Recycling Construction Materials
"A Path to Sustainable Infrastructure and Economic Resilience"

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Abstract. In Pakistan, the construction and demolition (C&D) sector produces a significant number of concrete debris, creating logistical and environmental issues. The feasibility and possible advantages of using recycled C&D concrete debris as an alternative aggregate in the creation of structural concrete are investigated in this study. The purpose of this study is to explore green practices that can improve the performance and durability of concrete constructions in Pakistan while addressing waste management challenges. In an era characterized by escalating concerns over environmental sustainability and the imperative to efficiently manage resources, the recycling of construction materials has emerged as a pivotal strategy for the development of resilient infrastructure and the mitigation of societal problems.

This research article investigates the salient features and critical innovation in recycling construction materials, with an overarching focus on controlling landfill waste, improving cost-efficiency, and promoting green practices. For this purpose, different parameters of C&D debris including impact value, specific gravity, unit weight, water absorption, fineness modulus are experimentally studied and compared them with the fresh aggregates. The experimental results show that the utilization of recycled materials, with their inherent capacity to enhance structural reliability, has assumed a pivotal role in the pursuit of sustainable infrastructure development. The diversion of waste materials from landfills to repurpose them in new projects not only reduces the volume of demolition waste but also offers a reasonable and economically possible alternative to acquiring new resources. These recycled materials not only contribute to cost-effective construction but also significantly reduce the carbon footprint, a testament to their environmental credentials.

Keywords: Recycling, construction materials, sustainability, innovation, infrastructure development, waste management, green practices, economic viability.

1. Introduction

Building and tearing down Waste materials build up during infrastructure development, modernization, restoration, retrofitting, or demolition. Using natural resources, roughly one million tons of construction and demolition waste (C&D) materials are created each year, with the majority being used in construction. It's time to start taking the harm caused by (C&D) seriously. Because most nations lack the equipment necessary to process these C&D materials, trash is discarded rather than being used and repurposed to create new buildings [1]. It's possible that a small quantity of waste from construction is recycled or used in place of naturally sourced resources. Using C&D materials instead of natural aggregates has emerged as a key focus for the circular economy. The production of new concrete uses roughly 20 billion tons of natural resources annually worldwide; in the next 20 to 30 years, that number is expected to increase. However, there is a substantial amount of solid trash generated during the demolition of existing buildings. In certain countries, it has been identified as one of the world's most significant sources of C&D, accounting for 20% to 40% of total trash. It's possible that a negligible quantity of waste from construction is recycled or used in place of naturally sourced resources. Using CDW products to replace natural aggregate has become a top focus for the circular economy. Approximately 20 billion tons of natural resources are needed annually to create new concrete around the world, and this figure is expected to rise over the next 20 to 30 years. However, the demolition of existing buildings generates a significant amount of solid trash. It is one of the most prevalent environmental contaminants in the world, accounting for 20-40% of all rubbish. [2]. The figure below depicts the yearly generation of C&D in a variety of nations, including China, the US, India, Australia, England, France, Italy, and the European Union. In the United States, recycling is more prevalent; out of 600 MT of debris from construction and demolition, about 75% is recycled. It has been reported that fewer than 40% of C&D in China is recycled [3]. Furthermore, only 1% of India's C&D is recycled and recovered. Appropriate C&D handling

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methods are required to protect the environment and lessen the depletion of natural resources.

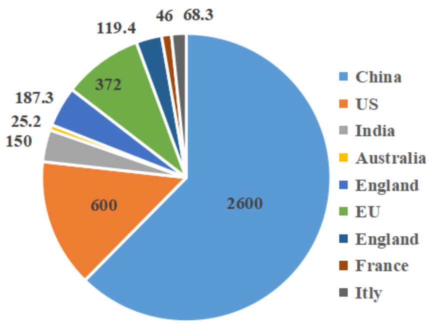

Fig. 1. Annual Generation of C&D waste in Million Tons [4]

