# A Comprehensive Review of Utilization of Construction and Demolition Waste as Fine Aggregate in Concrete

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**Abstract.** *In the dynamic landscape of the Asian region, particularly in India, a lot* of *waste is produced through construction and demolition operations, such as masonry dust and concrete debris. Growing interest in recycling and reusing these materials has arisen in response to environmental concerns around trash disposal. One possible way to repurpose this material is to utilize Construction and Demolition Waste (CDW) as a fine aggregate in concrete. Most researchers studying natural fine aggregate and its properties also study query dust as a fine aggregate but very little research work for fine aggregate produced from CDW. This review paper intends to offer a thorough analysis of the literature in this area, emphasizing the components and mechanical characteristics of concrete containing CDW. The review begins by discussing the sources and composition of C&D waste, highlighting the diverse range of materials that can be repurposed, including crushed concrete, brick, ceramic, and asphalt. Various techniques for processing and preparing C&D waste for incorporation into concrete are explored, emphasizing the importance of proper sorting, cleaning, and size reduction to ensure compatibility and quality. Furthermore, this research evaluates the mechanical, durability, and sustainability aspects of concrete containing C&D waste as fine aggregate. Studies indicate that while including C&D waste may slightly reduce compressive strength, it often enhances flexural strength and mitigates the adverse effects of shrinkage and cracking. Additionally, concrete with C&D waste exhibits comparable or even superior durability performance, attributed to the pozzolanic and filler impact of the recycled materials.*

## Keywords:

fine aggregates, construction demolition waste, dismantled building components.

## 1. Introduction

The construction industry stands as a vital driver of contemporary infrastructure development, fostering economic expansion and urban expansion. Nonetheless, this industry produces substantial waste, with construction and demolition activities constituting a significant portion of the global waste stream [1]. Consequently, there's an increasing urgency to adopt sustainable construction techniques aimed at waste reduction, natural resource preservation, and minimizing the environmental impact of construction projects. An encouraging approach toward realizing sustainability objectives involves the integration of Construction and Demolition Waste (CDW) as a fine aggregate in concrete. Concrete, one of the most widely used construction materials globally, traditionally relies on natural aggregates like sand and gravel. However, the extraction and processing of these natural materials come at substantial environmental expenses, encompassing habitat degradation, energy consumption, and carbon emissions. Moreover, the dwindling availability of these finite resources raises concerns about their long-term viability. In contrast, CDW encompasses diverse materials such as concrete debris, bricks, tiles, and ceramics, representing an underexplored resource with considerable potential for recycling. When meticulously processed and integrated into concrete mixes, CDW presents an environmentally friendly substitute to traditional aggregates, providing a multitude of benefits including environmental preservation, waste reduction, resource efficiency, and cost-effectiveness [2].

The exploration of CDW's application as a concrete aggregate encompasses various facets of this pioneering practice. This research delves into environmental advantages, technical implementation, potential obstacles, and the dynamic landscape of regulations and standards. It also mirrors the growing enthusiasm within the construction industry for adopting greener and safer methodologies [3].

**Fig. 1** Steel slag and recycled concrete aggregate

In this comprehensive guide, we will explore the fundamentals, methodologies, and prospects for incorporating CDW into concrete, unlocking its potential to transform construction practices in addition to conducting a higher sustainability and circular economy. As the construction industry strives to balance growth with environmental responsibility, incorporating CDW into concrete is emerging as an effective solution that holds the promise of reducing waste, saving resources, and leaving a smaller ecological footprint [4].

The development and demolition enterprise, while fundamental to financial improvement, additionally bears the doubtful distinction of being a massive contributor to environmental degradation and useful resource depletion. One of the most urgently demanding situations inside this region is the technology of full-size quantities of waste, called construction and Demolition Waste (CDW). CDW commonly consists of a wide range of materials, which includes concrete rubble, bricks, tiles, and wood, frequently ending up in landfills, posing an excessive burden on the surroundings. however, the want for revolutionary, sustainable, and resource-green creation practices has sparked a wave of research and exploration into the capability of utilizing CDW as the best combination in concrete manufacturing [5].

This exercise seeks to cope with several key problems simultaneously. First and foremost, it addresses the exponential increase of CDW with the aid of remodeling it from waste right into a precious resource. Second, it contributes to the conservation of natural resources, as the usage of CDW in concrete can lessen the call for classic, non-renewable high-quality aggregates. Third, this method can lower carbon emissions, as it circumvents the want to extract, procedure, and ship virgin aggregates. In essence, the integration of CDW into concrete aligns with the principles of sustainability and the circular financial system, offering a promising pathway in the direction of a greater sustainability and accountable production industry [6].

This introduction sets the degree for a more in-depth exploration of the usage of construction along with Demolition Waste as a satisfactory combination in concrete. It highlights the importance of this subject inside the context of sustainable creation and waste management and provides an outline of the key issues, possibilities, and demanding situations that this progressive technique addresses [7],[8]. In the next sections, we delve into the properties of CDW, its impact on concrete, the environmental blessings, and the want for standards and regulations, aiming to offer a comprehensive know-how of the topic[8].

### *1.1 Background*

The amount of construction and demolition (C&D) waste generated in Hong Kong exceeded 20 million tonnes in 2004. For continuous and permanent development projects, the non-reactive components of these C&D materials, such as soil, rocks, and concrete, were effectively repurposed as filler. Still, a great deal of land reclamation projects has been delayed or significantly scaled back because of public awareness of environmental issues [10]. The amount of space available for public filing to hold the extra C&D materials has significantly decreased because of this change. Ineffective handling of these materials may hasten the exhaustion of Hong Kong's limited landfill area. As a result, Hong Kong is currently having trouble handling these excess materials [11]. The amount of construction and demolition (C&D) waste generated in Hong Kong exceeded 20 million tonnes in 2004. For continuous and permanent development projects, the non-reactive components of these C&D materials, such as soil, rocks, and concrete, were effectively repurposed as filler. Still, a great deal of land reclamation projects has been delayed or significantly scaled back because of public awareness of environmental issues. The amount of space available for public filing to hold the extra C&D materials has significantly decreased because of this change. Ineffective handling of these materials may hasten the exhaustion of Hong Kong's limited landfill area [12]. As a result, Hong Kong is currently having trouble handling these excess materials.

As of 2014, a total of 137 million tons of crushed rock aggregate, commonly referred to as primary or natural aggregates, were extracted and marketed in England and Wales. These primary aggregates were utilized in various applications, including the production of concrete, road construction, railway ballast, and drainage systems.

