DCEA DISASTER IN CIVIL ENGINEERING AND ARCHITECTURE

POPULAR SCIENTIST

RESEARCH ARTICLE

Compressive Strength and Economic Evaluation of Concrete with Partial Replacement of Coarse Aggregate by Recycled Aggregate

Abdul Awol Rabby*, Imon Hasan Bhuiyan, Uzzal Al Aziz, Md Hasan Imam Siddique, Md.Al Amin, Abhijit Nath Abhi

Department of Civil Engineering, Faculty of Science, Dhaka Internaational University, Dhaka-1212, Bangladesh

***Corresponding Author:** Abdul Awol Rabby (abdulawoal045@gmail.com)

Articles History: **Received:** 3 October 2025; **Revised:** 16 October 2025; **Accepted:** 24 October 2025; **Published:** 29 October 2025

ABSTRACT

The depletion of natural aggregates and the rising volume of construction and demolition waste have made sustainable alternatives in concrete production essential. Recycled coarse aggregate (RCA) helps reduce landfill use and reliance on natural resources, but its variable quality raises concerns about structural reliability. Therefore, evaluating the balance between mechanical performance and economic feasibility is crucial for promoting sustainable construction. In this study, concrete mixes were designed with varying RCA replacement levels (0%, 50%, 70%, and 100%) compared to natural coarse aggregate (NCA). A controlled mix proportion of 1:1.5:3 (cement:sand:aggregate) with a water–cement ratio of 0.5 and 1% superplasticizer was employed. To ensure consistency, aggregates were classified into 19 mm (40%), 12.5 mm (30%), and 9.5 mm (30%) gradations. Cylindrical specimens (100 × 200 mm) were cast and cured, followed by compressive strength testing at 7, 14, and 28 days in accordance with ASTM C39. The total material cost for each mix was also computed on a per-cubic-meter basis to assess economic implications alongside strength performance. The results highlight a clear strength–cost trade-off. The control mix (100% NCA) achieved 26.5 MPa at 28 days, while the 50% RCA mix showed only a 3.92% reduction (25.5 MPa) with 18.4% lower cost. At 70% RCA, compressive strength dropped by 10.42% (24 MPa) with a 28.29% cost reduction, whereas 100% RCA replacement resulted in a severe 59.63% strength loss (16.5 MPa) despite maximum cost savings (49.07%). These findings establish 50% RCA + 50% NCA as the most rational compromise, offering structural adequacy with substantial cost efficiency, while also reinforcing RCA's role in sustainable construction.

Keywords: Aggregate Replacement Ratio, Cost-Effective Concrete, Compressive Strength, Recycled Aggregate Concrete, Sustainable Concrete

INTRODUCTION

Concrete is a composite material obtained by allowing a carefully proportioned mixture of cement, fine aggregate, coarse aggregate, and water to harden into the desired shape. Fine aggregates typically include sand and surki, while coarse aggregates commonly comprise brick chips or crushed stone. The rapid growth of new construction, renovation, reconstruction, repair, demolition activities, and infrastructure development has led to a substantial rise in construction and demolition waste (CDW) generation. If it is not managed effectively, these large volumes of CDW can pose significant environmental challenges [1]. The worldwide demand for construction aggregates in 2015 was estimated to be approximately 48.3 billion metric tons [2].

In response to these challenges, recycling CDW into useful materials such as recycled aggregates and crushed stone has emerged as a sustainable alternative and significantly lowers the carbon footprint as well [3]. Recycled aggregates, derived from previously used concrete or masonry, can produce concrete with strength and durability comparable to conventional concrete [4]. These aggregates consist of crushed, graded inorganic particles obtained from demolished buildings, roads, bridges, and, in some cases, disaster debris. On the otherhand, with increasing infrastructure development, the demand for natural aggregates continues to rise, making the utilization of recycled aggregates critical for resource conservation and waste management [5]. Using recycled aggregates not only reduces the consumption of natural resources but also lowers the cost of waste disposal and mitigates landfill pressure [6].

However, the incorporation of RCA in concrete production is not a recent practice; it originated after World War II, when massive building demolitions generated substantial waste, while at the same time there was an urgent demand for new infrastructure and road construction [7]. Historical evidence shows that road stones were reused since Roman times, and the recycling industry has been well established in Europe since World War II [8]. In the 1980s, crushed old concrete was widely used for road construction in Michigan, USA [9]. Despite its long history, the application of recycled aggregates in structural concrete continues to gain research attention due to its potential for sustainable construction and cost-effective infrastructure development.

