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BEHAVIOR OF REINFORCED CONCRETE SHORT COLUMNS: COMPARATIVE STUDY FOR THREE TYPES OF MIXTURES

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ABSTRACT: The mechanical behavior and failure properties of reinforced concrete short columns using different aggregate materials are investigated in this work. Each of the three concrete mixtures, standard reinforced concrete (RMC), plastic-modified concrete (PMC), and brick-modified concrete (BMC), replaced half of the coarse aggregate with crushed plastic or crushed brick. Tensile, compressive, and strain testing was applied to control specimens as well as full-scale columns (2 m height, 30 × 40 cm cross-section). With regard to mechanical performance, including compressive and tensile strengths, stiffness, and fracture resistance, RMC showed the best values. Although technically feasible, PMC and BMC demonstrated worse performance because of greater porosity and poorer interfacial bonding. PMC and BMC particularly showed their potential for non-primary structural uses by maintaining adequate load-bearing capability (up to 4000 N) with increasing distortion. This study provides important new perspectives on the viability of recycled aggregates in structural concrete, therefore providing a sustainable substitute for building materials without sacrificing structural safety under suitable conditions.

Keywords: Short Columns, Reinforced Concrete, Plastic-Modified Concrete, Brick-Modified Concrete, Compressive Strength, Tensile Strength.

1. INTRODUCTION

Fundamental stability, longevity, and resilience of many civil engineering constructions depend on the structural performance of reinforced short columns [1]. Integral components in load-bearing systems like building frames, bridges, and industrial infrastructures are short columns identified by their restricted height compared to their cross-sectional dimensions [2]. Understanding their mechanical behavior under different load circumstances is crucial, as these columns experience complicated stress distributions under axial and eccentric loads and must be avoided to prevent catastrophic breakdowns [3].

Short column structural integrity and load-carrying capability are substantially improved by reinforcement [4]. Mechanical performance, comprising resistance to applied loads, deformation characteristics, mechanical behavior, and general durability of reinforcement, is much influenced by its kind, configuration, and material qualities [5]. To improve structural performance and safety, several scientific investigations have looked at the behavior of reinforced short columns under different load circumstances [6].

For limited concrete, studies by Mander et al. (1988) provide a thorough stress-strain model of the effect of transverse reinforcement on the ductility and strength of short columns [7]. Paultre and Legeron (2008) also carried out experimental studies to see how transverse reinforcement designs and axial load ratios affected the seismic performance of reinforced concrete columns. Their results underlined the important part reinforcement detailing plays in increasing energy dissipation and postponing structural breakdown [8].

In line with carbon-neutral infrastructure targets, Onyelowe et al. (2023) successfully forecast the compressive strength of fly ash concrete by using artificial neural networks (ANN) and Gene Expression Programming (GEP). Their results assist the integration of models driven by artificial intelligence into sustainable material design and performance enhancement [9]. For environmentally friendly sidewalk and pavement uses, Suksiripattanapong et al. (2022) verified the possibility of including recycled plastic waste into fiber-reinforced concrete. Their findings underlined improved durability and resistance to cracks, therefore highlighting the potential of the material for the construction of sustainable infrastructure [10].

Moreover, a sustainable alternative with adequate mechanical performance for non-structural uses, recovered plastic trash may be efficiently utilized to strengthen concrete, according to Baciu et al. (2022). Their efforts advance environmental objectives and inspire further study on best practices for plastic-based reinforcing techniques.[11]. There is a great gap in current research on sustainable substitutes for traditional coarse aggregates, especially recycled or modified materials like crushed plastic and bricks. Substitution of non-renewable materials with recycled components provides an important environmental and technical problem, given the growing worldwide focus on lowering building waste and carbon emissions. Nevertheless, the body of current research often ignores the mechanical trade-offs, structural behaviors, and durability problems of such substitutes in important load-bearing components such as short columns. Moreover, although earlier studies on recycled aggregate concrete have addressed mechanical characteristics, few studies offer relative evaluations under full-scale axial loading conditions, especially with high percentages (e.g., 50%) of non-traditional aggregates in real column dimensions.