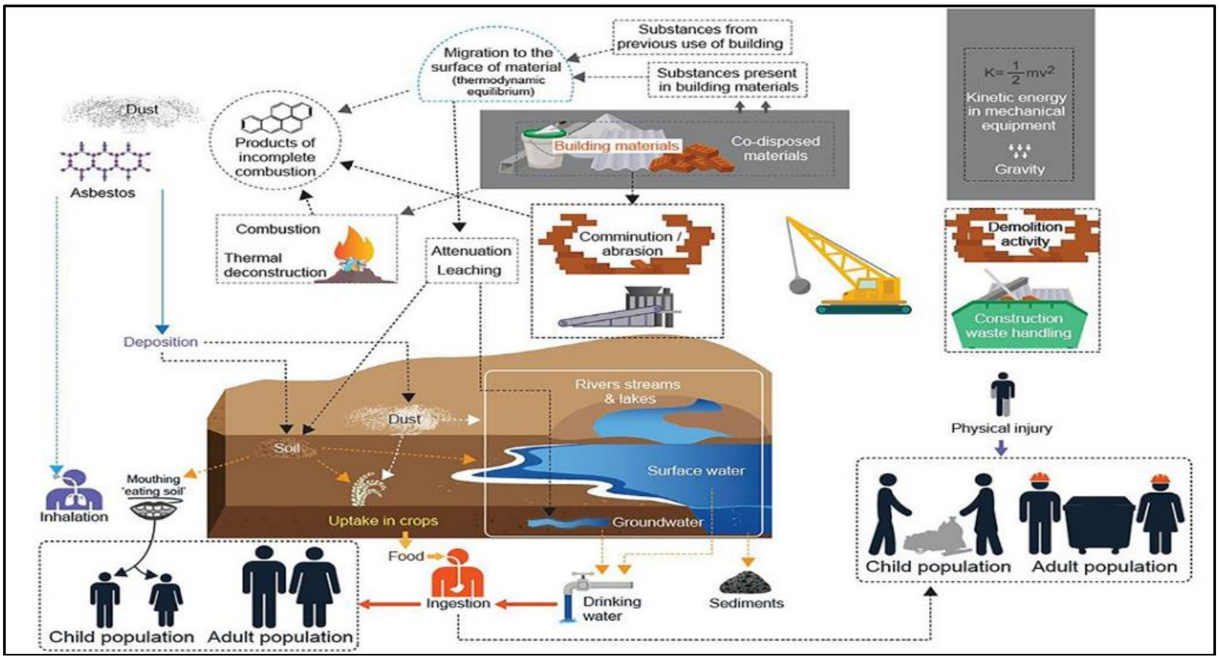


**Fig. 2** Life cycle of construction demolition waste[9] [Reprinted from Construction and Demolition Waste Management: A Systematic Scoping Review of Risks to Occupational and Public Health, Frontiers in Sustainability, Author: Cook E, Velis C, Black L, 10.3389/frsus.2022.924926, 2022]


**Fig. 3** Construction and demolition waste management

These quality requirements are equally applicable to recycled aggregates sourced from Construction and Demolition (C&D) waste. Therefore, it is crucial to conduct rigorous quality testing when considering the substitution of natural aggregates with C&D waste materials. C&D waste encompasses a range of materials, including concrete, ceramics/bricks, soil, and potential contaminants like gypsum/plaster, glass, wood, bituminous materials, metals, or plastics. The quality of C&D waste can fluctuate depending on the composition and proportion of these waste types, and if impurities exceed 1%, it could jeopardize the evaluation [13].

Recognizing the variability and inconsistent performance of source materials, research efforts have been undertaken to establish a classification system for recycled aggregates. This classification system allows for the categorization of recycled aggregates based on their suitability for specific applications compared to primary aggregates [14]. Present research primarily concentrates on evaluating the properties of recycled aggregates in specific application areas, such as concrete construction. Nevertheless, limited research has been conducted on cost-effective methods for assessing the suitability of C&D waste in various application domains, particularly through parametric sensitivity analysis [15].

A comprehensive review of existing studies related to aggregate assessment processes reveals a lack of standardization and consistency. The procedures in use differ in terms of the properties being tested (typically physical, mechanical, and chemical properties) and the resulting classification scales (ranging from A-C to A-G). Notably, the more complex the processes involved, the more resource-intensive they become, both in terms of time and cost. Therefore, the principal aim of this research is to identify a set of simplified process criteria that can be efficiently employed to assess aggregate quality straightforwardly and cost-effectively [16].

Furthermore, extensive research has been conducted on the recycling of concrete, brick debris, and other waste materials originating from construction and demolition activities. These studies have demonstrated the possibility of incorporating waste from construction and demolition (C&D) into structural concrete and other applications that call for aggregates with the right mechanical and physical characteristics [17],[18]. Waste materials are typically obtained from fixed facilities or processed in controlled laboratory environments for these types of research projects. Unfortunately, the use of fixed facilities is not financially feasible in many Southern Italian regions that are known for their low population density.

Furthermore, recycling C&D waste is not actively promoted because of several factors, such as the abundance of both legal and illegal quarries and the low cost of natural aggregates. The information shown in Table 1 makes a dramatic difference evident: there are over three times as many recycling facilities in Northern Italy as there are in Southern Italy. Comparing the population figures for the North and the South (20,621,144 and 27,382,585), Southern Italy has a much lower density of treatment facilities per capita. As a result, this suggests longer travel times to reach these treatment centers, which raises the costs associated with the effects on the environment and the economy [18].

Harnessing mobile plants to manage waste in more significant applications, beyond just using it for excavation filling, becomes feasible when we execute a precise selective demolition process. Through this method, we can effectively segregate and remove unsuitable materials during the demolition operation.

The utilization of construction and demolition (C&D) waste as fine aggregate in concrete presents a multifaceted approach to addressing several pressing issues in the construction industry. Let's break down the background and significance:

Environmental Sustainability: The construction industry is a significant contributor to environmental degradation through resource consumption, energy usage, and waste generation. Incorporating C&D waste into concrete reduces the demand for natural aggregates, thus conserving natural resources and minimizing the environmental impact of quarrying activities. By diverting waste from landfills, it also helps alleviate the burden on waste management systems and reduces greenhouse gas emissions associated with waste disposal.

Circular Economy: Integrating C&D waste into concrete promotes the principles of a circular economy by turning waste materials into valuable resources. Rather than treating waste as a problem to be disposed of, it becomes a valuable input for another industry, closing the loop and reducing the need for virgin materials.

Cost Efficiency: Utilizing C&D waste as fine aggregate can potentially lower the overall cost of concrete production. Since these materials are often available at lower or even no cost, incorporating them into concrete mixtures can result in cost savings for construction projects, making them more economically viable.

Improved Concrete Properties: Research has shown that incorporating C&D waste into concrete can enhance certain properties of the resulting concrete mixtures. While the exact effects depend on factors such as the type and characteristics of the waste materials and the concrete mix design, benefits may include improved workability, durability, and even strength in some cases.

### *1.2 Literature review*

The viability of incorporating a fine fraction of recycled aggregates (RA) into the composition of masonry mortars has been the subject of numerous scientific investigations. The literature I've read indicates a range of acceptable replacement percentages, some of which can be related to RA's unpredictability. For instance, Vegas et al. (2009) found that mortars can contain up to 25% fine RA without experiencing negative effects on their workability, shrinkage, or mechanical properties, nor requiring the addition of additional additives[19]. Concrete water absorption is assessed using capillarity and immersion tests, among other methods. While capillarity tests measure the capillary absorption resulting from the pressure differential between the liquid's free surface on the outside of the concrete and the free surface inside the concrete's capillaries, immersion tests primarily evaluate the open porosity. According to Coutinho, concrete has a higher capillary absorption rate the smaller its pore diameter [20].