Despite growing interest in sustainable construction, the widespread use of RCA in structural concrete remains limited due to concerns about its inconsistent quality and the resulting reduction in mechanical performance. These uncertainties make it difficult for engineers and policymakers to confidently adopt RCA as a reliable alternative to natural aggregates. Considering this challenge, the present study aims to evaluate how different proportions of RCA influence the structural performance of concrete. Specifically, it seeks to evaluate the compressive strength of concrete mixes containing 50%, 70%, and 100% RCA as replacements for natural aggregates; secondly, to compare the mechanical behavior of recycle aggregate concrete (RAC) with that of conventional natural aggregate concrete (NAC); and lastly, to determine the most practical and sustainable RCA replacement level that balances strength and cost benefits for structural use.

Materials and Methodology

The primary constituents of concrete used in this study are aggregates, binding materials, and water [10]. Aggregates play a critical role in determining the strength, durability, and workability of concrete [11]. They must possess adequate strength, resistance to weathering, and a surface free from impurities such as loam, silt, or organic matter that may weaken the bond with cement paste. Furthermore, aggregates should not exhibit any adverse chemical reactions with the cement.

Cement and Mix Ratio

Ordinary Portland Cement (OPC), manufactured by Crown Cement PLC, was used as the binding material throughout this research. Crown Cement OPC conforms to Bangladesh Standard (BDS EN 197-1:2003) and ASTM C150 Type I specifications, ensuring consistent quality and reliability for structural concrete specially for the compression member in building.

The compression member typically has a strength of at least 20 MPa and is thought to be stronger than the other structural elements of the building. In order to account for the higher absorption capability of RCA water–cement ratio of 0.5, the concrete mixes were designed as M20 grade with a mix ratio of 1:1.5:3 (cement:sand:coarse aggregate). To achieve the target slump of 70 mm and improve workability to remove honeycomb effect, 1% superplasticizer was added to all mixes. Maintaining constant cement content, water–cement ratio, and admixture dosage ensured that any variations in compressive strength or cost could be attributed solely to the replacement of NCA with RCA.

Collection and Characterization of Recycled Coarse Aggregate (RCA)

The RCA used in this study was obtained from the demolished reinforced concrete columns of an residential building located in Bashundhara Residential Area, Dhaka, Bangladesh. The demolished concrete was carefully selected from structural members (columns) to ensure that the aggregates were of relatively better quality compared to non-structural demolition debris. The method of demolishing reinforced concrete columns using a hydraulic hammer and the RCA's collection yard is depicted in Figure 1.

Figure 1. Collaction of column demolished aggregate (Location: Bashundhara RA, Dhaka)

https://doi.org/10.70028/dcea.v2i2.65

Preliminary Cleaning, Drying and Storage

After collection, the RCA was manually broken down into smaller pieces using a hammer and chisel. Adhered mortar, dust, and foreign impurities such as soil, plaster, and reinforcement fragments were carefully removed and cleaned. Then several tests were done both for collected NCA and RCA to get the comparison which have been discussed and illustrated in the following tables and graphs in this study.

Before use, RCA was air-dried to a saturated surface dry (SSD) condition and stored in covered bins to maintain consistent moisture content and prevent contamination. Proper drying and storage are essential because RCA has higher water absorption due to adhered mortar, which can affect workability, strength, and durability if uncontrolled [12]. Standardizing this step ensured that observed variations in concrete performance were solely due to RCA replacement levels, improving the reliability of the results.

Experimental

Characterization of NCA, RCA and Sand

To characterize the physical properties of RCA, several standard tests were conducted along with the NCA and fine aggregate (Sylhet sand). The Water Absorption Test was performed according to ASTM C127 to determine the water absorption capacity of aggregates. The Specific Gravity Test, also following ASTM C127, was carried out to obtain the apparent and bulk specific gravity of the aggregates. The Unit Weight (Bulk Density) Test was determined according to ASTM C29 to evaluate both the compacted and loose unit weights. Additionally, Sieve Analysis (Gradation Test) was conducted in accordance with ASTM C136 to determine the particle size distribution and ensure compliance with grading requirements.

Table 1. Different properties of Sylhet sand, NCA and RCA

Property	Fine Aggregate (Sylhet Sand)	Coarse Aggregate – Natural Stone Chips	Coarse Aggregate – Recycled Aggregate
Fineness Modulus (F.M.)	2.67	8.04	8.12
Maximum Particle Size (mm)	4.75	20	20
Specific Gravity	2.64	2.64	2.24
Bulk Specific Gravity (S.S.D.)	2.48	2.43	2.1
Dry Rodded Unit Weight (kg/m^3)	1645	1684	1589
Water Absorption Capacity (%)	1.23	1.25	4.13

From the Table 1 the physical characterization of the aggregates revealed notable differences between natural and recycled materials. Sylhet sand exhibited a fineness modulus of 2.67, whereas natural and recycled coarse aggregates recorded higher values of 8.04 and 8.12, respectively, consistent with their larger particle sizes (20 mm compared to 4.75 mm for fine aggregate). Both Sylhet sand and natural coarse aggregate had a specific gravity of 2.64, while the recycled aggregate showed a lower value of 2.24, reflecting its porous nature. A similar trend was observed for bulk specific gravity (SSD), with RCA

https://doi.org/10.70028/dcea.v2i2.65

recording the lowest (2.10) compared to 2.48 for fine and 2.43 for natural coarse aggregates. The dry rodded unit weight of RCA (1589 kg/m³) was also lower than that of natural aggregates (1684 kg/m³). Water absorption capacity showed the most significant variation, with RCA exhibiting 4.13%, considerably higher than that of Sylhet sand (1.23%) and natural coarse aggregate (1.25%), indicating the influence of residual mortar and higher porosity in recycled materials.

