental investigation to ensure optimal mix design and strength characteristics.

4. Test Data for Materials

Material Properties

- **Specific Gravity of Cement:** 3.14
- **Specific Gravity of Fine Aggregate:** 2.64
- **Specific Gravity of Coarse Aggregate:** 2.74

Manufacturing Process of Recycled Concrete Blocks

The manufacturing process of recycled concrete blocks involved the following steps:

1. **Mixing and Compaction:**
   - The entire mixture was subjected to a mechanical compaction machine to enhance the load-bearing capacity and aesthetics of the blocks.
2. **Initial Curing:**
   - The newly manufactured blocks were covered with a plastic sheet for **24 hours** to prevent rapid hardening.
3. **Water Curing:**
   - After the initial curing, the blocks were immersed in water for **26 days** for proper curing.
4. **Surface Drying:**
   - Following water curing, the blocks were removed and left to surface dry for **one day** before testing.

Preparation of Recycled Concrete Materials

1. **Collection and Processing:**
   - Concrete waste was procured from a demolished site and transported to a processing facility.
   - The waste was **crushed**, **segregated**, and subjected to several laboratory tests.
2. **Laboratory Tests Conducted:**
   - **Water Absorption**
   - **Sieve Analysis**
   - **Crushing Value Test**
   - **Impact Value Test**
   - **Abrasion Test**
   - **Workability Test**
   - **Compressive Strength Test**
3. **Fine Aggregate Fitness:**
   - The demolished waste was sieved through a set of IS sieves to obtain a fitness level

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suitable for use as fine aggregate.

Experimental Procedure

1. **Mix Design:**
   - To study the effect of partial replacement of demolished waste in fresh concrete, two nominal mixes (M15 & M20) were prepared:
     - M15 (1:2:4 ratio)
     - M20 (1:1.5:3 ratio)
2. **Casting and Testing:**
   - A total of **180 cubes** (150 mm size) were cast in the laboratory using fresh and demolished coarse aggregate with replacement percentages of **0%, 25%, 50%, 75%, and 100%**.
   - **Ordinary Portland Cement (53 grade)** and **locally available coarse sand** were used for both mixes.
   - **Locally available crushed stone aggregate** (size: 4.75 to 20 mm) was used as coarse aggregate.
3. **Curing:**
   - The cubes were cured in potable water and tested for compressive strength at **7 days** and **28 days**.
4. **Water-Cement Ratios:**
   - The following water-cement ratios were used for the study:
     - **0.60**
     - **0.625**
     - **0.65**

Objective of the Study

The experimental work aimed to compare the strength of concrete by replacing fresh coarse aggregate with demolished waste aggregate at varying replacement levels. The results from the study provide insights into the feasibility and effectiveness of incorporating demolished waste into fresh concrete mixes to improve sustainability and reduce waste.

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Fig 1 sample of Aggregate

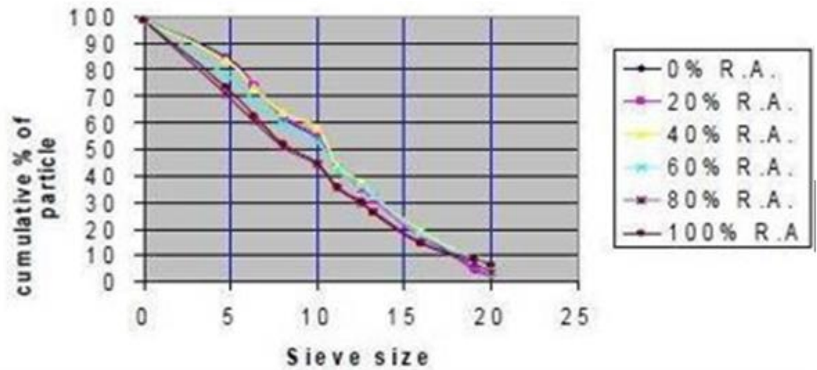

Fig 2 size vs cumulative % of particles.

4.1 Water Absorption

The results of water absorption capacity of aggregates at different replacement percentages indicate that recycled aggregates have a higher water absorption capacity compared to conventional aggregates. This is primarily due to the presence of old mortar adhered to the original aggregate particles. The porosity of the adhered mortar allows water to penetrate into accessible pores, resulting in a higher water absorption capacity compared to fresh aggregates.