Construction and demolition (C&D) waste is a growing issue in Pakistan, exacerbated by the country's recurring economic crises. In Pakistan, construction and demolition activities contribute significantly to solid waste generation, accounting for approximately 30% of the total waste. Specifically, in Punjab, materials wastage at construction sites constitutes 9.8% of the total waste produced. Given Pakistan's annual solid waste output of 48.5 million tons, construction waste alone amounts to an estimated 14 million tons annually. According to the Pakistani government, around 87,000 tons of solid garbage are generated everyday across the country, with major metropolitan centers accounting for the majority of this. Karachi, Pakistan's largest metropolis, generates around 13,500 tons of municipal waste daily. Significant economic effects have resulted from the prohibition on the exploitation of building aggregates from Islamabad's Margalla Hills, a vital supplier of these materials. Due to the lack of accessible aggregates, the building sector, a significant contributor to Pakistan's economy, is dealing with rising costs. This has affected the country's overall economic stability by causing project delays and rising building costs. Future demand for construction aggregates in Pakistan is anticipated to increase because of the country's fast urbanization, rising population, and requirement for the construction of a significant amount of infrastructure, including roads and buildings. Table 1 shows the population solid waste and C&D waste produced by the major cities of Pakistan. Pakistan has to diversify its sourcing practices to reduce the economic pressure brought on by the Margalla Hills aggregate ban and to guarantee a long-term supply of aggregates. Accepting the recycling and reuse of C&D trash can be transformative. If handled properly, these materials show benefits for the economy and the environment. By making use of already-existing resources, they can drastically lower construction costs while also easing environmental issues by easing the load on landfills and saving natural resources. Pakistan may handle its economic issues and advance environmental sustainability by using creative recycling and waste management practices for C&D products.

Table 1: C&D produced by major cities of Pakistan [8].

City	Population (Millions)	Solid waste Generated (Tons)	C&D waste (Tons)
Karachi	20.5	13.5	4.05
Lahore	10.0	7.51	2.25
Faisalabad	7.5	4.9	1.47
Rawalpindi	5.9	4.4	1.32
Hyderabad	5.5	3.88	1.16
Multan	5.2	3.6	1.08
Gujranwala	4.8	3.4	1.02
Sargodha	4.5	3.0	0.90
Peshawar	2.9	2.0	0.60
Quetta	0.6	0.7	0.21

While there were fewer cavities in the C&D trash, its bulk density (unit weight) was higher than that of the commercial product. As the absorption drops, the specific gravity rises. aggregates used in the manufacturing of concrete that have qualities appropriate for most structural concrete applications.

When natural aggregates were totally substituted with recycled aggregates, the concrete's workability and strength dropped. To address this, superplasticizers and greater cement tents (400-450 kgm3) were used to generate a more compact matrix, improving the performance of the structural concrete.
The total from each of the three sources C&D concrete waste, lab-tested concrete waste, and ordinary market aggregate were used to make three concrete specimens. The control samples were made with ordinary aggregate. All specimens were designed with a compressive strength of 35 MPa. Each specimen was tested for compressive strength at 7, 14, and 28 days in line with ASTM-C109/C109M-13. The control samples had the maximum strength at 28 days, according to the results. The specimens constructed from the lab-tested waste aggregate from case 1, which was collected from beams and columns, met the design strength, whereas the specimens made from the random concrete waste from case 2, which was taken from columns, fell somewhat short.

An experimental program was conducted to compare the experimental engineering properties of aggregate obtained from reclaimed concrete waste from various sources, including lab-tested concrete waste from a commercial ready-mix company known for its engineering properties, regular market aggregate, and construction and demolition (C&D) concrete waste with and without prior information. The amount of material that could be collected from the concrete rubble was determined after it was crushed into gravel. The recovered gravel was then run through an abrasion machine. It was determined that 30 kg of high-quality recycled aggregate could be retrieved from 100 kg of demolished waste concrete. [5].

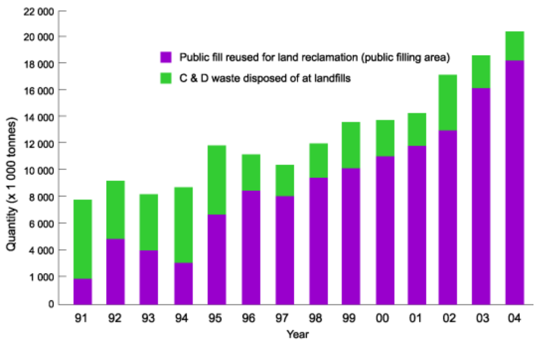

Fig. 2. Public fill reused and C&D disposed of at land fill [4]

1.1. Research Significance

Investigate the mechanical characteristics of concrete using construction and demolition debris as coarse aggregate. Use of C&D waste coarse aggregates in concrete by reducing environmental waste protecting environment by using C&D waste from landfills and produce efficient concrete. This research created bridge for a path to sustainable infrastructure and economic resilience.

1.2. Test standards

All the tests were done according to ASTM, BI and SI standards listed below:

1.3. Test standards

All tests were done according to ASTM standards as listed below:

Mechanical tests

- Unit weight (ASTM C29-78).
- Water Absorption (AASHTO T 85 - ASTM C 127).
- Impact value (ASTM C131-BS812).
- Specific gravity: (AASHTO T85-10).
- Fineness modulus (ASTM C33).

2. Study Area

We have conducted a comparison analysis in our study between recycled and fresh coarse aggregate, assessing their appropriateness for concrete applications with a battery of demanding tests. Specific gravity, impact value, water absorption, unit weight, and fineness modulus are among the tests that are included in this series. Through a thorough analysis of these characteristics, we hope to ascertain whether recycled coarse aggregate can successfully replace fresh coarse aggregate during the manufacture of concrete.