Description of Aggregate Gradation Based on Fineness Modulus (FM)

Sieve analysis results for Sylhet sand, NCA, and RCA showed clear differences in gradation. The calculated fineness modulus (FM) values were 2.67 for Sylhet sand, 8.04 for NCA, and 8.12 for RCA, reflecting their distinct particle size distributions which are illustrated in Figures 2 to 4.

Sylhet sand was dominated by medium-to-fine fractions, with 41.3% retained on the 0.6 mm sieve and 25.6% on the 1.18 mm sieve, placing it within the well-graded fine aggregate range. NCA showed a coarser distribution, with 47.8% retained on the 19 mm sieve, 25% on 12.7 mm, and 15.3% on 9.5 mm, leaving only 4.4% finer content. RCA followed a similar pattern but with slightly coarser gradation: 54.8% was retained on the 19 mm sieve, 19.7% on 12.7 mm, and 14.6% on 9.5 mm, resulting in a marginally higher FM (8.12).

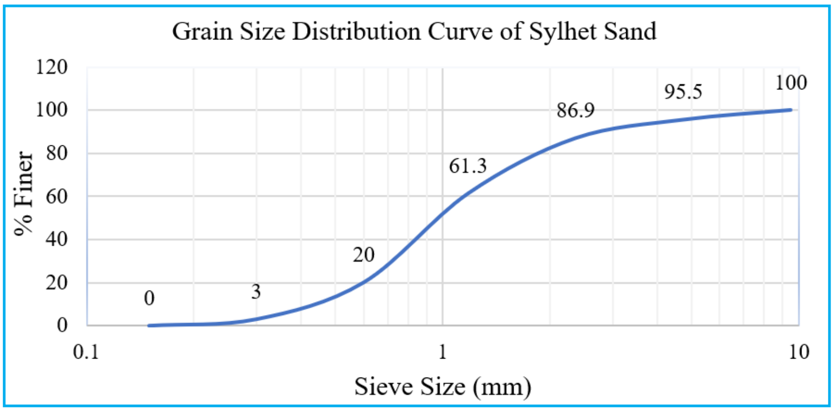

Figure 2. Grain size distribution curve of Sylhet sand

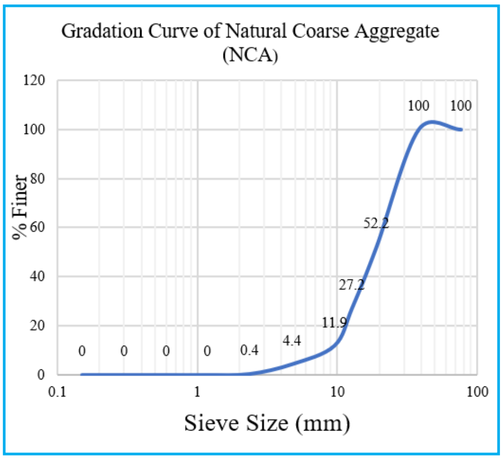

Figure 3. Gradation curve of NCA

https://doi.org/10.70028/dcea.v2i2.65

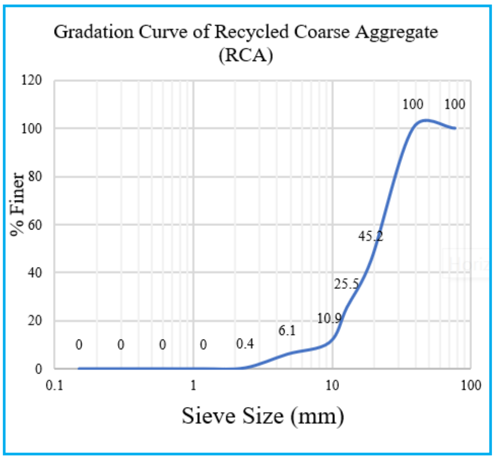

Figure 4. Gradation curve of RCA

However, Sylhet sand provides a fine, well-graded matrix, whereas NCA and RCA form the coarse skeleton of concrete [13]. The slightly higher FM of RCA suggests a coarser distribution, likely due to adhered mortar and irregular particle shape, which may influence concrete workability and performance. However, in order to mitigate this obstacle a batching has been done on weight based mixing of 40, 30 and 30 percent of required quantity in 19mm, 12.5mm and 9.5mm of aggregate respectively so that the mix get better compacted ressult. Details procedure has been discussed in the following sections.

