UTILIZATION OF CONSTRUCTION AND DEMOLITION WASTE (CDW) IN SUSTAINABLE CONCRETE PRODUCTION IN CONSTRUCTION INDUSTRY OF PAKISTAN

Rohan Ahmed[1], Abdul Rehman[*2], Muhammad Abdullah Najmuddin[3], Kazi Omer Sadik[4], Abdul Basit Musab[5], Subyyal Saad[6]

[1]*NED University of Engineering & Technology, Karachi*
[*2]*Faculty of Engineering, Science, Technology & Management, Department of Civil Engineering, Ziauddin University, Karachi*
[3,4,5,6] *NED University of Engineering & Technology, Karachi*

[1]engr.rohanahmed@gmail.com, [*2]abdulrehman.khuwaja@zu.edu.pk,
[3]najmuddin.muhammadabdullah@gmail.com, [4]engr.kaziomersadik@gmail.com,
[5]engrabdulbasitmusab@gmail.com, [6]subyalsiddiqui135@gmail.com

Copyright @Author
Corresponding Author: *
Abdul Rehman

Abstract
Pakistan's escalating solid waste crisis, particularly in Karachi with its annual generation of 49.6 million tons, necessitates the adoption of circular economy principles in construction. This study investigates the feasibility of substituting natural coarse aggregate with Construction and Demolition Waste (CDW) comprising crushed concrete, bricks, and tiles in concrete. Using a 1:2:4 mix design with a constant 0.5 water-cement ratio, six replacement levels (0–100%) were evaluated for compressive strength at 7 and 28 days. Results revealed a nonlinear strength response, with 40% CDW replacement yielding optimal performance (33.12 MPa at 28 days), surpassing the control mix (28.5 MPa). This enhancement is attributed to internal curing from the porous recycled materials. Beyond 60% replacement, however, strength declined due to increased porosity and weakened interfacial transition zones, with 100% replacement achieving only 22.11 MPa. Notably, the 80% replacement mix exhibited the highest strength gain (72.4%) between 7 and 28 days, suggesting potential for non-structural applications. The study concludes that 40% CDW replacement offers an optimal balance between structural integrity and sustainability, providing a viable pathway for waste reduction and resource optimization in Karachi's construction sector.

1. INTRODUCTION

The rapid urbanization and industrialization sweeping through Pakistan have placed the construction sector as a central pillar of the national economy. With a population exceeding 240 million and an annual urban growth rate of nearly 2.5% [15], the demand for housing, commercial infrastructure, and transportation networks has reached unprecedented levels. However, this progress comes with a heavy environmental price: the staggering volume of Construction and Demolition Waste (CDW).

While the global construction industry is responsible for roughly 35% of all waste produced worldwide, Pakistan's specific challenge is compounded by a lack of formal data, regulatory gaps, and a linear "take-make-dispose" culture. Every year, Pakistan generates approximately 49.6 million tons of solid waste, and researchers estimate that **up to 30%** of this is comprised of construction and demolition debris [14]. Despite the potential for circularity, the majority of this waste is either illegally dumped in empty plots or buried in landfills, wasting materials that could otherwise be a resource for sustainable concrete production.

1.1 The Problem: Why CDW is a Crisis In Pakistan

The issue of CDW in Pakistan is not merely one of "messy sites"; it is a systemic failure across economic, environmental, and technical dimensions.

Legislative and Policy Vacuum: Unlike municipal solid waste, which has some (albeit limited) policy focus, CDW exists in a regulatory "grey area." The Pakistan Environmental Protection Act (PEPA) provides a broad framework [16], but specific bylaws for construction waste are largely absent. This lack of enforcement encourages "fly-tipping" the illegal dumping of debris in drains and open spaces which exacerbates urban flooding, as seen in metropolitan hubs like Karachi and Lahore.

The Economic "Double Loss": The Pakistani construction industry often operates on thin margins. Research indicates that the actual cost of waste on a project can be 20 times the cost of disposal [2]. When materials like structural steel, bricks, and concrete are wasted due to poor workmanship (a leading cause of waste in the country), the developer loses twice: first on the cost of the wasted virgin material and second on the cost of hauling it away.

Root Causes of Waste Generation: Based on recent studies the top factors contributing to the CDW crisis in Pakistan include[2], [3]:

- **Poor Workmanship & Lack of Skills:** Inexperienced labor leading to high rework rates and material off-cuts.
- **Design Inefficiencies:** Last-minute changes and faulty drawings that require partial demolition of already constructed elements.
- **Substandard Materials:** Poor quality bricks or concrete that fail during installation, turning instantly into waste.