Table 1: Water Absorption of Recycled & Fresh Aggregates

S. No.	Material	Observed Value (%)
1	0% Recycled Aggregate	1.50
2	25% Recycled Aggregate	2.05
3	50% Recycled Aggregate	2.87
4	75% Recycled Aggregate	3.40
5	100% Recycled Aggregate	4.60

4.2 Aggregate Crushing Value Test

The **Aggregate Crushing Value Test** provides a relative measure of the resistance of coarse aggregates to crushing under gradually applied compressive load. The aggregate crushing value is expressed as the percentage by weight of crushed material obtained under standard test conditions. It is a numerical index of aggregate strength and is particularly significant in the construction of roads and pavements.

- Aggregates with **lower crushing values** are preferred for roads and pavements as they exhibit better resistance under load and provide longer service life with more economical performance.
- A crushing value of **30% or higher** may indicate anomalies, and in such cases, the ten percent fines value should be determined instead.
- Strong aggregates are essential to withstand crushing under roller and traffic loads for the

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construction of roads and pavements.

4.3 Workability

During specimen casting, the **slump test** is carried out to determine the workability of different mixes. Fresh concrete generally exhibits higher slump values. However, as the percentage of demolished waste increases in the concrete mix, the slump value decreases.

This reduction in workability is attributed to the large amount of old mortar adhered to the recycled aggregates, which absorbs more water. To maintain the same slump value, a **higher water-cement ratio** is required for mixes with higher percentages of recycled aggregates.

- **Observation:** The decreasing slump value indicates the necessity of adjusting water content to ensure sufficient workability for concrete mixes with recycled aggregates.

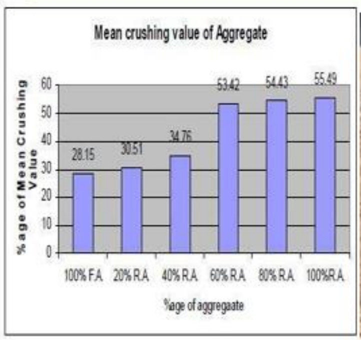

Fig 3 %age of aggeregate vs %age of Test mean crushing value.

Fig 4 Casting Cube

Fig 5 Compression

Fresh Behavior and Compressive Strength of Concrete

Fresh Behavior of Concrete

The fresh behavior of concrete was assessed by conducting **slump tests** to evaluate the workability of different mixes.

- **Compressive Strength Tests** were carried out on cube specimens to determine the strength of the concrete.
- **Splitting Tensile Strength Tests** were performed on cylinder specimens to establish the stress–strain relationship of the concrete.
- **Stress–Strain Relationship:**
  The stress–strain response of concrete under axial compression was evaluated by observing the behavior of specimens from initial cracking to final failure. Stress and corresponding strain values were recorded and plotted as a curve, illustrating the deformation behavior of concrete before and after failure.
  - This relationship highlighted the effect of the addition of **MPW** (Material from Processed Waste) on deformation behavior.

4.4 Compressive Strength of Concrete

The **compressive strength test** was carried out using **150 mm concrete cubes** on a **Universal Testing Machine (UTM)** or a **Compressive Testing Machine**. The procedure and conditions for testing included:

1. **Temperature Conditions:**

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- o All materials were stored and maintained at an approximate temperature of **27 ± 3°C** before testing.

2. **Mixing and Preparation:**
   - o Cement was uniformly mixed with a trowel to ensure no lumps were present.
   - o Concrete was mixed in a **high-capacity tilting drum mixer** to ensure uniformity.
3. **Specimen Testing:**
   - o At least **3 specimens** from different batches were tested.
   - o The **mean compressive strength** of the specimens was calculated to determine the actual strength of each batch.
   - o A total of **180 specimens** were prepared:
     - ▪ **M15 and M20 mixes** (1:2:4 & 1:1.5:3 ratios) were used.
     - ▪ Water-cement ratios: **0.60, 0.625, and 0.65** were considered for testing.
     - ▪ Five sets of cubes were cast, replacing fresh aggregate with demolished waste at the following proportions: **0%, 25%, 50%, 75%, and 100% by weight.**
     - ▪ A **0% demolished waste mix** indicates that only fresh aggregate was used in the mix.
4. **Curing Process:**
   - o Specimens were **demoulded after 24 hours** and placed in water for curing to ensure proper hydration and strength development.