Gradation and Batching

After characterization, the RCA was separated into different fractions using standard sieves. For this study, the aggregates were batched into three retained fractions: 19 mm (3/4 in), 12.5 mm (1/2 in), and 9.5 mm (3/8 in) sieve retained. This fractioning ensured a well-graded aggregate system for concrete production and allowed a direct comparison between RAC and NAC.

Batching involves accurately measuring and proportioning concrete components cement, fine and coarse aggregates, water prior to mixing [14]. While batching can be done by volume or by weight, modern standards favor weight-based batching for better precision and consistency, especially in structural concrete. In this study, as shown in Figure 5, all materials were batched by mass to maintain accurate mix proportions and ensure reliable experimental outcomes.

Figure 5. Weigth based batching of aggregate, sand and cement

https://doi.org/10.70028/dcea.v2i2.65

Table 2 summarizes the weight batching used for preparing concrete cylinders with different percentages of RCA. A uniform mix ratio for M20 grade of 1:1.5:3 (Cement:Sand:Coarse Aggregate) was applied across all batches , with a constant water–cement ratio 0.5 as per the experimental design. To reduce the additional water requirement and 70mm slump, 1% sika pasticizer was applied which worked to improve the workability of mix as well as the strength of concrete. However to make a better understanding of comparison between NCA and RCA and to maintain the well graded ratio both the RCA and NCA were taken as 19mm aggregate 40%, 12.5mm aggregate 30% and 9.5mm aggregate 30% on weight basis. When mixed of RCA and NCA was used the aggregate was batched in the same proportion for required mass. For different percentage replacement of NCA with RCA 4inch by 8inch cylinders were made considering 3 days, 7 days and 28 days testing. Detailed quantity is provided in the Table 2 below. The total casting for nine cylinders in each mix ID is 0.52 cft and after considering 1.5 times shrinkage factor and individual unit weight the materials requirements are found.

Table 2. Quantity of cement, sand , RCA and NCA for nine (4’’×8’’) cylinder casting

Mix ID	Number of Cylinders	Casting Quantity (cft)	Cement (kg)	Sand (kg)	Sand				Sand			
					40% 19mm (kg)	30% 12.5mm (kg)	30% 9.5mm (kg)	Total (kg)	40% 19mm (kg)	30% 12.5mm (kg)	30% 9.5mm (kg)	Total (kg)
0% RCA+ 100% NCA	9	0.52	5.71	10.20	-	-	-	-	8.16	6.12	6.12	20.4
50% RCA+ 50% NCA	9	0.52	5.71	10.20	3.85	2.89	2.89	9.63	4.08	3.10	3.10	10.28
70% RCA+ 30% NCA	9	0.52	5.71	10.20	5.39	4.04	4.04	13.47	2.45	1.84	1.84	6.13
100%RCA+ 0% NCA	9	0.52	5.71	10.20	7.70	5.77	5.77	19.24	-	-	-	
Total	**36**	**2.08**	**22.84**	**40.80**	**16.94**	**12.70**	**12.70**		**14.69**	**11.06**	**11.06**	

Final Preparation for Casting

Before casting, the RCA was pre-soaked in water for 24 hours to account for its relatively high water absorption. The aggregates were then surface-dried to the saturated surface-dry (SSD) condition in accordance with ASTM C128, minimizing inaccuracies in the effective water–cement ratio during concrete mixing [15].

Concrete Mixing, Compaction, and Curing

In this study, concrete was mixed manually as shown in the Figure 6, due to the small batch size, which is acceptable for research purposes provided uniformity is maintained, although ASTM C192 generally recommends mechanical mixing [16]. The dry constituents were thoroughly blended until uniform, after which water and admixture were added gradually to achieve a homogeneous mix within 10–12 minutes. Fresh concrete was then cast immediately into standard cylindrical molds (100mm×200mm) prepared in accordance with ASTM C470.

https://doi.org/10.70028/dcea.v2i2.65

Compaction was carried out as per ASTM C31 and ACI 309R-05 guidelines, where specimens were filled in three layers and each layer was tamped 25 times using a standard rod to eliminate air voids and ensure proper density [17].

Figure 6. Casting and molding procedure of cylinder specimens

Curing was performed following ASTM C511 by demolding the specimens after 24±2 hours and immersing them in water maintained at 23±2°C. Pond curing ensured continuous hydration and minimized shrinkage, with specimens cured for 7, 14, and 28 days, the latter being the benchmark age for strength evaluation.

Results and Discussion

Compressive Strength Test

The compressive strength of concrete was evaluated in accordance with ASTM C39 Standard. Test Method for Compressive Strength of Cylindrical Concrete Specimens. Cylindrical specimens of 100 mm diameter × 200 mm height (4 in × 8 in) were prepared and cured in water for specified durations of 7, 14, and 28 days.