By methodically analyzing the behavior of short reinforced concrete columns generated with two novel aggregate substitutions, 50% crushed plastic and 50% crushed brick, this work seeks to overcome these constraints. This work uses full-scale columns and control specimens under a wide variety of mechanical tests (compressive strength, tensile strength, strain, and fracture propagation), unlike previous studies, which depended on partial replacement or small-scale specimens. One of the few thorough studies on recycled material integration in full-sized structural components, since the research is unique in its twin focus: it not only quantifies the structural performance of these modified mixtures but also establishes pragmatic thresholds for their load-bearing capacities.

Under similar circumstances, direct comparison of conventional and modified concretes offers fresh understanding of mechanical consequences, design constraints, and future feasibility of recycled aggregates in structural concrete. Given the worldwide building industry's pressing requirement to strike performance goals against environmental sustainability criteria, this is particularly relevant.

2. RESEARCH SIGNIFICANCE

This work fills in a major need in sustainable building by assessing the structural performance of full-scale reinforced concrete columns constructed with 50% substitution of coarse aggregates using crushed plastic and brick. Unlike most other investigations focused on tiny specimens or low replacement levels, this work provides real-scale testing and thorough mechanical analysis under axial stresses. Supporting their possible usage in non-primary structural components, the results provide a pragmatic understanding of the strength, deformation, and fracture behavior of modified concretes. This approach gives engineers data-driven direction for sustainable material substitution in structural design and helps green building techniques evolve.

3. METHODOLOGY

3.1 Study Design

The primary objective of the research is to examine the loading effects and causes of deformities (vertical deformation and cracks) resulting from stress and strain. Utilized three types of reinforced concrete columns, each measuring 2 meters in length and 30×40 centimeters in size. The laboratory tests were conducted on mixtures (cement, sand, gravel, water, steel). The tests are conducted on a cube and a cylinder as control specimens. Each mixture has five cubic shapes and three cylinders.

3.2 Concrete Mixture

For the reference concrete mixture (RMC), the investigated components were 900 kg of gravel, 450 kg of sand, and 150 kg of cement. For the altered mixes, 50% of the coarse aggregate in PMC and BMC, respectively, was replaced with 450 kg of crushed plastic and 450 kg of crushed brick, respectively.

Table 1. The studied material

No	Material	Weight Kg/m^3
1	Cement	150
2	Sand	450
3	Gravel	900
4.	Plastic	450
5	Brick	450

Keeping the same mix ratio, the PMC mixture consisted of substituting crushed plastic for half of the coarse gravel. In a similar way, the BNC mixture replaced crushed bricks for half of the coarse aggregate. This change sought to assess the mechanical characteristics of concrete under different aggregates. These combinations called for fine sand from Karbala, gravel from Habania, and premium cement from Kobasa. Crushed bricks and plastic were used as partial substitution for the course materials in the modified mixes. Keeping a 40% water-to-cement (w/c) ratio across all combinations guarantees consistency in hydration and workability.

Using a 50% replacement ratio for coarse aggregates was deliberate to assess the structural soundness of recycled plastic and brick materials at a quite high substitution level, where possible mechanical trade-offs become more noticeable. This threshold provides useful information for designs motivated by sustainability, as it lets one evaluate performance under important criteria. This work offers a cautious upper-limit example balancing mechanical feasibility with environmental advantages by using 50%. From these findings, future studies might interpolate to investigate ideal mix designs at intermediate levels (e.g., 25%, 35%, or 40%) that could give enhanced performance with reasonable trade-offs.

3.3 Ratios of Materials

Materials were painstakingly measured to guarantee uniformity. Using 0.05 tons of cement, 0.15

tons of sand, 0.5 tons of gravel, and 20 liters of water, the RMC set. The PMC mix called for 20 liters of water, 0.15 tons of cement, 0.15 tons of sand, 0.15 tons of crushed plastic, and 20 liters of gravel. The BNC mix called for 20 liters of water, 0.15 tons of cement, 0.15 tons of sand, 0.15 tons of broken bricks, and 20 kg of gravel. Before casting the specimens, these mixes were fully combined to reach homogeneity. For every concrete mix, the sample preparation consisted of casting 15 cube specimens (15 x 15 x 15 cm), Table 2 shows the mixture of any material.