Wainwright et al. looked into water absorption in a study where they submerged concrete that contained coarse and fine RA from crushed concrete. According to their findings, porosity appears to be more significantly influenced by the quality of the concrete that the RA originates from than by the final concrete's target strength. Furthermore, Jimenez et al. (2013) found that, aside from density and workability, adding up to 40% of ceramic waste during the mortar-making process had no discernible effect on the characteristics of cement mortar in either its fresh or hardened state [21].

The mechanical and rheological characteristics of cement mortars made with three distinct types of recycled aggregates (RA)—rejected prefabricated concrete material, recycled brick waste, and plant recycling rubble—were assessed by Corina, Desi, and Moriconi in 2009. In all cases, 100% RA made up the entire mortar composition. When compared to conventional mortars, the results indicated that these recycled mortars had less mechanical strength but more mortar-to-brick adhesion strength [22].

Fernandez et al. (2015) investigated the feasibility of adding a fine portion of recycled aggregates (RA) to masonry mortars that contained CEM II/BL 32.5 cement in a comparable situation. The results showed that it was possible to achieve a 50% substitution rate in mortars meant for indoor use. The principal objective of this research was to evaluate the properties of recycled mortars in their fresh and hardened forms while adjusting the percentages of natural sand replacement with three distinct

kinds of recycled aggregate (RA) procured from cooperative recycling facilities. The study's findings add to our current understanding of the subject and might offer suggestions for increasing CDW (construction and demolition waste) recycling rates, which would ultimately lower the number of natural resources used by the construction sector [23],[24].

## 2. Methodology

It started with a literature study and was followed up by the collection of construction and demolition waste (CDW). Creating a workflow for using construction along with demolition waste (CDW) just as fine aggregate in concrete involves several stages, from research and planning to implementation and monitoring. Below is a general workflow to guide the process:

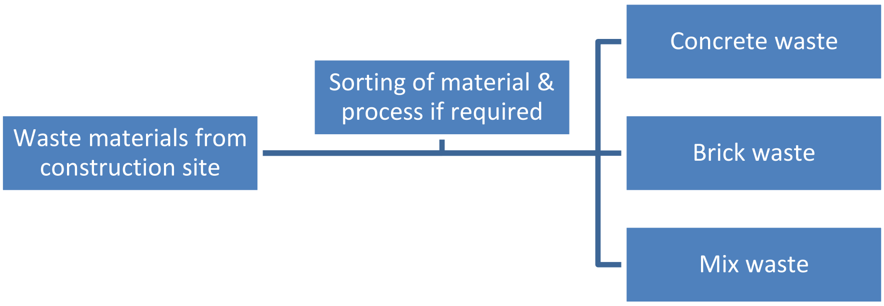


**Fig. 4** Finding the bulk density of construction waste.

*Preliminary Studies and Feasibility Studies:*

- Determine the goals and objectives of adding CDW to concrete.
- Review the literature to gather information on the benefits, challenges, and best practices associated with CDW-based concrete.
- Assess the availability of CDW resources and their proximity to the construction site.
- Assess regulatory requirements and environmental compliance.

*Construction Demolition Waste Quality Evaluation:*

- Collect samples of CDW materials from potential sources.
- Conduct laboratory tests to assess CDW quality and suitability for use as fine aggregate.
- Analyze CDW properties such as particle size distribution, density, and contaminants.
- Ensure compliance with relevant quality standards

**Table 1** Particle Size Analysis for Fine Aggregates Using Sieves

| IS Sieve size | Weight retained | Cumulative weight retained (g) | %cumulative weight retained |
|---|---|---|---|
| 10 mm | 0 | 0 | 0.00 |
| 4.75 mm | 115 | 115 | 11.50 |
| 2.36 mm | 60 | 175 | 17.50 |
| 1.18 mm | 180 | 355 | 35.50 |
| 600 μ | 135 | 490 | 49.00 |
| 300 μ | 260 | 750 | 75.00 |
| 150 μ | 250 | 1000 | 100.00 |

**Table 2** Properties of construction demolition waste

| Properties | Color | Specific gravity | Water absorption | Unit weight | Fineness modulus | Bulk density | Fineness modulus | Specific gravity |
|---|---|---|---|---|---|---|---|---|
| Observed values | Brown | 2.11 | 2.04 | 1485.0 | 6.79 | 1690 | 2.81 | 2.71 |

Mix design and material selection:

- Develop a concrete mix design incorporating CDW as fine aggregate.
- Determine the optimal CDW-to-total ratio.
- Select cement materials, additives, and other components based on project requirements.
- Conduct mix trials and tests to optimize mix design for desired concrete properties.

Processing and Preparing CDW:

- Build a processing plant to crush, refine, and purify CDW material.
- Implement quality control measures to ensure consistency and quality of processed CDWs.
- The control used a CDW unit to prevent contamination.

Construction Planning and Execution:

- Prepare a construction plan showing the use of CDW-based concrete in specific construction stages.
- Train construction workers in handling and placing CDW-based concrete.
- Monitor and document placement and maintenance processes to ensure compliance with approved mix design.

Quality control and testing:

- Implement a rigorous quality control program to monitor the properties of CDW-based concrete during production.
- Perform routine tests for compressive strength, workability, durability, and other relevant properties.
- Adjust the mixture ratio, if necessary, based on the test results.

**Table 3** Mechanical properties of construction demolition waste as a fine aggregate

| Properties | Requirement as per IS:8112-1989 and IS:456-2000 | Observed Values |
|---|---|---|
| Normal consistency | - | 29% |
| Initial setting time | 30min | 112 min |
| Final setting time | 600 min | 320 min |
| Compressive strength 3 days | 23N/mm2 | 23.67 N/mm2 |
| Compressive strength 7 days | 33N/mm2 | 34.67 N/mm2 |
| Compressive strength 28 days | 43N/mm2 | 44.33 N/mm2 |
| Soundness test | Up to 10 mm | 3.5 mm |
| Fineness test (90 µ sieve) | Up to 10% | 2.89% |

Environmental and Safety Compliance:

- Ensure compliance with environmental norms and safety standards during construction.
- Implement dust and noise controls at CDW processing facilities.
- Dispose of hazardous CDW components properly.

Documents and reports:

- Maintain detailed records of materials, composite design, test results, and construction activities.
- Generate reports documenting the performance of CDW-based concrete in various applications.
- Use this information for future reference and continuous improvement.
- Monitoring and evaluation of results:
- Monitoring the long-term performance of structures built with CDW-based concrete.
- Evaluate factors such as durability, strength retention, and resistance to environmental conditions.
- Perform necessary maintenance or remedial action based on inspection results.
- Knowledge sharing and communication:
- Share results and success stories related to CDW-based concrete with construction professionals, policymakers, and the public.
- Upgrade the benefits of sustainable construction practices and environmental responsibility.