Prior to testing, each specimen was removed from the curing tank, surface-dried to remove excess moisture, and then weighed. The test was performed using a Universal Testing Machine (UTM) with 1000 kN capacity, ensuring proper alignment of the specimen along the loading axis to avoid eccentric loading.

The load was applied continuously and without shock at a rate of 0.25±0.05 MPa/s, as prescribed in ASTM C39, until the specimen failed [18]. The maximum load at failure was recorded. Compressive strength of concrete with varying percentages of RCA replacement at different curing ages are provided in the Figure 7.

The compressive strength results of RAC compared with natural NAC are represented in Figure 7 for curing ages of 7, 14, and 28 days. The control mix with 100% natural coarse aggregate (NCA) exhibited strengths of 10.9 MPa, 22.5 MPa, and 26.5 MPa at 7, 14, and 28 days respectively, serving as the reference for performance evaluation. When 50% of NCA was replaced by RCA, the compressive strength values were slightly lower than the control, with reductions of about 12.3% at 7 days, 10.8% at 14 days, and only 3.9% at 28 days. This indicates that a 50% replacement ratio provides strength development

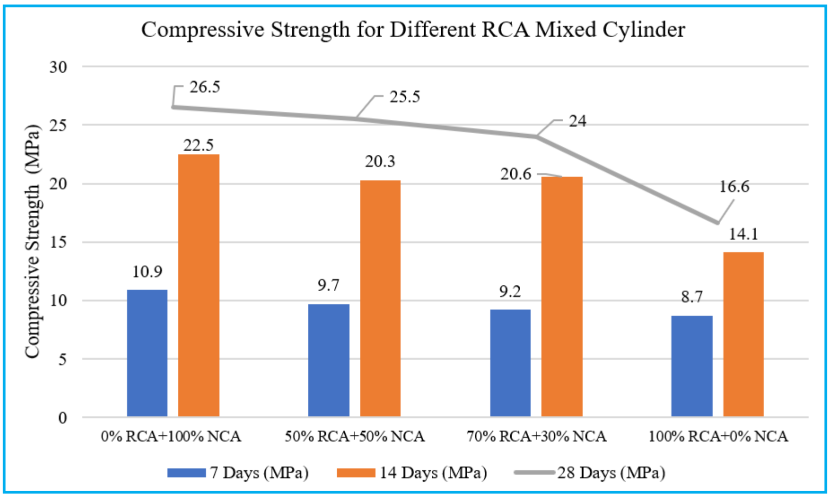

Figure 7. Compressive strength for different% of RCA mixed cylinders different ages

comparable to the control, especially at later ages, suggesting the feasibility of using RCA at this level without significant structural compromise.

For 70% RCA replacement, the reductions were 18.5% at 7 days, 9.2% at 14 days, and 10.4% at 28 days relative to the control. Although early-age strength loss was more pronounced, the difference narrowed with curing, and by 14 days the performance was nearly equivalent to the 50% RCA mix. This shows that a moderate level of RCA (up to 70%) can still produce acceptable strength if adequate curing and mix proportioning are ensured.

In contrast, 100% RCA replacement resulted in significant strength reductions of 25.3% at 7 days, 59.6% at 14 days, and 59.6% at 28 days. This clearly demonstrates the limitations of full replacement, as the weaker, porous, and adhered mortar content of RCA substantially lowers strength development. The entire condition is observed in the Figure 7.

Cost Analysis

For casting one three sets of cylinders (comprising nine specimens of size 4″ × 8″), the required amounts of RCA and NCA were determined on a weight basis. To achieve proper gradation, the total coarse aggregate was divided proportionally among the sieve sizes, with 40% retained on the 3/4″ sieve, 30% retained on the 1/2″ sieve, and 30% retained on the 3/8″ sieve.

Based on this gradation, the corresponding weight distribution of RCA and NCA was calculated for different replacement levels as 50% RCA, 70% RCA, 100% RCA, and 100% NCA as presented in the following Table 3. The local price of cement is 550 taka per 50kg bags and the available available sylhet sand price was 63.77taka per cft. Considering the test result of unit weight of sand as 1645kg/m^3 (46.55kg/ft^3), per kg pprice of sand becomes 1.37 taka. On the other hand, in similar way the average per kg cost of NCA and RCA was found to be 4.17 and 2.16 taka respectively.

So the material usage and costs for varying RCA replacement levels illustrated in Figure 8. Cement (5.71 kg, Tk 62.81) and sand (10.20 kg, Tk 13.97) remained constant, while only the coarse aggregate portion varied. With increasing RCA replacement, NCA content decreased, leading to lower overall costs.