Environmental Degradation: The environmental footprint is massive. Landfilling CDW leads to soil and water contamination through the leaching of heavy metals. Furthermore, the production of virgin concrete for new projects is a carbon-intensive process. Using 100% natural aggregates is no longer sustainable when the industry contributes significantly to Pakistan's greenhouse gas emissions [2].

Table 1. Impact of CDW in Pakistan

Factor	Impact in Pakistan
Annual Waste Generation	49.6 million Tons (Solid Waste Total)
CDW Contribution	Estimated 25% – 30% of total waste stream
Recovery Rate	Very Low (Mainly informal scavengers)
Primary Disposal	Open dumping / Illegal landfilling

Moving Toward a Solution: Sustainable Concrete: The transition toward utilizing CDW in concrete production is no longer a luxury it is a necessity for Pakistan. By replacing natural aggregates with recycled concrete aggregates (RCA), the industry can reduce the pressure on natural quarries and mitigate the environmental damage caused by dumping. This research aims to explore how these waste materials, currently a burden on Pakistan's urban landscape, can be engineered into high-quality, sustainable concrete, effectively closing the loop in the construction lifecycle.

1.2 Literature Review

Mulenga et al. [1] conducted an extensive investigation into the Zambian construction industry, which, despite contributing significantly to the national GDP at a growth rate of 12% in 2014, faces a severe lack of regulatory framework for construction and demolition waste (CDW). Their research, spanning four provinces, revealed that waste generation typically ranges from 1% to 10%, primarily driven by a lack of technical skills and poor workmanship on-site. The study highlighted a stark disparity in waste utilization, noting that while 36% of stakeholders "rarely" or "never" reuse materials, those in industrial hubs like the Copperbelt and Lusaka show higher engagement. To address this, the authors proposed a project life-cycle framework that emphasizes the need for pre-audits during demolition to maximize material recovery and move beyond the current trend of temporary landfilling.

Zhang et al. [4] applied the Pressure-State-Response (PSR) model to evaluate the comprehensive benefits of CDW recycling in Chongqing, China, marking a significant shift toward multi-dimensional sustainability analysis. Their findings indicated that the introduction of advanced recycling technologies, such as the C2CA process, improved the supply-demand ratio of recycled products to between 0.11 and 0.21. Economically, the study established a benefit-cost ratio of 0.32 to 0.39, proving that technological innovation can drive profitability while simultaneously reducing carbon dioxide emissions by approximately 100,000 tons annually. Socially, the research underscored the industry's role as a job creator, estimating that every 10,000 tons of processed waste supports 1.47 jobs, thereby aligning economic growth with environmental preservation.

Table 2. Impact of CDW Reusage [4]

Indicator	Current State/Impact
Supply-Demand Ratio	0.11 – 0.21
Benefit-Cost Ratio	0.32 – 0.39
Social Benefit	1.47 jobs per 10,000 tons of CDW
CO_2 Reduction	100,000 tons per year (Chongqing case)

Hartell et al. [5] explored the "circular potential" of the United States' largest solid waste stream, focusing specifically on Vertical CDW (VCDW) in Texas. This study broke technical barriers by demonstrating through laboratory testing that concrete mixtures utilizing 100% minimally sorted VCDW as a fine aggregate replacement can achieve the compressive strengths required for non-structural masonry units. Logistically, the researchers utilized seven years of landfill intake data to model a statewide network of 23 reuse facilities capable of capturing 88.4% of landfilled CDW. By distinguishing "Vertical" debris from the more easily recycled "Horizontal" road waste, the authors provided a scalable roadmap for regions where mixed building waste has historically been ignored due to high sorting costs and perceived inferior performance.

Table 3 Summarized Data of the Research's

Region	Primary Drivers	Key Challenges	Management Status
Zambia [1]	Rapid infrastructure growth (Vision 2030)	Lack of specific legislation; poor site skills	Low utilization (1–10%); mainly landfill
China[4]	Massive urbanization (2.3B tons/year)	Illegal dumping; immature recycling technology	Increasing focus on "Pressure-State-Response" models
USA (Texas)[5]	High-volume building demolition	Economic disincentives for "Vertical" CDW	Dominant landfilling (143.8M tons in 2018)

1.3   Research Gap:

Despite the global surge in Construction and Demolition Waste (CDW) research, a critical analysis of existing literature reveals several significant gaps, particularly when transitioning from developed economies to the specific industrial landscape of Pakistan.