Table 2. Proportions for RMC, PMC, and BMC concrete types

Mix	Water Litter	Cement kg/m³	Gravel kg/m³	Plastic kg/m³	Crush kg/m³
Referansec oncrete	20	50	150	0	0
Plastic concrete	20	50	75	75	0
Brick concrete	20	50	75	0	1.5

9-cylinder specimens (15 x 30 cm), and 3 full-scale short columns (30 x 40 x 200 cm) were cast. Before testing, the specimens were controlled to guarantee appropriate hydration and strength development. Table 3 shows columns and control specimens**.**

Table 3. Columns and control specimens

No.	Samples	Dimension cm	Samples No.
1	cubes	15*15*15	15
2	Cylinders	15*30	9
3	Columns	30*40*200	3

To guarantee homogeneity in strength growth and hydration, all specimens, including cubes, cylinders, and full-scale columns, were cured under the same circumstances. Under ASTM C511, curing was carried out in a controlled laboratory setting at (20 ± 2) °C and relative humidity of ≥95%. Following demolding for their different curing times, 7, 14, 28, 60, and 90 days, all samples were immersed in clean water tanks; water was replenished routinely to preserve uniformity. Given the porous character of crushed plastic and brick aggregates, which are prone to water absorption and shrinkage, this consistent curing schedule was particularly crucial. Through the reduction of environmental variability, the research guaranteed that variations in mechanical performance could be firmly linked to material composition instead of curing variations.

3.4 Tests

Axial loads were applied to the specimens using compression testing equipment for the mechanical testing, therefore evaluating their compressive strength and deformation behavior. Accuracy in load application and deformation measurement was made possible by other tools like loading frames and proving rings. To assess load-bearing capacity, deformation behavior, and the beginning of cracking and failure, the testing process applied increasing axial loads ranging from 500 N to 4500 N. Strategically positioned strain gauges on the specimens allowed one to track deformation under stress, therefore providing exact strain distribution statistics. Manual measurement of crack widths at many load levels helped to evaluate the degree of damage and failure development. Comprising compressive strength, tensile strength, elastic modulus, strain behavior, and patterns of fracture propagation, the gathered data were.

Every specimen received axial stresses applied using calibrated compression testing equipment. Using steel bearing plates at both ends of the column, the axial load was precisely centered to provide consistent stress distribution. Using a spirit level, the columns were aligned vertically; the hydraulic piston of the machine was changed to guarantee direct contact with the column centroid, therefore reducing the possibility of eccentric loading. Any lateral movement or initial tilting before testing was tracked using proving rings and dial gauges. This arrangement guaranteed equal distribution of axial force throughout the cross-section, therefore reproducing ideal column loading conditions advised in ACI 318 and BS EN 12390-4 standards.

3.5 Data Analysis

Employing structural integrity and failure mechanisms, the study of this data offers insightful information on the performance variations among RMC, PMC, and BNC. Using the comparative analysis, the impact of different aggregates on the mechanical characteristics of concrete was found, therefore enabling the creation of more environmentally friendly and strong building materials.

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4. RESULTS

4.1 Workability and Density

The three concrete mixes, Reference Mixture Concrete (RMC), Plastic-Modified Concrete (PMC), and Brick-Modified Concrete (BMC), were evaluated based on flow, settlement, and density. With a settlement of 100 cm and a peak flow of 180 cm, RMC shows better workability. With flow values of 160 cm and 85 cm, respectively, PMC and BMC showed decreased workability; settlements of 80 cm and 90 cm, respectively, also indicated this. The observed dry densities for RMC, PMC, and BMC were 2.5 kg/m¹ for RMC, 1.46 kg/m¹ for PMC, and 1.70 kg/m¹ for BMC, thereby stressing the changes in density resulting from the various aggregate substitutes. Fig. 1 shows the wet densities and mixture, while Fig. 2 shows the dry densities and mixture. Wet and dry density is calculated according to C642-1982, using the following equation:

$$\gamma_{wet}=\frac{wt}{v} \qquad (1)$$

$$\gamma_{dry}=\frac{wd}{v} \qquad (2)$$

where wt is wet weight, wd is dry weight, V is volume

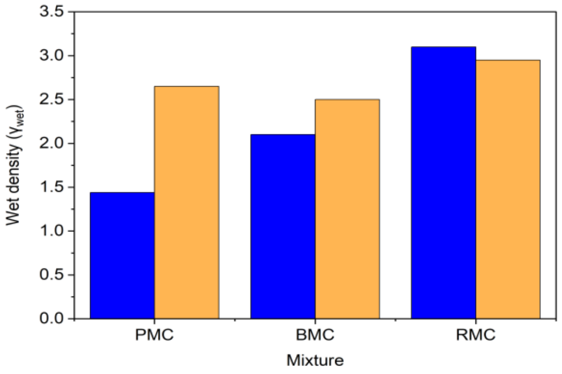

Fig. 1 Relationship between γ_W and mixture

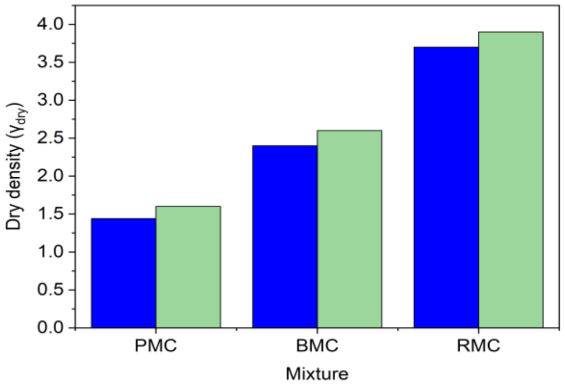

Fig. 2 Relationship between dry density and mixture

4.2 Compressive Strength

Compressive strength was measured at 7, 14, 28, 60, and 90 days. Rising to 57 MPa, RMC showed the best compressive strength; PMC followed with 33.7 MPa and BMC with 33.3 MPa. Table 4 shows the compression strength Test (σ_C). According to the tendency, conventional aggregates in traditional concrete provide better compressive strength than in modified combinations. Fig. 3 shows the relationship between compressive strength and curing age to show the trend over different curing periods. Compression stress is calculated according to B.S.88 PART (11) 1988, using the following equation:

$$\sigma c=\frac{P}{A} \qquad (3)$$

Where P= Applied load (N), A = Section Area (mm²)

Table 4. Compression strength test (σ_C) for cube

Mixture	Compression $\boldsymbol{\sigma_C}$= MPa(N/mm²)				
Age/ days	7	14	28	60	90
Reference mixture (RMC)	14.63	15.14	14.89	23.60	25.12
Plastic %50+%50 gravel (PMC)	13.35	13.05	19.2	20.25	23.05
Brick %50 + %50 Gravel (BMC)	13.11	14.01	18.75	22.50	24.75

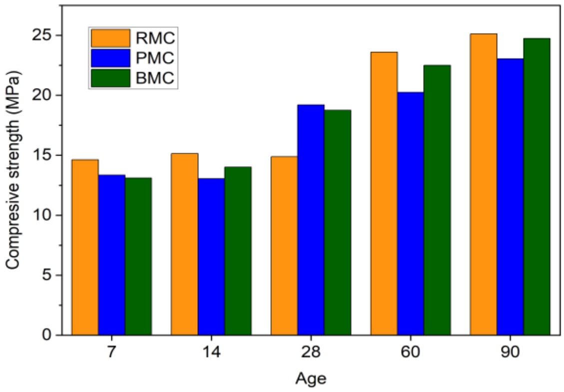

Fig. 3 The relationship between σ_C and age

4.3 Tensile Strengthening

The patterns in compressive strength matched the findings in tensile strength. Following BMC at 7.4 MPa, RMC had the greatest tensile strength at 7.6 MPa, and PMC at 6.8 MPa. Consistent across the testing periods, these findings reflected the effect of aggregate type on tensile performance as shown in Table 5 and Fig. 4 Tensile strength is calculated according to ASTM C496/496M-11, using the following equation:

$$f\ spt=\frac{2F}{pi\ D\ L} \qquad (4)$$

Where: a is the cross-section from the sample, L is the sample length

This work used the indirect splitting tensile test (ASTM C496/496M) because of its feasibility, standardization, and reproducibility in tensile strength evaluation across concrete mixes. Widely recognized for comparison of various mix designs, this approach offers a practical way to evaluate the tensile performance of cylindrical specimens.