Table 3. Cost and quantity of cement, sand , RCA and NCA for nine (4’’×8’’) cylinder casting

Materials	Price per kg	0% RCA+ 100% NCA		50% RCA+ 50% NCA		70% RCA+ 30% NCA		100% RCA+ 0% NCA	
		Quantity (kg)	Cost (Tk)	Quantity (kg)	Cost (Tk)	Quantity (kg)	Cost (Tk)	Quantity (kg)	Cost (Tk)
Cement	11.00	5.71	62.81	5.71	62.81	5.71	62.81	5.71	62.81
Sylhet Sand	1.37	10.20	13.97	10.20	13.97	10.20	13.97	10.20	13.97
RCA	2.16	-	-	9.63	20.80	13.47	29.10	19.24	41.56
NCA	4.71	20.4	85.07	10.28	48.42	6.13	25.56	-	-
Total Cost			**161.85**		**146**		**131.44**		**161.85**

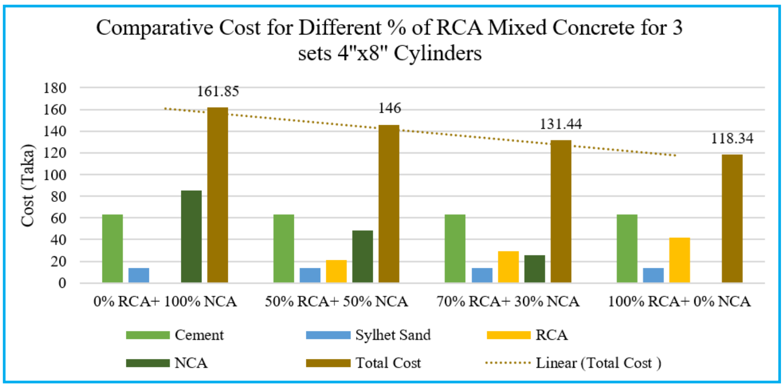

Figure 8. Comparative cost for different % of RCA mixed concrete

To enhance practical relevance, all parameters were recalculated per cubic meter, as large-scale construction is typically quantified by volume. This standardization allows direct comparison with conventional mix designs and enables meaningful cost–quantity analysis for real-world applications.

The Figure 9 presents material requirements and costs for casting 1 m^3 of concrete with varying levels of RCA replacement. Cement and sand quantities remained constant across all mixes, while coarse aggregates varied depending on the replacement level. As RCA content increased, the need for natural coarse

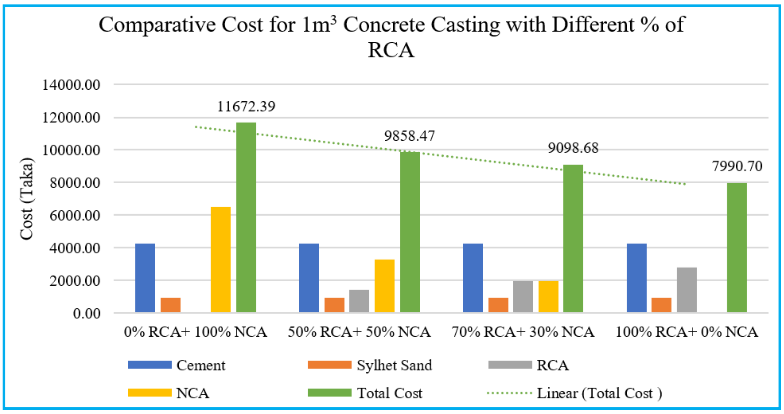

Figure 9. Comparative Cost for 1m^3 of concrete with different % of RCA mixed concrete

aggregate decreased, resulting in a progressive reduction in total cost—from the control mix (100% NCA) at Tk 11,672 to the 100% RCA mix at Tk 7,991. This clearly demonstrates that higher RCA replacement can significantly reduce material costs, while maintaining consistent cement and sand usage.

Total cost reduced from Tk 161.85 (0% RCA) to Tk 118.34 (100% RCA), showing that RCA use significantly lowers material expenses. However, the effective cost and strength of RCA mixed concrete with the 100% NCA is represented in Figure 10.

The comparative evaluation of NCA and RCA replacement reveals a clear trade-off between cost efficiency and mechanical performance. At 0% RCA (100% NCA), the concrete exhibits the highest 28-day compressive strength of 26.5 MPa, but it also incurs the maximum cost (11,672.39 Tk/m^3). Substituting 50% RCA results in only a marginal strength reduction (3.92% loss, strength=25.5 MPa) while achieving a notable 15.5% cost savings. A further increase to 70% RCA shows more significant compromise, with strength dropping to 24 MPa (10.42% loss) but cost efficiency improving by 22% compared to full NCA. However, at 100% RCA, the compressive strength plummets to 16.5 MPa, corresponding to a drastic 59.63% reduction, despite offering the lowest cost (7,990.7 Tk/m^3).