Absence of Regional Legislative and Quantitative Frameworks: Global studies emphasize that a robust circular economy is predicated on specific legislation and accurate waste quantification. For instance, in Zambia, CDW management remains a challenge primarily due to the absence of dedicated legislation and the focus of researchers on municipal waste rather than construction debris Mulenga et al [1]. Similarly, in Brazil, while CDW represents 38.2% of the total waste stream, only a tiny fraction returns to construction activities Nunes et al [6]. In Pakistan, there is a profound lack of empirical data regarding the annual volume of CDW generated across major metropolitan hubs like Karachi and Lahore. Current management relies on informal "fly-tipping" rather than the "Pressure-State-Response" models utilized in regions like China to evaluate integrated environmental and social benefits Zhang et al [4]

Technical Optimization for Local Material Compositions: While research in the United States has demonstrated that concrete mixtures using 100% "Vertical" CDW (mixed building debris) as a fine aggregate replacement can achieve sufficient strength for non-structural masonry Hartell et al [5], these findings cannot be directly applied to Pakistan. The Pakistani construction sector is dominated by low-quality clay brick masonry rather than the structural concrete frames common in the West. Existing literature lacks a standardized "mix design" that addresses the interaction between Recycled Brick Aggregate (RBA) and the specific chemical properties of Pakistani cement brands. Furthermore, while review studies suggest that recycled aggregates can generally be used in construction Gunasekar et al ([7], there is a gap in research regarding the long-term durability of such concrete in Pakistan's unique subtropical climate.

Neglect of Specialized Concrete Applications: Innovative uses of CDW are being explored globally, such as in pervious interlocking paving blocks to manage urban drainage Deleprani et al [8]. However, the Pakistani construction industry has yet to adopt these technologies at scale. There is a notable research gap in exploring the technical and economic feasibility of using Pakistani-derived CDW for high-performance applications like geo-polymerization, which has shown promise in South Asian contexts for developing sustainable building materials Pathak et al [9]

Socio-Economic and Informal Sector Integration: The transition from a linear to a circular economy in Pakistan faces unique socio-economic barriers. Unlike the organized waste management systems in Turkey or the EU Alankus et al. n.d.[10], Pakistan's waste is largely handled by an informal sector. Current literature fails to provide a framework for integrating these informal waste-pickers into a formal industrial supply chain for concrete production. Additionally, there is a lack of "Action-Oriented" policy briefs that provide

specific guidelines for local public spaces, a model that has been successfully proposed in other developing regions to bridge the gap between policy and practice. Cárdenas Cleves et al [11]

Summary of the Identified Gap: In summary, while the technical possibility of utilizing CDW is established internationally, the research gap addressed by this study is the lack of a localized, standardized, and socio-economically viable framework for incorporating Pakistani CDW specifically recycled brick and concrete into sustainable concrete production. This study seeks to bridge this gap by providing experimental validation using indigenous materials and proposing a practical pathway for industrial adoption in Pakistan.

1.4   Objectives

The primary objective of this study is to establish a data-driven approach to incorporate Construction and Demolition Waste (CDW) into the local concrete value chain. The objectives of this study can be clearly defined as follows:

- To evaluate the mechanical properties of concrete containing construction and demolition waste as coarse aggregate.
- To compare the construction and demolition concrete with normal concrete.
- To help achieve sustainable construction methods through advocating for recycling within the concrete sector.

2.   Materials Selection and Collection

The primary materials used in this study included Ordinary Portland Cement (OPC), fine aggregate (sand), coarse aggregate, and Construction and Demolition Waste (CDW). All materials were locally sourced from Karachi, Pakistan.

- **Ordinary Portland Cement (OPC)** of Grade 53–60, conforming to ASTM C150 standards, was used as the main binding material. The cement was stored in a dry environment to

prevent moisture absorption and ensure consistent quality throughout the study.

- **Fine aggregate** consisted of natural river sand, which was clean, well-graded, and free of organic impurities, complying with the requirements of ASTM C33 for use in concrete.
- **Coarse aggregate** was obtained from crushed natural stone with a maximum size of 20 mm. Prior to use, the aggregate was cleaned to remove dust and other deleterious materials. The natural coarse aggregate was used as the reference material in control mixes.
- **Construction and Demolition Waste (CDW)** was collected from local construction and renovation sites within Karachi. The waste primarily consisted of crushed concrete, broken bricks, and mortar debris. The collected CDW was manually cleaned to remove dust and foreign particles, crushed using a hammer, and sieved to obtain particle sizes in the range of 10–20 mm, making it suitable for use as a partial replacement for natural coarse aggregate in concrete mixes.
- **Water** used for mixing and curing the concrete was potable and met the requirements of ASTM C1602.

The described materials were utilized to prepare various concrete mixes, where CDW was incorporated at different replacement levels of natural coarse aggregate to evaluate its feasibility in sustainable concrete production [5].