Ongoing development: Regular evaluation and cleaning of CDW-based concrete production and construction activities. Incorporate lessons learned and best practices into future projects to improve efficiency and sustainability [26].

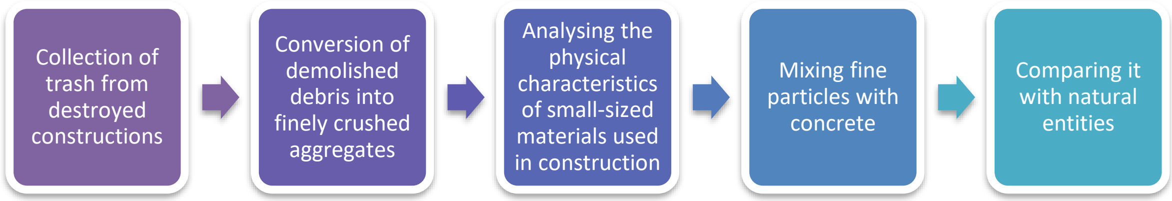


**Fig. 5** Flow Chart of implementing construction demolition waste as a fine aggregate in concrete while ensuring quality

## 3. Material Characteristics

When used as fine aggregate in concrete, construction, and demolition waste (CDW) can affect various material properties and concrete mix properties [27]. These properties and characteristics influence the type and quality of CDW, the processing method, and the design of special concrete mixes. The main material properties and properties affected using CDW as a fine aggregate are:

Concrete workability refers to the ease of placement and decoration. CDW-based concrete may have reduced workability due to the irregularity and angularity of CDW particles. Additional water or chemical additives may be required to maintain operability. (Permeability): CDW-based concrete can have higher permeability due to the presence of porous and less dense CDW particles. This can affect water penetration and resistance to chemical attack [28]. Freeze-thaw resistance of CDW-based concrete can affect the quality of CDW and the porosity of the resulting concrete. Proper care and mix design are essential to maximize freeze tolerance. The chemical composition of CDW can vary, which can affect the chemical compatibility of CDW-based concrete. A potential assessment of alkali-silica reactions and other chemical problems is required.

It should be noted that the properties of CDW-based concrete can be influenced by factors such as CDW quality, processing methods, and mix design. Proper testing, quality control, and compliance with required standards and guidelines are essential when using CDW as a fine aggregate to ensure that the desired specific performance and durability are achieved [29],[30].

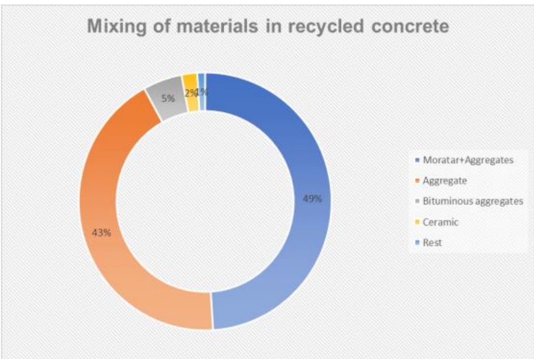


**Fig. 6** Mixing of materials in recycled concrete.

Utilizing Graphene Oxide for Improving Material Characteristics. Making recycled aggregate concrete with recycled aggregates (RA) derived from C&D waste is one of the best ways to recycle construction and demolition (C&D) waste. However, because RA is used, the qualities of recycled aggregate concrete usually don't match those of regular concrete. Thus, the purpose of this study is to investigate how graphene oxide (GO) can be applied to improve the properties of ultra-high-performance concrete (UHPC) that incorporates premium RA [31].

An initial UHPC mixture with high-quality RA was prepared in this study by modifying the particle packing model of Andreasen & Andersen. The study assesses how different GO contents affect UHPC with premium RA's mechanical characteristics, volume stability, and durability. The main conclusions drawn from the data were as follows:

1. Compared to UHPC using natural river sand, the mechanical qualities, volume stability, and durability features of UHPC with high-quality RA were either equal to or better.

2. Considering the pore structure of UHPC as well as mechanical and durability characteristics, the ideal GO content was determined to be 0.06 weight percent.

3. After adding GO, UHPC's tensile strength, flexural strength, elastic modulus, and compressive strength all significantly increased. The increases ranged from 2.04% to 16.04%, 7.36% to 30.50%, 5.83% to 23.40%, and 3.62% to 12.95%, respectively.

4. The addition of GO significantly improved UHPC's resistance to freezing and thawing cycles as well as resistance to chloride penetration.

5. To sum up, this research highlights the potential of graphene oxide.

The use of glass waste in concrete: The study demonstrated that waste glass can efficiently be utilized as fine aggregate replacement (up to 40%) without a noticeable reduction in strength. The employment of building and demolition wastes as an aggregate for the making of concrete is considered in current research investigations. The employment of building and demolition waste aggregates aids in reducing the depletion of natural aggregates and challenges associated with mining the aggregates [33],[34].

The experiment's goals were to assess the properties of concrete that contains crushed bricks and investigate important elements including the compressive strength of concrete mixtures that substitute different amounts of brick debris for fine aggregate. The Indian Standard for Conventional Concrete (IS 10262:1982) with a grade of M20 served as the basis for the design of the concrete mix. In Table 2, the material proportions are given in detail. The concrete mixes used varying percentages of brick powder (5%, 10%, 15%, and 20%) in place of sand [35].