Table 5. Tensile strength results

Mixture	Tensile σ_t =MPa(N/mm^2)				
Age / days	7	14	28	60	90
Reference Mixture (RMC)	4.26	4.58	6.03	7.15	7.61
Plastic %50+%50 gravel (PMC)	3.71	3.38	5.6	6.13	6.8
Brick %50 + %50 Gravel (BMC)	3.97	4.12	5.7	6.18	7.4

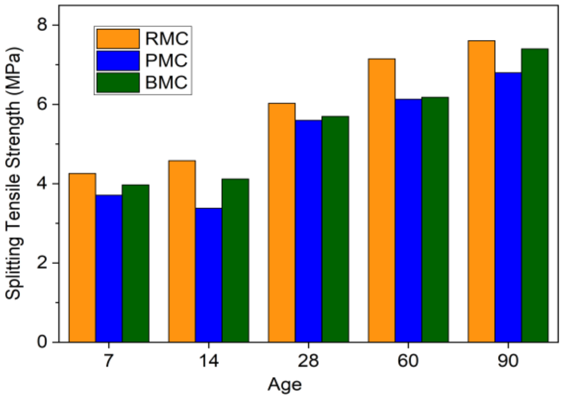

Fig. 4 Relationship between tensile strength and age

4.4 Strain and Crack Analysis

Under a load of 4500 N, strain measurements found little deformation in RMC, with a strain of 0.0073. Under comparable loading circumstances, PMC and BMC showed greater strain values of 0.0075 and 0.0080, respectively, as Fig. 5 shows the relationship between strain and stress. The widths of fractures were also analyzed; RMC showed tiny cracks (0.2 mm), whereas PMC and BMC showed broader cracks (0.4 mm), thus showing less resistance to cracking in modified combinations. Fig. 6 shows the relationship between stress and lateral strain.

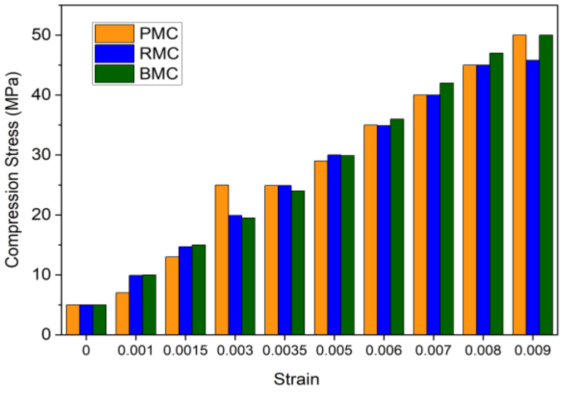

Fig. 5 Relationship between strain and stress

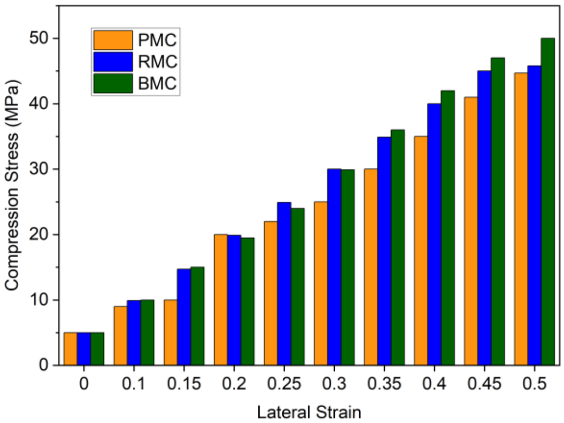

Fig. 6 Relationship between compressive stress and lateral strain

4.5 Load-Bearing Capacity

Incremental loading between 500 N and 4500 N allowed one to determine the load-bearing capability. While PMC and BMC handled 4000 N apiece, they showed more deformation, RMC maintained the greatest load (4500 N) with minimum strain. This supports the fact that under the same load, conventional concrete offers higher structural integrity.

5. DISCUSSION

Important markers of concrete mixes' performance, their workability, and density directly affect mechanical qualities and durability. With a flow of 180 cm and a settlement of 100 cm, the Reference Mixture Concrete (RMC) shows a better workability than Plastic-Modified Concrete (PMC) and Brick-Modified Concrete (BMC), which showed correspondingly lower flow values of 160 cm and 85 cm, respectively.

These results are in line with those of Nevile (2011), who underlined that because of their homogeneous particle size and surface roughness, conventional aggregates provide higher cohesiveness [12]. The uneven forms and high absorption rates of crushed plastic and brick, which impede smooth flow and raise internal friction, help to explain PMC's and BMC's poor workability [13].