2.1 Mix Design And Sample Preparation

In order to examine the impact of using Construction and Demolition Waste (CDW) as a partial substitute for natural coarse aggregate, concrete mixes were created10%, 20%, and 30% of the total coarse aggregate were taken into consideration as replacement levels. In order to guarantee consistent workability and consistency, the mix designs were created using the ACI mix design procedure, keeping the water-to-cement ratio at 0.45 for every mix [5].

Table 4. The mix proportions for the different CDW replacement levels

Mix ID	Cement (kg/m³)	Sand (kg/m³)	Coarse Aggregate (kg/m³)	CDW Replacement (%)	Water (kg/m³)
M10	437.5	812.5	1500	10%	197.5
M20	437.5	812.5	1500	20%	197.5
M30	437.5	812.5	1500	30%	197.5

Each mix was prepared in batches sufficient to cast cylinders of **150 mm × 150 mm × 300 mm**, as well as beams for compressive, split tensile, and flexural strength testing at different ages (7, 28, 90, 180, and 365 days).

Cement, sand, coarse aggregate, and the specified quantity of CDW were manually mixed in a clean tray as part of the preparation procedure. To get a consistent consistency, water was added gradually while mixing. After mixing, three layers of freshly mixed concrete were put into molds, and each layer was tamped 25 times to eliminate any air spaces. When a vibration table was available, it was used. After a day, the molds were covered with plastic sheets and demolded.

Before testing, the samples were cured for the necessary amounts of time in potable water at room temperature This methodology ensured consistency across all mixes and replacement levels, allowing for a systematic evaluation of the effect of CDW on concrete performance.

2.2 Mixing, Casting, And Curing Procedure

The concrete mixes were prepared manually to ensure uniform distribution of the constituents [12]. The procedure involved the following steps:

1. **Dry Mixing:** Cement, sand, coarse aggregate, and the designated percentage of CDW were thoroughly mixed in a clean, dry tray to achieve a uniform blend.
2. **Water Addition:** Potable water was added gradually while mixing to achieve the desired workability and consistency. The water-to-cement ratio was maintained at 0.45 for all mixes.
3. **Molding:** The fresh concrete was placed into the molds in three layers, with each layer being tamped **25 times** using a tamping rod to remove air pockets. Where available, a **vibration table** was employed to further eliminate entrapped air.
4. **Initial Curing:** After filling the molds, the concrete specimens were covered with plastic sheets to prevent moisture loss and were demolded after 24 hours.
5. **Water Curing:** The demolded specimens were immersed in clean, potable water at room temperature for the required curing periods of 7 and 28 days before testing. Extended curing was carried out for additional ages (90, 180, and 365 days) for long-term evaluation of concrete properties.

This procedure ensured that all concrete specimens, including those with varying CDW replacement levels, were prepared under consistent and controlled conditions, providing reliable and reproducible results for subsequent mechanical testing.

2.3 Testing Procedure

To evaluate the performance of concrete containing Construction and Demolition Waste (CDW), several standard tests were conducted following recommended procedures [12], [13].

2.3.1 Compressive Strength Test:

- Follows the procedure in ASTM C39 using 150mm cubes.
- Specimens are subjected to 7 and 28-day curing periods in order to observe the gain in compressive strength with age.
- A compression testing machine with a 2000kN capacity is used in the experiment.

Procedure: The cube specimens are removed from the curing tank and dried at room temperature prior to the experiment. To remove any unwanted moisture and impurities, the surfaces of the specimens are cleaned. To ensure proper loading, each cube specimen is placed in the middle of the compression testing machine. The loading is done slowly and without shock until the specimen fails. The reading on the machine is used to determine the maximum load at failure. By dividing the failure load by the area of the cube, the compressive strength is obtained. The ultimate value of compressive strength is obtained by averaging the values of specimens [13].

2.3.2 Workability (Slump) Test:
- It is carried out to determine the consistency and flow of fresh concrete.
- It is carried out following standard procedures, ensuring that all the mixtures are handled in the same way.

Procedure: A standard slump cone was placed on a smooth, non-absorbent surface, and the test was carried out. Three equal amounts of fresh concrete were placed in the cone, and 25 tamps were given to each amount using a tamping rod to prevent air spaces in the concrete. The cone was then filled completely, and the top of the concrete was leveled. The cone was lifted vertically, and the decrease in height of the concrete was measured using a scale as it subsided. The slump was the difference in height between the initial height of the cone and the final height of the concrete. The procedure had to be repeated for all the mixtures to ensure consistency in the results [13].

2.3.3 Water Absorption Test:
- Conducted with the objective of evaluating the porosity as well as the durability potential of the concrete with CDW.
- The curing of the specimens was done as per the procedure followed in Section 2.3, followed by the water absorption test.