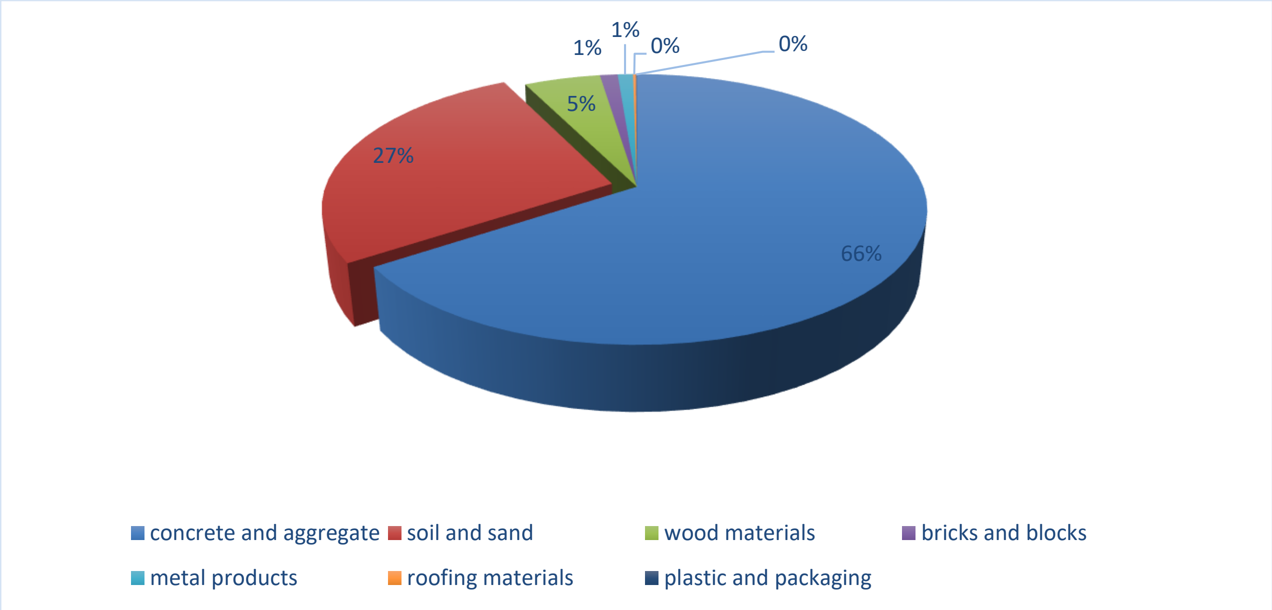


**Fig. 7** Waste composition

**Table 4** Properties of constituent materials

| No. | Parameter | OPC Used | Brick Debris | Fine Aggregate |
|---|---|---|---|---|
| 1. | Normal Consistency | 30% | -- | -- |
| 2. | Initial Setting Time (minutes) | 50 | -- | -- |
| 3. | Final Setting Time (minutes) | 250 | -- | -- |
| 4. | Specific Gravity | 3.20 | 2.12 | 3.50 |
| 5. | Bulk Density | -- | 875 | 1245 |
| 6. | Fineness Modulus | -- | 3.85 | 5.73 |
| 7. | Water Absorption | -- | 5.35% | 3.15% |
| 8. | Apparent Specific Gravity | -- | 3.34 | 3.75 |
| 9. | % of Voids | -- | 121.88% | 55.02% |

**Table 5** Gradation analysis of fine aggregate

| No. | Sieve Size | Weight of Aggregate retained | Cumulative Weight retained | Cumulative % weight retained | Percentage Passing (%) |
|---|---|---|---|---|---|
| 1. | 4.75 | 0 | 0 | 0 | 100 |
| 2. | 2.36 | 5 | 5 | 0.5 | 99.5 |
| 3. | 1.18 | 223 | 228 | 22.80 | 77.20 |
| 4. | 500µ | 370 | 598 | 59.8 | 40.20 |
| 5. | 300µ | 230 | 828 | 82.80 | 17.20 |
| 6. | 150 µ | 120 | 948 | 94.8 | 5.20 |
| 7. | 75 µ | 40 | 988 | 98.8 | 1.20 |
| 8. | pan | 12 | 1000 | 100 | -- |

**Table 6** Gradation analysis of brick debris

| No. | Sieve Size | Weight of Aggregate retained | Weight retained (%) | Cumulative % weight retained | Percentage Passing (%) |
|---|---|---|---|---|---|
| 1. | 4.75 | 0 | 0 | 0 | 100 |
| 2. | 2.36 | 34 | 34 | 3.4 | 96.6 |
| 3. | 1.18 | 145 | 179 | 17.9 | 82.10 |
| 4. | 500 µ | 165 | 344 | 34.4 | 65.60 |
| 5. | 300 µ | 165 | 509 | 50.9 | 49.10 |
| 6. | 150 µ | 320 | 829 | 82.9 | 17.10 |
| 7. | 75 µ | 160 | 989 | 98.9 | 1.10 |
| 8. | pan | 11 | 1000 | 100.0 | -- |

## *Physical properties*

CDW-based concrete has a lower density than normal concrete due to the low density of CDW particles. This can reduce the weight of structural elements. The presence of colored or mixed CDW materials can affect the color and appearance of concrete, which may be undesirable in some architectural applications [36]. The particle size distribution of C&D waste needs to be just like that of natural sand to ensure proper mixing and workability in concrete. The gradation or grading of C&D waste needs to meet the specs required for high-quality combination in concrete. This ensures that it can be used effectively without causing issues such as bad workability or segregation. The form and texture of C&D waste debris should be suitable for concrete applications. Irregularly fashioned or exceptionally angular particles may affect the workability and mechanical houses of the concrete. C&D waste needs to be examined for water absorption capability. high water absorption can cause a boom in the water-cement ratio, affecting the power and sturdiness of the concrete [37].

## *Stress and strain behavior of CDW concrete.*

1. Four distinct phases of cracking emerge in plain concrete during the early stages of applying stress under compression, before the peak point on the stress-pressure curve.
2. First Stage: Even though there are already pores and internal microcracks between the aggregates and the matrix before loading, the microstructure is stable in this initial stage and the microcracks do not propagate under light loads. At this point, concrete exhibits linear elastic behavior. Point A, where the stress-pressure curve diverges from linearity and internal microcracks start to open (also known as first-crack strength, indicates the start of localized cracking [38].

3. Stage II: The propagation of interfacial microcracks at point B, also referred to as the crack initiation stress, is a defining feature of Stage II. This marks the end of Stage II and the point at which the volumetric stress curve deviates from linearity [39].
4. Stage III: At point C, also known as the critical stress, microcracks that were first formed at the paste-aggregate interface become unstable, spread out in different directions, and eventually come together to form one or more large cracks. The point at which the volumetric pressure reaches its maximum value is represented by this number [39].
5. Stage IV: The specimen exhibits its peak compressive strength (point D) at this stage, which is marked by the stable propagation of these large cracks until one of them reaches a critical size. The primary cracks propagate even as the applied load decreases after surpassing the peak strength. The descending part of the stress-pressure curve represents the work-softening phase that characterizes this post-peak deformation [40],[41].

Based on experimental findings, it is evident that recycled aggregates exhibit lower values for both compacted and loose unit weights compared to conventional aggregates. This lower density can be attributed to the presence of porous cement mortar adhering to the recycled aggregates. Furthermore, the water absorption rates of recycled aggregates were notably higher than those of conventional aggregates, with percentages of 1-2% for the former and 8-10% for the latter[42]. The Los Angeles abrasion test results revealed that recycled aggregates experienced a 43% increase in wear and abrasion compared to conventional aggregates. Interestingly, both recycled and conventional aggregates demonstrated similar outcomes in tests evaluating sand equivalency, methylene blue absorption, and the separation of organic materials. Various physical properties of both recycled and conventional aggregates were determined through the experimental analysis of fine aggregate.

**Table 7** Physical properties of different size recycled aggregate

| Physical properties | Recycled fine Aggregate (0-5mm) | Recycled fine aggregate (0-12mm) | Normal stone powder (0-5mm) | Normal sand (0-3mm) |
|---|---|---|---|---|
| Close unit weight (kg/m3) | 1373 | 1558 | 1734 | 1643 |
| Loose unit weight (kg/m3) | 1377 | 1259 | 1630 | 1357 |
| Apparent specific weight (kg/m3) | 2700 | 2700 | 2730 | 2600 |
| Water absorption (%) | 10.9 | 9.7 | 1.2 | 1.2 |
| Fineness module | 3.88 | 5.00 | 4.42 | 3.05 |
| Methylene blue | 1.10 | 1.35 | 1.12 | 0.64 |
| Water content (%) | 0.77 | 0.66 | 1.20 | 6.80 |
| Over fine material content (%) | 5.44 | 7.24 | 9.20 | 0.8 |
| Sand equivalent (%) | 71 | 73 | 75 | 90 |
| Organic matter indication | * | * | * | * |

## *Mechanical properties*

One of the key considerations of using CDW in concrete is its effect on mechanical properties. This section examines the compressive strength, flexural strength, and durability of CDW-based concrete compared to conventional concrete. Insights into mechanical performance and potential limitations are provided [43]–[45].