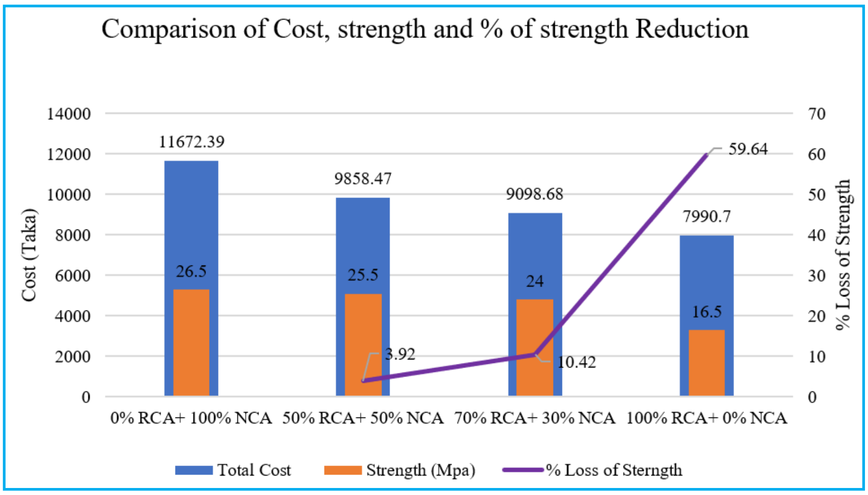

Figure 10. Comparison of cost, strength and % of strength reduction

This trend underscores that partial RCA replacement (up to 50%) provides an optimal balance, achieving meaningful cost reductions without substantially undermining structural performance. Conversely, complete dependence on RCA, though economical, critically compromises mechanical reliability and is unsuitable for structural applications demanding higher strength.

Therefore, the data suggest that the 50% RCA + 50% NCA mix offers the most rational and economical compromise, maintaining acceptable strength while significantly reducing construction costs, whereas higher RCA replacement levels should be cautiously applied depending on the intended performance requirement.

Conclusions

This study investigated the influence of RCA replacement on the mechanical and economic performance of concrete. A uniform gradation was maintained by batching RCA and NCA into 40% (19 mm), 30% (12.5 mm), and 30% (9.5 mm) fractions to ensure consistency across mixes. All specimens were designed as M20 concrete with a 0.5 water–cement ratio and 1% plasticizer to maintain workability.

- The compressive strength results showed that 100% natural coarse aggregate (NCA) achieved the highest 28-day strength of 26.5 MPa, while partial RCA replacement demonstrated acceptable performance. At 50% RCA, the reduction in strength was minimal (3.92% loss) compared to the control, with compressive strength of 25.5 MPa, indicating that half replacement can be achieved without compromising structural reliability. At 70% RCA, the strength decreased moderately (24 MPa; 10.42% loss), while at 100% RCA the strength fell drastically to 16.5 MPa (59.63% loss), making full replacement unsuitable for structural applications.
- From an economic perspective, RCA replacement significantly lowered material costs. The total cost decreased progressively from 11,672 Tk/m³ for 100% NCA to 7,991 Tk/m³ for 100% RCA. The 50% RCA mix reduced cost by 18.40% with only marginal strength loss, whereas 70% RCA achieved 28.29% cost savings at the expense of moderate strength reduction.
- Overall, the findings highlight a clear trade-off between cost efficiency and mechanical strength. Partial RCA replacement particularly 50% RCA+ 50% NCA emerges as the most rational solution, balancing economic benefits with acceptable structural performance. While RCA can effectively contribute to sustainable and economical concrete production, its use beyond 70% should be limited to non-structural or low-strength applications due to the significant loss in compressive strength.

Acknowledgement

The authors gratefully acknowledge the Department of Civil Engineering, Dhaka International University, Dhaka, Bangladesh, for their support in this research by providing the necessary laboratory facilities.

Conflicts of Interest

The authors declare no potential conflicts of interest with respect to the research, authorship, or publication of this article.

Author Contributions

Abdul Awol Rabby: conceptualization, methodology, calculation, writing-original draft preparation. **Imon Hasan Bhuiyan:** data curation, visualization. **Uzzal Al Aziz:** visualization, investigation. **Md Hasan Imam Siddique:**

supervision, investigation. **Md.Al Amin:** investigation. **Abhijit Nath Abhi:** supervision, investigation.

Data Availability Statement

The data used to support the findings of this study are included within the article.