Procedure: The concrete specimens were removed from the curing tank and left at room temperature to dry after the completion of the curing period. The concrete specimens were then placed in the oven at 105 ± 5°C for 24 hours in order to obtain the oven-dry weight of the specimens. The specimens were removed from the oven, left to cool, and then the dry weights were recorded by using a digital balance. The concrete specimens were then left submerged in pure water for a day. The concrete specimens were removed from the water, dried with a cloth, and then weighed again in order to obtain the saturated weights of the specimens. The water absorption percentage was obtained by determining the difference between the saturated weights and the dry weights with respect to the dry weights of the specimens [13].

All the tests were conducted under a controlled environment, i.e., the laboratory. This helped in maintaining the consistency of the tests carried out on all the mix designs at various replacement levels. This helped in the reliability of the test results obtained from the tests conducted on the concrete mixes with varying CDW contents.

3. Thorough Review Of Concrete Compressive Strength
The report is a synthesis of experimental data obtained to determine the performance of concrete in the presence of different amounts of Construction and Demolition Waste (CDW) used as an alternative to conventional aggregates.

Table 1: Compressive Strength Results of Concrete Mix

Waste Replacement (%)	7-Day Strength (MPa)	28-Day Strength (MPa)	Strength Gain (%)
20%	22.44	32.01	42.60%
40%	20.79	33.12	59.30%
60%	17.82	27.28	53.10%
80%	15.73	27.12	72.40%
100%	14.19	22.11	55.80%

The following table shows the main results of compressive strength at two critical points of curing (7 days and 28 days), as tested using a 2000 k N Capacity Compression Testing machine (CTM) according to C39
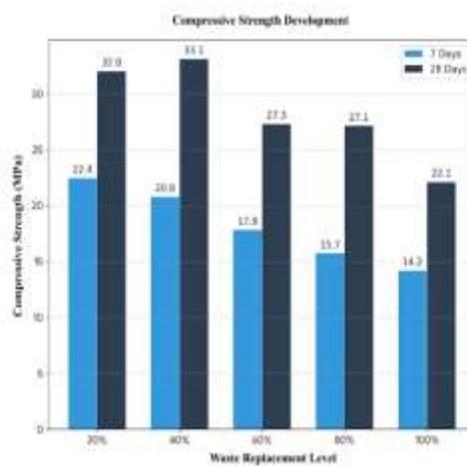

Fig. 1: Representing Compressive Strengths and Waste Replacement Level

3.1 Statistical Performance Metrics

Statistical analysis is essential in civil engineering, as we want to be able to compare the overall competence of the various levels of replacement without necessarily becoming mired in the individual sample variations. High SD would indicate that the C&D waste is not mixed uniformly, and there are weak points in the concrete matrix

Average (Mean): This provides the "typical" performance of the batch.
- **7-Day Average:** 18.19 MPa
- **28-Day Average:** 28.33 MPa

Standard Deviation (SD): This measures the "spread" or inconsistency in the data.
- **7-Day SD:** 3.07 MPa
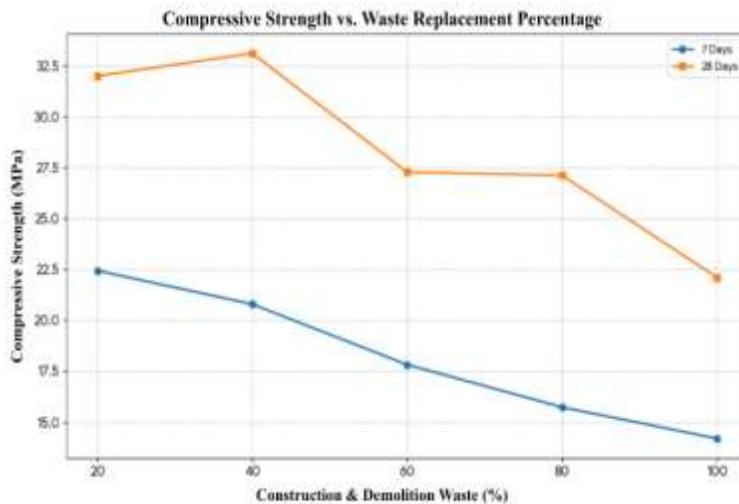- **28-Day SD:** 3.94 MPa