The noted dry densities 2.5 kg/m^1 for RMC, 1.46 kg/m^1 for PMC, and 1.70 kg/m^1 for BMC shows how aggregate type affects density. Pacheco-Torgal et al. (2013) have shown similar findings, substituting recycled materials for natural aggregates results in lower specific gravity and therefore reduced density [14]. Lower density in PMC and BMC might potentially affect mechanical performance as density is usually connected with compressive strength and durability [15].

Consistent with past results, Suksiripattanapong et al. (2022), where substitution of coarse aggregates with plastic waste led to 20–35% decreases in density, depending on plastic type and gradation, the notable decline in dry density was found in PMC (1.46 kg/m¹) compared to RMC (2.55 kg/m³). The main causes of this decline are plastic aggregates reduced specific gravity and larger void content, which also influences strength and stiffness, especially in structural uses [10].

RMC exceeded PMC (33.7 MPa) and BMC (33.3 MPa) by showing the maximum compressive strength of 57 MPa. This better performance corresponds with those of Mehta and Monteiro (2014), who underlined the need for robust interfacial transition zones and dense aggregate packing in improving compressive strength [16].

Evangelista and de Brito (2007) observed in research on recycled aggregate concrete that reduced strength in PMC and BMC may be ascribed to decreased bonding at the aggregate-matrix interface, increased porosity, and micro-cracks [17]. Moreover, the porous character of crushed plastic and brick lowers load transfer efficiency, which causes early fracture starting under pressure [18].

With RMC hitting 7.6 MPa, then BMC (7.4 MPa) and PMC (6.8 MPa), tensile strength values matched patterns of compressive strength. RMC's high tensile strength may be connected to its dense microstructure, which efficiently distributes tensile stresses and delays fracture initiation. Strong, well-bonded aggregates greatly increase tensile strength, as claimed by Alexander et al. (2017) [19].

The angularity of crushed bricks, which improves mechanical interlocking as suggested by Silva et al. (2014), might be the somewhat superior performance of BMC over PMC [20]. Furthermore, affecting tensile strength is the aggregate-matrix bond quality, which is naturally worse in modified concrete mixes because of the irregularity of recycled components [21].

Under a 4500 N load, strain readings showed little deformation in RMC (0.0073) as opposed to PMC (0.0075) and BMC (0.0080). These results complement those of Esmaeily & Xiao (2005), who showed that improved load distribution increases strain capacity by means of conventional aggregates [22].

Under the identical stress circumstances, the higher strain seen in BMC (0.0080) than in RMC (0.0073) points to a larger degree of deformability. This behavior presents possible questions for long-term serviceability, especially in connection to creep and shrinking, even if it indicates less stiffness. Recycled brick aggregates tend to retain internal moisture and incur more drying shrinkage, according to past research by de Brito et al. (2021), because of their porous nature and high water absorption. Furthermore, under constant loads, the weak interfacial transition zones (ITZs) in such blends help to cause microstructural creep. Therefore, even although BMC may provide sufficient strength for short-term applications, its usage in long-span or time-dependent structural systems may produce too large deflections or dimensional instability. Particularly when using recycled brick aggregates at high replacement rates, future studies should probe these long-term deformation tendencies using creep compliance testing and autogenous shrinkage analysis.[23].

Higher resistance to the spread of fractures was indicated by smaller RMC (0.2 mm) cracks in comparison to broader PMC and BMC (0.4 mm). This finding is in line with the research of Zhang et al. (2015), which revealed that homogeneity of the concrete matrix considerably influences fracture resistance [24].

Progressive loading allowed one to manually measure the noted fracture widths of 0.2 mm in RMC and 0.4 mm in PMC and BMC. This approach is intrinsically restricted by visual resolution, operator subjectivity, and sensitivity to micro-cracking, even if it offers a broad knowledge of fracture progression. Thus, using Digital Image Correlation (DIC) or Acoustic Emission (AE) monitoring will help to improve the accuracy of crack initiation and propagation monitoring in further investigations.

RMC (0.880×10^3 MPa) has the greatest modulus of elasticity, therefore resulting in more rigidity and load-bearing efficiency. PMC and BMC's lower modulus may be ascribed to their heterogeneous composition and greater void content, which thus lessen the material's deformation resistance.