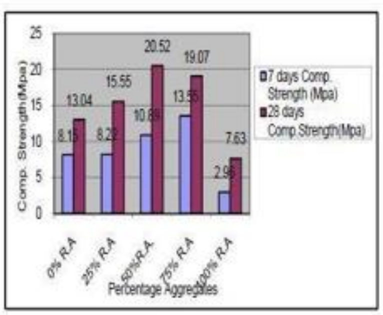

Fig 6 %of Aggregate vs Compressive Compressive strength

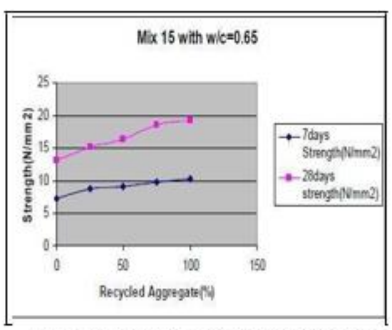

Fig 7 %of Recycle Aggregate vs Compressive strength w/c=0.65

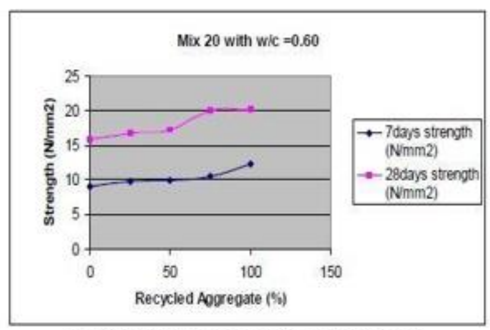

Fig 8 %of Recycle Aggregate vs strength w/c=0.60

5. Conclusion

Concrete recycling is poised to become one of the most critical components for achieving construction sustainability. Concrete, in which binders, additives, and aggregates are made from cement or cement-based materials, can be reused as raw materials after hardening. Concrete containing waste products as aggregates is often referred to as **"Green" concrete**.

This study focused on the feasibility of utilizing construction waste aggregates to create new green concrete. Various standard tests were conducted on recycled aggregates, including water absorption, sieve analysis, impact value, abrasion value, crushing value, workability, and compressive strength tests using 150 mm standard cubes.

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The tests involved replacing fresh aggregates with recycled aggregates at varying percentages (0%, 25%, 50%, 75%, and 100%). Based on the observations, the following conclusions are drawn:

1. **Water Absorption:**
   - Water absorption increased from **1.5% (100% fresh aggregate)** to **4.6% (100% recycled aggregate)**, indicating a higher water-cement (w/c) ratio requirement for mixes with higher recycled aggregate content. This was supplemented by slump test observations.
2. **Crushing Value:**
   - Higher percentages of recycled aggregates increased the crushing value of aggregates.
   - According to IS standards, the **aggregate crushing value** should not exceed **30%** for cement concrete pavements and **45%** for other types of concrete.
3. **Impact Value:**
   - Impact value tests showed that only **20% replacement** with recycled aggregates is permissible for roller-compacted concrete pavement construction.
   - Abrasion tests allowed up to **30% replacement** for concrete in roller-compacted pavements.
4. **Compressive Strength & Workability:**
   - At a w/c ratio of **0.60**, replacing **75% of fresh aggregates** with recycled aggregates increased compressive strength by **26.75%**, although slump decreased to **two-thirds of its original value**.
   - Increasing the w/c ratio to **0.625** increased slump from **21 mm to 60 mm** and enhanced compressive strength by **12.68%**.
   - For a w/c ratio of **0.65**, replacing 75% fresh aggregates with recycled aggregates in **M15 and M20 mixes** increased compressive strength by **40%**, but slump reduced to **half (20 mm to 10 mm)**.
5. **Environmental Benefits:**
   - Using recycled aggregates reduces the dumping of solid waste on existing and fill sites.
   - Reuse of dismantled concrete minimizes environmental damage by reducing:
     - Mining activities.
     - Dust pollution during aggregate production.
     - Vehicular pollution caused by transporting aggregates from mining sites.
6. **Economic and Sustainable Benefits:**
   - The study demonstrates that dismantled concrete is not a waste material but a valuable resource that can be recycled to produce fresh concrete.
   - This approach saves cement, reduces costs, and contributes to eco-friendly construction practices.

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