Fig. 2: Representing Strength vs. Replacement Percentage

The graph demonstrates a strong negative relationship between replacement and compressive strength on day 7. Nevertheless, at 28 days, it becomes evident that at 40% replacement, the highest strength of 33.12 MPa is recorded, which is better than the 20% replacement. This implies that the amount of C&D waste can result in the optimal hydration of the particle packing of the concrete mix at late stages.
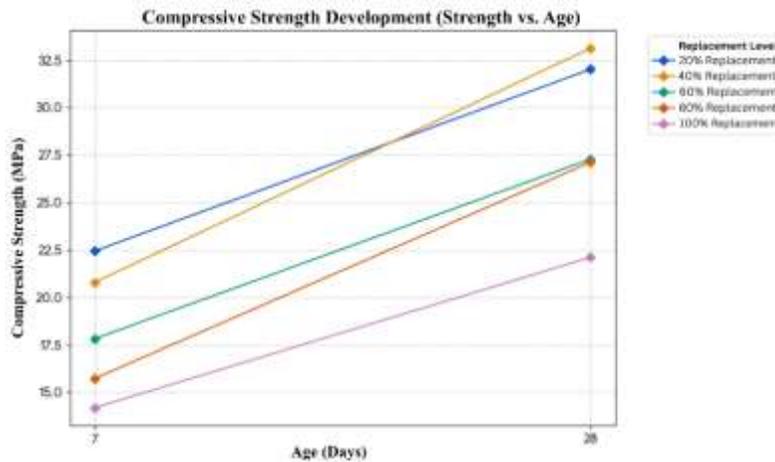

Fig. 3: Graph Representing Compressive Strength Development at Different Stages

The graph represents the maturity of the concrete. Although all mixes begin at various baselines at 7 days, the percentage of growth of 80 percent replacement mix was the largest one (+72.4%). This implies that concrete mixes that have high recycled contents may take longer durations to attain its full structural potential than the conventional mixes.

4. DISCUSSION & ANALYSIS
4.1. Interpretation Of Graphs and Tables
The experimental results provide a clear understanding on how the use of Construction and Demolition Waste (CDW) affects the compressive strength of concrete. The relationship between CDW replacement and strength is not linear and varies with curing time.

In Table 1, at 7 days of curing, a steady decrease in compressive strength is observed as the percentage of CDW increases. The strength drops from 22.44 MPa at 20% CDW to 14.19 MPa at 100% replacement with CDW. This indicates that the higher content of CDW negatively impacts early-age compressive strength of concrete. The graphical representation of same Table 1 is provided in Fig. 1, and the trend also provides the visual data that the compressive strength in 7 days curing decreases with the increase of CDW material, showing a strong negative relationship between replacement percentage of CDW material and Compressive strength of concrete at 7 days of curing.

However, In table 1 the compressive strength of concrete changes at 28 days of curing. The compressive strength improves significantly with curing time for all mixes. The most optimum result is at 40% replacement with CDW material, where the concrete achieves the highest strength of 33.12 MPa at 28 days of curing. From this point onwards, the strength begins to decline, reaching 22.11 MPa at 100% replacement. This indicates that there is an optimum replacement level around 40%, where the hydration of the particle packing of the concrete mix at late stages.

The strength development percentage in Table 1 shows that mixes with higher CDW content gain strength more gradually. For instance, the 80% replacement mix shows a strength increase of about 72.4% between 7 and 28 days.

The statistical results shown in Fig. 2 also support these observations. The average 28-day strength is 28.33 MPa, which indicates that the average 28 days compressive strength of CDW at various percentages is similar to the traditional aggregates, while the standard deviation of 3.94 MPa suggests moderate variation in the results. This variation is expected due to the non-uniform nature of CDW materials.

Fig. 3 illustrates the development of compressive strength of concrete mixes containing different percentages of Construction and Demolition Waste (CDW) between 7 days and 28 days of curing.

The graph shows that all mixes gain strength over time, which is due to the continued hydration of cement. The rate of strength gain varies significantly depending on the percentage of CDW used.

The most notable observations is that mix with higher CDW content, exhibit the highest percentage increase in strength (approximately 72.4%) over time. This behavior indicates the delayed strength development associated with recycled aggregates.

In general, CDW aggregates are more porous and tends to absorb water during mixing. This absorbed water is gradually released during the curing period, which promotes continued hydration of cement at later stages. As a result, these mixes show relatively slower strength gain at early ages but improved strength development over time.

Despite this significant percentage increase, it is important to note that mixes with higher CDW content still achieve lower absolute strength compared to mixes with moderate replacement levels. For example, although the 80% mix shows rapid growth, its final strength remains lower than the optimum 40% mix.

In contrast, mixes with lower CDW content (such as 20% and 40%) exhibit higher initial strength and more stable strength development.

In summary, Figure 3 highlights that higher CDW content leads to delayed but accelerated strength development, while lower to moderate replacement levels provide better overall strength performance. This behavior reflects the influence of material properties such as porosity, water absorption, and bonding characteristics of CDW aggregates.