We hope to learn more about the practical and technical viability of using recycled aggregates in concrete construction through this inquiry. Examining the outcomes of these experiments, we hope to offer insightful information about recycled coarse aggregate's potential as a sustainable substitute that will support resource preservation and environmental responsibility in the building sector.

The field of study concerning the integration of C&D waste materials recycled coarse aggregate into concrete is a complicated one. This study explores the structural performance, environmental effects, and technological viability of using such recycled aggregates in concrete manufacturing. It includes several steps, such as gathering aggregate from roadside sources, evaluating it for quality and applicability to concrete, and creating mix designs that are optimized to guarantee the final concrete has the necessary mechanical qualities and longevity. This study also investigates any potential advantages in terms of waste reduction and resource conservation, as well as any obstacles or limits linked to the use of recycled aggregates in concrete construction. A variety of qualities are investigated in the research area that focuses on building and demolition debris, specifically concrete, to determine its potential for recycling and reuse in the manufacturing of concrete. In order to establish if leftover concrete may be processed into recycled aggregates, its physical characteristics, including its moisture content, density, and particle size distribution, are first evaluated. Chemical properties, such as the presence of pollutants or harmful substances, are extensively evaluated to verify compliance with environmental regulations and to mitigate any potential risks to human health or the environment.

In addition, mechanical attributes including durability, tensile strength, and compressive strength are assessed to determine how well recycled concrete aggregates work in structural applications. These mechanical qualities are influenced by various factors, which are important to take into account in the study. These factors include the original concrete's quality, the level of contamination, and the efficiency of processing methods.

The environmental sustainability of using building and demolition debris in the manufacturing of concrete is also evaluated by looking into the recycled concrete's energy consumption during processing, carbon footprint, and potential to reduce landfill waste. Through a thorough examination of these attributes, scientists want to create practical plans for the environmentally friendly handling of trash from building and demolition projects, all the while supporting the concepts of the circular economy within the building sector.

The case study focused on the Old Grand Trunk Road that runs from Faiz-Abad to Rawat (Fig. 3). The element of the rigid road pavement that was removed had known engineering parameters, such as compressive strength.

Fig. 3. sample collecting area.

Fig. 4. Process involves extracting the required coarse aggregates

2.1 Process of the Recycling of C&D waste.

1.case study Road.
2.Selective Demolition (concrete).
3.Crush in Required sizes.
4.Sieve Analysis of Demolished material.
5.Collecting Required aggregate sizes.
6.Weight of samples and stored with respect to its sizes.

3. Objectives

To reduce construction waste in the construction sector, it is vital to study the feasibility of employing recycled concrete aggregates (RCA) as a sustainable building material in structural concrete. Specifically, RCA's mechanical qualities, durability, and environmental advantages should be evaluated.

3.1 Other Targets

- Sustainable resource use.
- Conservation of land fill space.
- Material availability and accessibility.
- Environmental benefits.
- Energy and cost saving.
- Waste reduction.

4. Testing on samples, Experimental work

4.1. Impact value test

Impact value test is used to determine the toughness and resistance on coarse aggregates. This test is carried out in accordance with ASTM C131 - BS812 for the impact value of aggregate. Impact value is given in table 2.

4.2. Water absorption

Water absorption test on aggregates is conducted to determine the durability property of aggregates such as quality and behavior of aggregates in weathering. This test is carried out in accordance with AASHTO T 85 - ASTM C 127. Absorption value of aggregates is given in table 2.

4.3. Specific gravity

Aggregates are subjected to the specific gravity test to ascertain their density in relation to water. It offers important details regarding the aggregate particles' porosity and compactness, two critical elements affecting the characteristics of concrete. Precise proportioning of concrete mixes depends on the specific gravity of the particles. This test is carried out in accordance with AASHTO T85-10. Specific gravity of aggregates is given in table 2.

4.4. Unit weight

Unit weight (is also known as bulk density and bulk unit weight) of aggregates is determined for several reasons in construction materials testing and concrete mix design like estimation of yield, quality control and density and strength of concrete. This test is carried out in accordance with ASTM C29-78. Unit weight of aggregates is given in table 2.

4.5. Fineness modulus

To design concrete mixes and maintaining quality, one crucial metric is the coarse particles' fineness modulus. We calculate coarse aggregates' fineness modulus for the following reasons.

- Gradation analysis. (Given below in fig 5)
- Concrete mix design.
- Workability and pumpability.
- Strength and durability.
- Quality control

This test is carried out in accordance with ASTM C33.