CDW-based concrete can show lower compressive strength compared to conventional concrete, depending on the type and quality of CDW used. Proper mix design and processing can minimize this effect. Elastic modulus, which measures the strength of concrete, can be affected by using CDW as fine aggregate. CDW particles are stronger than natural aggregates, which can affect the overall strength of concrete. CDW-based concrete can show higher shrinkage than conventional concrete. Proper mix design and curing techniques are essential to reduce compaction. CDW-based concrete can have low flexural strength, but admixtures or modified mix designs can improve this property [46].

The test data and analysis in this study allow for the following conclusions to be made:

1. The reference mixture's compressive, bending, and tensile strengths increased when recycled aggregates were substituted for natural aggregates. Nonetheless, no significant changes were detected in the elastic modulus of the mixtures that were examined [47].

2. The reference concrete's fracture behavior was impacted by the addition of construction and demolition waste (CDW). The first crack strength, crack initiation

stress, and critical stress all experienced slight increases and decreases as a result.

The mechanical properties of CDW-concrete were improved, and its fracture pattern was effectively controlled, by the addition of steel fibers and recycled aggregates. In the stress-strain curve of recycled concrete mixtures, the post-crack behavior was particularly well-regulated by the addition of steel fibers. The steepness of the stress-strain curve's descending section indicates that the addition of steel fibers improved the toughness of recycled concrete. As a result, recycled concrete's compressive behavior began to resemble that of conventional aggregate concrete reinforced with fibers [48].

The inclusion of steel fibers and recycled aggregates had a positive impact on the mechanical characteristics of CDW concrete and provided effective control over its fracture pattern. The addition of steel fibers was especially advantageous in regulating the post-crack behavior observed in the stress-strain curve of recycled concrete mixtures. When steel fibers were introduced, the toughness of recycled concrete increased, as evidenced by the steepness of the descending section of the stress-strain curve. This made the compressive behavior of recycled concrete more closely resemble that of fiber-reinforced conventional aggregate concrete [49].

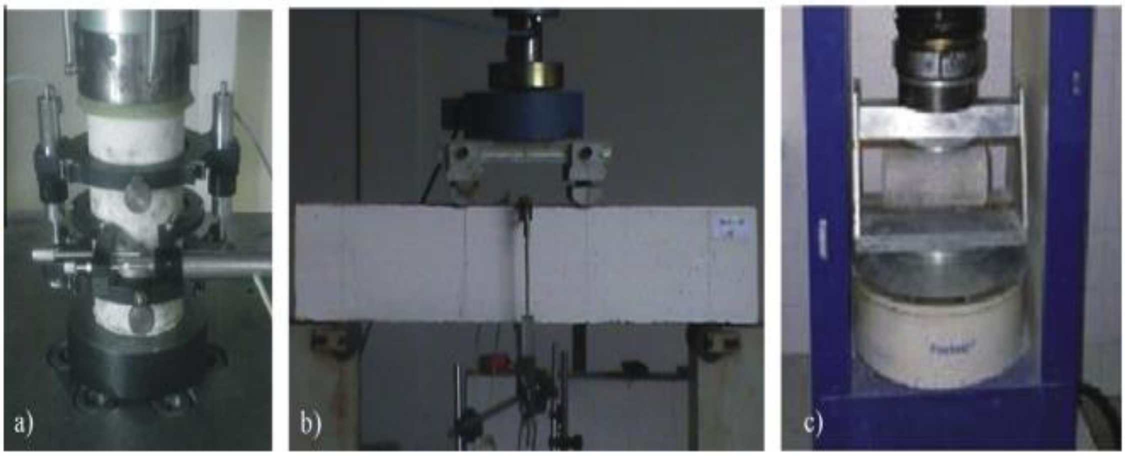


**Fig. 8** Test setup: (a) compression; (b) bending (c) splitting tensile test.

## 4. Summary

The utilization of construction and demolition waste (CDW) as a substitute for fine aggregate in concrete is a sustainable and environmentally conscious strategy in the realm of construction materials. This innovative approach carries numerous advantages, including waste reduction, resource conservation, and cost-efficiency, all the while tackling the challenges of natural resource depletion and waste generation within the construction sector. The journey towards integrating CDW into concrete commences with initial research and quality assessments of CDW materials to ensure their adherence to specified standards. Mix design and material selection become pivotal stages in crafting a particular blend using CDW while upholding the intended properties and performance. Effective processing and preparation of CDW materials become imperative to generate uniform, high-quality aggregates for concrete production. In the planning and execution of construction projects, personnel training, and ongoing supervision are crucial to ensure alignment with the approved mix design. To maintain the integrity of CDW-infused concrete, quality control, and testing procedures are applied, guaranteeing that it fulfills the specific requirements concerning strength, workability, and durability. Compliance with environmental and safety regulations remains paramount throughout the project's lifecycle. Documentation, reporting, and data analysis contribute to the collective knowledge base and endeavors for continuous enhancement regarding CDW-based concrete. Monitoring and assessing outcomes provide insights into the long-term robustness and performance of structures constructed with these sustainable materials. By disseminating knowledge and advocating the advantages of CDW-based concrete, the construction industry can embrace a more sustainable and circular approach, ultimately curbing waste, conserving resources, and contributing to a more environmentally conscious future. In summation, the incorporation of CDW into concrete presents a promising avenue for sustainable construction practices that align with environmental objectives and champion responsible resource management in the construction sector.

## 5. Application

The incorporation of construction and demolition waste (CDW) as a substitute for fine aggregate in concrete presents a range of significant advantages and benefits, rendering it an appealing choice for the construction industry. Additionally, this article acknowledges and addresses challenges, including optimizing efficiency, accommodating the varying characteristics of CDW, and the necessity for standardized regulations and standards.

The study underscores the importance of fine-tuning mix designs and adjusting processes to enhance the performance of concrete incorporating CDW [49]. The primary motivations for considering CDW in concrete are as follows:

Environmental Sustainability: The recycling of CDW diminishes the reliance on landfill disposal, thereby mitigating environmental concerns like limited landfill space and the release of hazardous substances. The utilization of CDW in concrete aligns seamlessly with sustainability goals, curbing the depletion of natural resources, notably sand, which is commonly used as an aggregate[50],[51].