4.2. Reasons For Strength Reduction At Higher CDW Percentages

Although moderate amounts of CDW improve performance, a noticeable drop in strength occurs when the replacement exceeds 60%. This can be explained by several material-related factors.

One of the main reasons is the weak bonding between CDW aggregates and the cement paste. Since CDW particles often have old mortar

attached to them, they form a weaker Interfacial Transition Zone (ITZ). As the proportion of CDW increases, this weak zone becomes more dominant, which reduces the overall strength of the concrete.

Another important factor is the higher porosity of CDW aggregates. These materials tend to absorb more water, which can lead to internal voids and reduce the effectiveness of the water-cement ratio. As a result, the concrete becomes less dense and weaker in initial stage.

In addition, CDW aggregates are usually irregular in shape and may contain microcracks from the crushing process. These imperfections act as weak points within the concrete and make it more prone to failure under load.

At higher replacement levels, the role of natural aggregates is significantly reduced. Since natural aggregates provide strength and stability to concrete, their reduction leads to a decrease in overall performance. This is why mixes with very high CDW content show lower compressive strength and are generally not suitable for structural use.

4.3 Comparison with Literature

The results of this study are generally in line with the findings reported in previous research, while also highlighting some differences due to local conditions.

Mulenga et al. [1] pointed out that poor workmanship and lack of uniformity in materials can affect the performance of CDW. This is reflected in the current study through the observed variation in strength values.

Zhang et al. [2] emphasized that proper processing and controlled use of CDW can improve its performance in concrete. The identification of an optimum replacement level at 40% supports this idea, showing that CDW can perform well when used in the right proportion.

Hartell et al. [3] demonstrated that even high percentages of CDW can be used in concrete for non-structural purposes. This is consistent with the present results, where higher replacement levels (such as 80% and 100%) show lower

strength but may still be suitable for applications where high strength is not required.

Similarly, Gunasekar et al. [5] concluded that partial replacement is effective, but excessive use of recycled aggregates reduces strength due to weaker internal structure. This matches the trend observed in this study, where strength decreases beyond 60% replacement.

An important point to note is that many studies suggest an optimum range of 20% to 30%, whereas this study identifies 40% as the best-performing level. This difference supports the research gap identified in the literature, which highlights the need for region-specific studies. In Pakistan, the composition of CDW, especially the presence of brick-based materials, may influence the results and lead to a different optimum value.

5.CONCLUSION

The study was able to explore the possibility of using Construction and Demolition Waste (CDW) as a partial substitute to natural coarse aggregates in concrete use, in terms of industrial and environmental settings in Karachi in Pakistan. The experimental results present a number of critical regional issues in terms of structural and sustainable performance of the CDW integrated concrete

5.1 Optimal Replacement Level

The research determines that the most effective CDW replacement level is 40 which is the most efficient between structural integrity and sustainability. At this level, the compressive strength of the concrete of 33.12 MPa at the end of 28 days of curing is very high compared to the level of the 20% replacement mix.

5.2 Strength Development Dynamics

The nature of the relationship of concrete and compressive strength is non-linear at this level and it is also more affected by the curing time. Although an increase in CDW content has a negative effect on strength at early age (7-day performance), this effect is highly enhanced at an advanced age. This is because recycled aggregates are porous and thus absorb water during mixing

and release it gradually to ensure further hydration of cement takes place over time.

5.3 Performance Thresholds

Although moderate replacement is desirable, there is a noted tipping point. Compressive strength starts to decrease drastically after 60% replacement as it is below the 25-30 MPa range of normal structural work. Maturity and Growth Potential: Interestedly the maximum percentage change of the 80 percent replacement mix was recorded at 22.11 MPa.

5.4 Maturity and Growth Potential

Interestingly, the maximum percentage change was recorded at 22.11 MPa at 7 to 28 days at 80 percent replacement mix. This indicates that although high-recycled-content mixes require more time to realize their potential, they could be applicable to non-structural projects or applications with sufficient time to cure.

5.5 Sustainability and Regional Impact

This study would offer a viable roadmap to circularity in the construction industry of Pakistan because it demonstrates that high-recycled-content mixes can be developed into high-quality concrete. Urban centers such as Karachi face the environmental catastrophe of fly-tipping at construction sites and the replacement rate of 40 percent is the best way to reduce the carbon footprint of the industry and overcome the environmental crisis. Although high replacement will decrease absolute strength as it will be more porous and weaker in interior bonding, 40 percent controlled replacement will provide an eco-friendlier alternative to traditional concrete, without affecting the structural integrity.