References

[1] M. Marzouk and S. Azab, "Environmental and economic impact assessment of construction and demolition waste disposal using system dynamics," Resour Conserv Recycl, vol. 82, pp. 41–49, 2014, doi: http://dx.doi.org/10.1016/j.resconrec.2013.10.015

[2] M. S. Meddah, "Recycled aggregates in concrete production: engineering properties and environmental impact." MATEC Web Conf. vol. 101, 2017, doi: http://dx.doi.org/10.1051/matecconf/201710105021

[3] A. De Luca, L. Chen, and K. Gharehbaghi, "Sustainable utilization of recycled aggregates: robust construction and demolition waste reduction strategies," International Journal of Building Pathology and Adaptation, vol. 39, no. 4, pp. 666–682, Oct. 2021, doi: http://dx.doi.org/10.1108/IJBPA-04-2020-0029

[4] S. Yehia, K. Helal, A. Abusharkh, A. Zaher, and H. Istaitiyeh, "Strength and Durability Evaluation of Recycled Aggregate Concrete," Int J Concr Struct Mater, vol. 9, no. 2, pp. 219–239, Jun. 2015, doi: http://dx.doi.org/10.1007/s40069-015-0100-0

[5] M. Yunus, Y. Karim, Z. Khan, M. S. Alsoufi, and " A Review, "A Review on Recycled Aggregates for the Construction Industry," American Journal of Civil Engineering and Architecture, vol. 4, no. 1, pp. 32–38, 2016, doi: http://dx.doi.org/10.12691/ajcea-4-1-5

[6] M. Marvila, P. de Matos, E. Rodríguez, S. N. Monteiro, and A. R. G. de Azevedo, "Recycled Aggregate: A Viable Solution for Sustainable Concrete Production," Aug. 01, 2022, MDPI. doi: http://dx.doi.org/10.3390/ma15155276

[7] F. Ma, A. Sha, R. Lin, Y. Huang, and C. Wang, "Greenhouse gas emissions from asphalt pavement construction: A case study in China," Int J Environ Res Public Health, vol. 13, no. 3, Mar. 2016, doi: http://dx.doi.org/10.3390/ijerph13030351

[8] J. Vrijders and J. Desmyter, "Overview regarding construction and demolition waste in several countries," RILEM State-of-the-Art Reports, vol. 8, pp. 37–173, 2013, doi: http://dx.doi.org/10.1007/978-94-007-4908-5_3

[9] G. R. Robinson, W. D. Menzie, and H. Hyun, "Recycling of construction debris as aggregate in the Mid-Atlantic Region, USA," in Resources, Conservation and Recycling, Oct. 2004, pp. 275–294. doi: http://dx.doi.org/10.1016/j.resconrec.2004.04.006

[10] M. A. Khalaf, C. C. Ban, and M. Ramli, "The constituents, properties and application of heavyweight concrete: A review," Aug. 10, 2019, Elsevier Ltd. doi: http://dx.doi.org/10.1016/j.conbuildmat.2019.04.146

[11] H. Guo et al., "Durability of recycled aggregate concrete – A review," Cem Concr Compos, vol. 89, pp. 251–259, May 2018, doi: http://dx.doi.org/10.1016/j.cemconcomp.2018.03.008

[12] S. Ismail and M. Ramli, "Mechanical strength and drying shrinkage properties of concrete containing treated coarse recycled concrete aggregates," Constr Build Mater, vol. 68, pp. 726–739, Oct. 2014, doi: http://dx.doi.org/10.1016/j.conbuildmat.2014.06.058

[13] M. S. Alam et al., "Effect of sand types and mixing procedures on the physical and mechanical properties behavior on the mortar and concrete in Bangladesh," Next Research, vol. 2, no. 2, p. 100244, Jun. 2025, doi: http://dx.doi.org/10.1016/J.NEXRES.2025.100244

[14] O. Joshua et al., "Construction Research Congress 2018 582 Downloaded from ascelibrary."

[15] B. L. Damineli, M. Quattrone, S. C. Angulo, M. E. S. Taqueda, and V. M. John, "Rapid method for measuring the water absorption of recycled aggregates," Materials and Structures/ Materiaux et Constructions, vol. 49, no. 10, pp. 4069–4084, Oct. 2016, doi: http://dx.doi.org/10.1617/s11527-015-0773-5

[16] N. N. Gerges, C. A. Issa, and S. Fawaz, "Effect of construction joints on the splitting tensile strength of concrete," Case Studies in Construction Materials, vol. 3, pp. 83–91, Dec. 2015, doi: http://dx.doi.org/10.1016/j.cscm.2015.07.001

[17] S. J. Woo, J. M. Yang, H. Lee, and H. K. Kwon, "Comparison of properties of 3d-printed mortar in air vs. Underwater," Materials, vol. 14, no. 19, Oct. 2021, doi: http://dx.doi.org/10.3390/ma14195888

[18] K. Sobhan, L. Gonzalez, and D. V. Reddy, "Durability of a pavement foundation made from recycled aggregate concrete subjected to cyclic wet–dry exposure and fatigue loading," Materials and Structures/Materiaux et Constructions, vol. 49, no. 6, pp. 2271–2284, Jun. 2016, doi: http://dx.doi.org/10.1617/s11527-015-0648-9