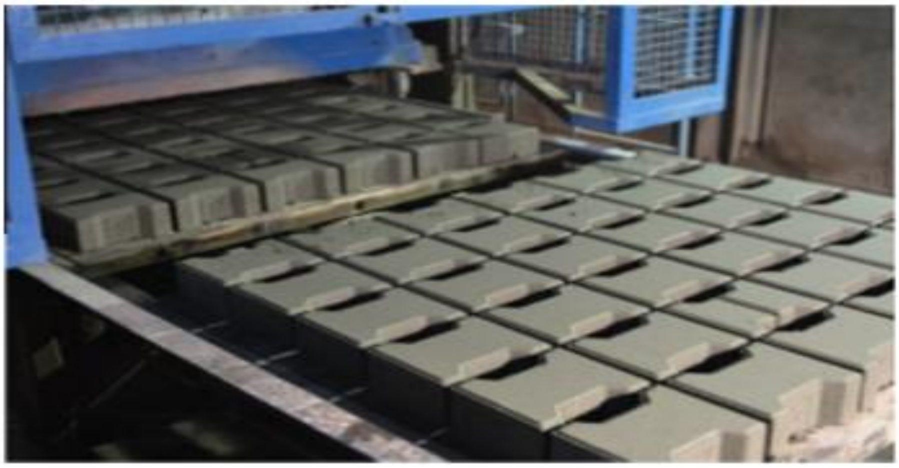

**Fig. 9** Application of paving stones manufactured from concrete wastes.

Resource Conservation: The extraction and processing of natural aggregates demands substantial energy and water resources. Properly incorporating construction and demolition waste (CDW) into concrete offers a means to conserve these resources, thereby reducing the environmental impact associated with concrete production [52].

Waste Minimization: Construction and demolition activities generate significant volumes of waste. The utilization of CDW in concrete represents a valuable strategy to address this waste stream, effectively diminishing the overall waste produced and managed. This, in turn, leads to cost savings and diminishes the reliance on landfills for waste disposal.

Energy Efficiency: The integration of recycled CDW into concrete contributes to energy savings during the manufacturing process. CDW typically requires less energy for processing and transformation in comparison to natural aggregates [53].

Cost Effectiveness: Depending on local availability and processing methods, CDW can serve as a cost-effective substitute for natural aggregates. This can result in substantial cost reductions, particularly for construction projects of interest to builders and contractors.

**Table 8** Comparative statement of strength and economy mix.

| Items | Strength (KN/mm$^2$) | Cost per m$^3$ | Decrease in cost |
|---|---|---|---|
| Natural concrete | 40 | 3524.21 | - |
| Recycled concrete with 10% of fine aggregate replacement | 45 | 3646.63 | 12.88 |
| Recycled concrete with 20% fine aggregate replacement | 41 | 3668 | 1.42 |
| Recycled concrete with 30% fine aggregate replacement | 42 | 3480 | 7.10 |

Enhanced Resource Utilization: Construction and demolition waste (CDW) can be effectively incorporated into concrete without sacrificing its structural integrity or performance. By repurposing materials that might otherwise go to waste, concrete production can optimize the utilization of available resources, improving overall resource efficiency [54]–[56].

a) b)

**Figure 10**: a) Reinforced concrete pipe manufactured from C&D waste. b) Application of paving stones manufactured from concrete wastes.

Tailoring and Adaptability: Concrete blends incorporating construction and demolition waste (CDW) can be precisely processed and graded to fulfill specifications, offering a high degree of customization. This adaptability proves advantageous in attaining the intended properties and performance. attributes for various construction applications [57],[58].

## 6. Discussions

As far as other countries are concerned, the utilization of CDW as a fine aggregate in concrete following is the table depicting their recycled aggregate in volume.

**Table 9** Allowed recycled aggregate utilization in other countries.

| Countries | Application | Recycled aggregate in volume (%) | Recycled fine aggregate utilization | Concrete grade | Other materials in weight (%) |
|---|---|---|---|---|---|
| Belgium | In nonaggressive environmental effects | 0-100 | In the states when it is provided of normal aggregate standards permitted | Max C30/37 depending on the aggregate | <1non-mineral mixes |
| Denmark | In nonaggressive environmental effects | 0-100 for >4mm part | Permitted | Max 21 MPa depending on aggregate | - |
| Germany | Except in strong chemical effects and reinforced concrete | Only 0-42 for broken concrete | Max 7% for <2mm part | Max C35/45 | <0.2 wood and plastic material |
| Japan | In moisture-free components | Only 0-42 for broken concrete | Permitted | Max C30/37 depending on the aggregate | Max 10Kg/m3 gypsum and max 2Kg/m3 asphalt |
| Holland | In nonaggressive environmental effects | Only 0-20 for broken concrete | Permitted up to 20% | According to all concrete building standards | Max 1% bitumen and 0.15% organic matter |
| USA | In concrete and reinforced concrete components | Only 0-100 for broken concrete | Permitted | According to ACI 318-95 | - |

After being obtained, the compressive electricity values for 7, 14, and 28 days are listed in the following desks, numbered 6, 7, and 8, respectively.

Test results and the experimental studies carried out in the lab to ascertain the energy residences of the concrete with the additional combination of overwhelmed brick are discussed. The compressive energy as compared to conventional/natural concrete for five percent, ten percent, fifteen percent, and twenty percent replacement of a satisfactory combination with brick particles[59],[60].