REFERENCE:

[1] Michael N Mulenga, "Factoring construction and demolition waste in the Zambian construction industry," *Global Journal of Engineering and Technology Advances*, vol. 11, no. 2, pp. 102–112, May 2022, doi: 10.30574/gjeta.2022.11.2.0089.

[2] M. Alhawamdeh, J. A. Ferriz-Papi, and A. Lee, "Examining the Drivers to Support Improved Construction and Demolition Waste Management for a Circular Economy: A Comprehensive Review Using a Systematic Approach," Jul. 01, 2024, *Multidisciplinary Digital Publishing Institute (MDPI)*. doi: 10.3390/su16146014.

[3] H. Arshad, M. Qasim, M. J. Thaheem, and H. F. Gabriel, "Quantification of material wastage in construction industry of Pakistan: An analytical relationship between building types and waste generation," *Journal of Construction in Developing Countries*, vol. 22, no. 2, pp. 19–34, 2017, doi: 10.21315/jcdc2017.22.2.2.

[4] H. Zhang, S. Shi, F. Zhao, M. Hu, and X. Fu, "Integrated Benefits of Sustainable Utilization of Construction and Demolition Waste in a Pressure-State-Response Framework," *Sustainability (Switzerland)*, vol. 16, no. 19, Oct. 2024, doi: 10.3390/su16198459.

[5] J. A. Hartell, B. L. Jones, and A. Aryal, "Unlocking the Circular Potential of Construction and Demolition Waste: A Pathway for Texas' Construction Industry." [Online]. Available: https://doi.org/

[6] K. R. A. Nunes and C. F. Mahler, "Construction & Demolition Waste and Circular Economy: The Case Study of a Brazilian City," *Recent Prog. Mater.*, vol. 06, no. 04, pp. 1–20, Dec. 2024, doi: 10.21926/rpm.2404029.

[7] S. Gunasekar, N. Ramesh, and G. Shivani, "Effective Utilisation of Construction and Demolition Waste (Cdw) As Recycled Aggregate in Concrete Construction – A Critical Review," *International Research Journal of Multidisciplinary Technovation*, vol. 1, no. 6, pp. 465–469, Nov. 2019, doi: 10.34256/irjmtcon65.

[8]   F. B. Deleprani, R. V. da Silva, and G. S. Araújo, "Pervious concrete using construction and demolition waste (CDW) and recycled EPS," *Revista Materia*, vol. 30, p. NAe20, 2025, doi: 10.1590/1517-7076-RMAT-2025-0216.

[9]   A. Pathak, S. Kumar, and V. K. Jha, "Development of Building Material from Geopolymerization of Construction and Demolition Waste (CDW)," *Transactions of the Indian Ceramic Society*, vol. 73, no. 2, pp. 133–137, 2014, doi: 10.1080/0371750X.2014.922429.

[10]   B. Alankus, R. Gokturk, D. Kirlak, and N. Cosgun, "Construction and Demolition Waste (CDW) Management with a Circular Economy Approach: Current Situation, Opportunities and Challenges in Türkiye."

[11]   L. M. Cárdenas Cleves, A. M. Muñoz Chávez, Á. M. Franco-Calderón, C. D. Acevedo Sánchez, and L. Arango Vásquez, "Use of construction and remolition waste (CDW) in public spaces," Dec. 2024. doi: 10.25100/policy-briefs.PB.14-eng.

[12]   Dr. Gul Muhammad, Abdul Rehman, Dr. Abdul Aziz Ansari, and Dr. Mirza Munir Ahmed, "CONSOLIDATION BEHAVIOR OF SOIL STABILIZED WITH CEMENT: EXPERIMENTAL ANALYSIS OF ROHRI CANAL'S SOIL (PAKISTAN)," 2026, doi: 10.5281/zenodo.18951294.

[13]   Abdul Rehman, Saira Sidhu, and Mohsin Ali, "EFFECT OF NAOH MOLARITY ON THE COMPRESSIVE STRENGTH OF CORN COB ASH-BASED GEOPOLYMERS WITH LIMESTONE POWDER ADDITIVES", doi: 10.5281/zenodo.18844693.

[14]   International Trade Administration. (2024, January 4). *Pakistan - Waste Management*. Official Guide of the U.S. Department of Commerce. https://www.trade.gov/country-commercial-guides/pakistan-waste-management

[15]   Pakistan Bureau of Statistics. (2023). *7th National Population and Housing Census: Main Results Report*. Government of Pakistan. https://www.pbs.gov.pk/content/final-results-census-2023

[16]   Government of Pakistan. (1997). *The Pakistan Environmental Protection Act (PEPA), 1997*. Act No. XXXIV of 1997. http://www.environment.gov.pk/images/Laws/PEPAAct97.pdf