4.6. Process of sieve analysis and specification

For sieve analysis we take sieve sizes between 4.75mm to 25mm.First we sieve the available material and collect the retain of 3/4,1/2,3/8 and No 4 sieve. Then we calculate cumulative percentage to find fineness modulus and calculate percentage passing to draw gradation curve between sieve openings and percentage passing.

Table 2: experimental results of aggregates.

Sr no	Tests performed	Properties of aggregates		
		Recycled aggregate	***Fresh aggregate***	***Standards***
1	Impact value	32.6%	29.9%	ASTM C131 - BS812
2	Water absorption	8.4%	1%	AASHTO T 85 - ASTM C 127
3	Specific gravity	1.98	2.42	AASHTO T85-10
4	Unit weight	79.37 lb/cft	90.30 lb/cft	ASTM C29-78
5	Fineness modulus	7.5	7.75	ASTM C33

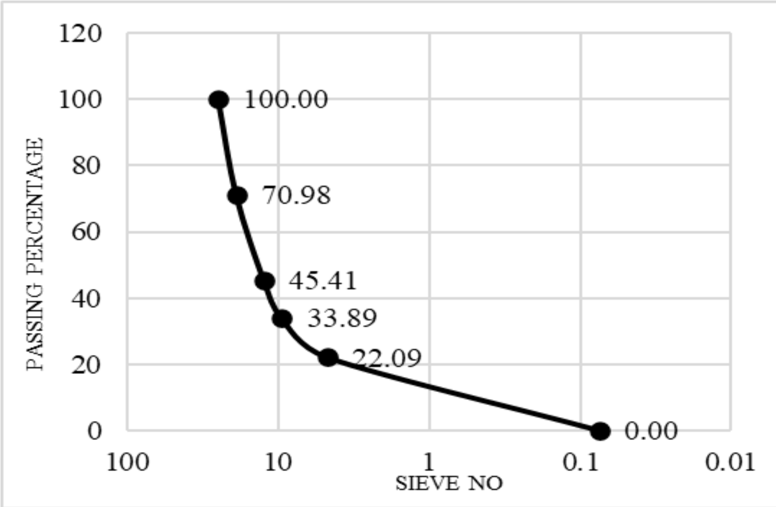

Fig. 5. Sieve analysis gradation curve.

5. Results and discussion

Recycled aggregates undergo extensive laboratory testing to assess their suitability for construction use. These tests include examining specific gravity, impact value, water absorption, and unit weight of both fresh and recycled aggregates. While there are slight differences between the specific gravity, impact value, water absorption, and unit weight of recycled and fresh aggregates, these values generally fall within acceptable ranges for construction materials. For instance, recycled aggregate exhibits a specific gravity of 1.97, compared to 2.4 for fresh aggregate. Despite the slightly higher impact value of recycled aggregate (32.6% versus 26.9% for fresh aggregate), it remains within acceptable limits. Additionally, although the water absorption of recycled aggregate is slightly higher (8%) compared to fresh aggregate (1%), it still meets the requirements for concrete production. Moreover, the unit weight of recycled aggregate is suitable for structural purposes, albeit slightly lower than fresh aggregate's unit weight of 90.36 pounds per cubic feet (79.37 pounds per cubic feet). These findings affirm the viability of recycled aggregates for use in construction applications.

6. Conclusion

In conclusion, comprehensive laboratory testing conducted on both fresh and recycled aggregates yields valuable insights into their suitability for construction applications.

- Extensive laboratory testing validates the suitability of recycled aggregates for construction purposes.
- Properties such as specific gravity, impact value, water absorption, and unit weight were evaluated for both fresh and recycled aggregates.
- Slight differences exist between recycled and fresh aggregates, yet all values fall within acceptable ranges for building materials.
- Recycled aggregates, with a specific gravity of 1.97 and impact value of 32.6%, remain within acceptable bounds compared to fresh aggregates (specific gravity: 2.4, impact value: 26.9%).
- Despite slightly higher water absorption (8% for recycled versus 1% for fresh), recycled aggregates meet concrete manufacturing requirements.

- Recycled aggregates' unit weight, though marginally lower than fresh aggregates (79.37 pounds per cubic feet versus 90.36 pounds per cubic feet), remains suitable for structural applications.
- The collective findings confirm the viability and effectiveness of recycled aggregates in sustainable construction practices.

Thus, it is possible to conclude that recycled aggregate is suitable for use in building, providing a sustainable route towards the development of infrastructure and economic resilience, based on these laboratory results. In addition to lowering the need for virgin materials, using recycled aggregates in building projects promotes resource efficiency and environmental preservation, opening the door to a more sustainable future.

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The authors affirm that no competing interests, such as personal, professional, or financial ties, influenced the content of this research. All the data and resources used in this work are available for examination, and the authors are committed to presenting their findings with transparency and integrity.

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