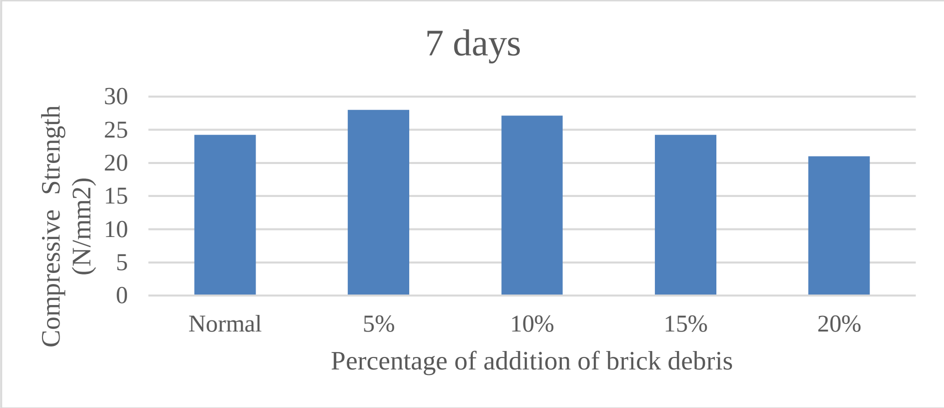


**Fig. 11** Compressive strength result for 7 days

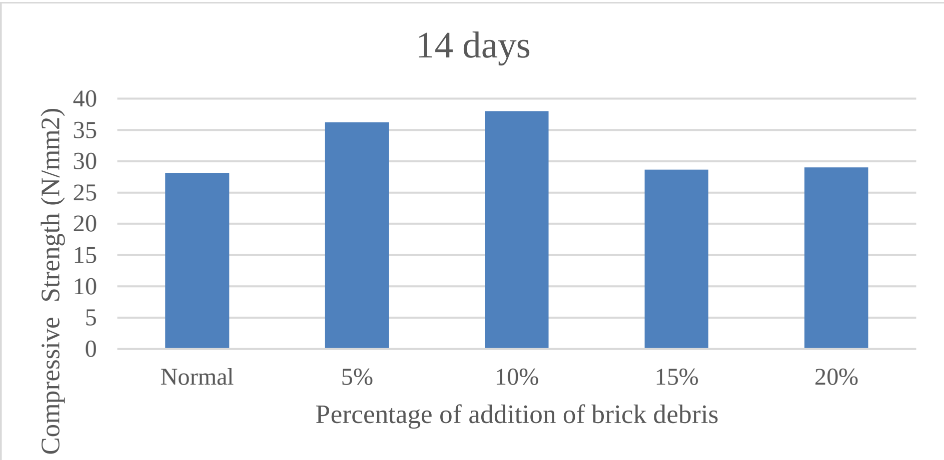


**Fig. 12** Compressive strength result for 14 days

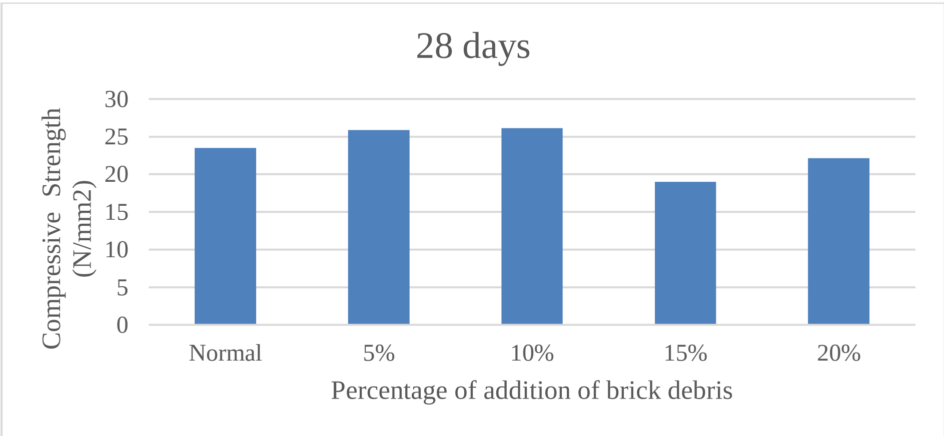


**Fig. 13** Compressive strength result for 28 days

It was concluded in both studies that these recycled aggregates could be used to produce concrete pipes, curb stones, paving stones, and reinforced concrete pipe elements that meet the relevant standards. Different substitution rates were first defined and applied to various experimental scenarios to prevent redundancy.

A detailed analysis was conducted to determine the effects of utilizing recycled aggregates in various applications and the related costs of substitution. It was discovered that the final products' durability and mechanical qualities complied with the requirements. Recycled aggregates from demolition and construction waste can be used to make new construction products by using them as secondary raw materials [61],[62]. This strategy can also incorporate recycled aggregates into innovative building materials to mitigate environmental issues resulting from manufacturing processes. Because of this, it is wise to consider lower substitution rates to make sure that the intended mechanical properties meet the requirements of the product.

## 6. Conclusion

In summary, this review paper underscores the feasibility of employing construction and demolition waste (CDW) as fine aggregates in concrete. While CDW holds the promise of environmental advantages and resource conservation, its successful integration into concrete production necessitates a meticulous examination of material properties, physical attributes, and mechanical behavior. Although CDW-based concrete exhibits promise across diverse applications, further research is essential to optimize its performance and address potential challenges. Ultimately, the adoption of CDW in concrete contributes to sustainable construction practices, mitigating the environmental impact of the construction industry.

Similarities and Differences with Past Research: Our findings align with previous studies that have highlighted the potential of CDW as a sustainable alternative to natural fine aggregate in concrete production. However, our review also identified discrepancies and gaps in knowledge regarding specific aspects such as material characterization, mix design methodologies, and long-term performance evaluation, indicating areas where further research is warranted.

Recommendations for Future Studies: Based on the findings of this review, several recommendations can be made for future research endeavors. Firstly, there is a need for standardized testing protocols and methodologies for assessing the properties of CDW and its performance in concrete mixes to ensure consistency and comparability across studies. Additionally, longitudinal studies examining the durability and environmental impacts of CDW concrete in real-world applications are essential to validate its long-term viability and sustainability.

Policy Implications and Recommendations: The utilization of CDW as a fine aggregate in concrete aligns with the goals of sustainable development and circular economy principles. Policymakers and regulatory bodies are encouraged to incentivize and promote the adoption of CDW recycling and reuse practices in the construction industry through policy frameworks, tax incentives, and procurement guidelines. Furthermore, collaborative efforts involving government agencies, industry stakeholders, academia, and research institutions are essential to facilitate knowledge sharing, technology transfer, and capacity-building initiatives aimed at mainstreaming CDW utilization in concrete production.

## 7. Future Scope

There are several prospective avenues for the utilization of CDW as a fine aggregate in concrete, including:

7.1 Sustainable construction practices: Considering increasing concerns about sustainability and the environmental footprint, the construction industry will persist in seeking methods to curtail the depletion of natural resources and minimize waste. The utilization of CDW in concrete aligns with this objective and is poised to gain even more prominence.

7.2 Regulatory support: Governments and regulatory agencies can introduce policies and incentives to encourage the use of CDW in construction materials, including concrete. These regulations can promote research and development in this area and facilitate implementation.

7.3 Technological Development: Continued research and development efforts may lead to more advanced technologies for processing and incorporating CDW into concrete mixes. Innovation in processing methods and quality control methods can improve the performance of CDW-based concrete.

7.4 Performance standards and guidelines: Developing performance standards and comprehensive guidelines for concrete incorporating CDW can offer clarity and assurance to builders, architects, and engineers. Such standards will guarantee that CDW-based concrete aligns with the necessary structural and strength requirements.

7.5 Research and Development: Ongoing research can reveal new ways to improve the properties of CDW-based concrete by addressing all limitations related to strength, durability, and workability. Research can also explore the use of admixtures or alternative binders to further optimize CDW-based concrete.

7.6 Education and Awareness: Both the construction industry and academic institutions have a vital role to play in educating professionals and the public about the advantages of incorporating CDW into concrete. Raising awareness has the potential to drive wider acceptance and implementation of this practice.

7.7 Circular Economy Initiative: The concept of a circular economy where materials are reused, recycled, and recycled is gaining popularity. CDW can be a valuable resource in such initiatives, especially in the construction industry.

7.8 Market demand: As more construction projects seek sustainable and environmentally friendly solutions, the demand for CDW-based concrete will likely increase. This demand may encourage companies to invest in CDW processing facilities and research. In conclusion, the future scope of using construction and demolition waste as fine aggregate in concrete looks promising with the goal of sustainability, technological progress, and regulatory support. However, the successful implementation of CDW-based concrete will depend on continued research, innovation, and collaboration in the construction industry and other relevant sectors.

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