Sonawane et al. (2013) reached similar results: the incorporation of recycled materials reduces the modulus of elasticity because of the lower mechanical characteristics of the recycled aggregates [25]. Furthermore, the elastic behavior of modified concretes usually deteriorates quickly under repeated loading circumstances, which can restrict their use in structural parts exposed to dynamic forces [25].

With little distortion, RMC showed the best load-bearing capacity (4500 N), thereby confirming its better structural performance. Reflecting their lowered rigidity and structural integrity, PMC and BMC showed more deformation under load, even if they could maintain 4000 N.

These results are consistent with those of Tam et al. (2021), who found that, because of poorer aggregate-matrix bonding, recycled aggregate concrete often displays lower load-bearing capability than conventional concrete. Furthermore, the compactness and continuity of the matrix in RMC help load distribution to be more efficient, thus lowering stress concentrations that can cause early failure in modified concretes [26].

Although the current work concentrated on the short-term mechanical behavior of reinforced concrete columns, long-term performance is still a major issue, especially for modified concretes using recycled plastic and brick components. Natural porosity, water absorption, and interfacial bonding properties of these materials affect their endurance. Particularly under hostile weather circumstances, brick aggregates, for example, are well-known to have significant water absorption rates, which over time may cause internal microcracking, freeze-thaw damage, and alkali-silica reactions (ASR) [20].

Regarding fatigue resistance, the heterogeneous microstructure and weak interfacial transition zones (ITZs) of PMC and BMC might affect performance under cyclic or seismic stress. Recycled materials, unlike traditional aggregates, may not transmit loads consistently, which might start early fracture propagation and shorten fatigue life. Particularly in high-replacement recycled concretes, studies have shown that cyclic stresses may weaken bonds and hasten microstructural degradation [26].

Confirmed by theoretical studies incorporating stress-strain correlations, the experimental findings were that PMC and BMC showed delays and reduced stress thresholds owing to greater porosity and uneven aggregate distribution, whereas RMC's dense structure enabled quicker wave transmission and higher stress resistance. Emphasizing the crucial part of material homogeneity in structural performance, these results match the theoretical models put forward by Kong (2017) [27].

The internal structure of the concrete greatly influences the propagation of stress waves; voids and weak zones in PMC and BMC provide reflection and refraction sites, therefore lowering the general stress transfer efficiency [28,29].

All things considered, the theoretical studies and practical data point to RMC's higher mechanical performance than PMC and BMC. The use of recycled materials such as brick and plastic brings variation in mechanical characteristics, mostly related to microstructure, bonding quality, and density. Although employing recycled materials has clearly environmental advantages, its effect on structural performance calls for careful thought in load-bearing uses.

Although mechanical and structural performance was the main emphasis of this study, the use of waste plastic and crushed brick as aggregate replacements offers great environmental benefits, especially in lowering natural resource consumption, landfill pressure, and carbon emissions related to aggregate extraction and processing. Depending on transportation routes and processing techniques, recent life cycle assessment (LCA) studies show that substituting recycled materials for natural aggregates may lower embodied CO_2 emissions by 20–40%. Eliminating quarrying, crushing, and shipping phases helps each ton of virgin coarse aggregate substituted with recycled brick or plastic trash reduce around 20–30 kg of CO_2 emissions [30].

Furthermore, using post-consumer plastic trash helps to avoid non-biodegradable materials ending up in landfills and lessens the need for burning, which otherwise releases dangerous pollutants. Often derived from building and demolition waste (CDW), crushed brick aggregates help to promote circular economy goals by extending material lifetime and reducing building waste. Although this research did not do a complete LCA, the observed structural feasibility of 50% replacement ratios suggests that, particularly for non-structural uses, environmentally friendly mix designs may be devised without appreciably reducing performance [30].

Future research should include extra experimental trials and numerical simulations (e.g., finite element modeling) to validate the mechanical performance of recycled aggregate concretes under different loading and environmental conditions, thereby improving the robustness and applicability of the present findings. Researchers are also urged to investigate a wider spectrum of replacement levels (e.g., 10%, 25%, 35%, 75%), and assess the usage of alternative recycled materials such as ceramic waste, recycled concrete aggregate (RCA), or glass to maybe improve the performance of PMC and BMC without compromising environmental goals.

Moreover, a thorough life-cycle analysis (LCA) has to be carried out to fairly analyze the environmental effects of replacing recycled materials with natural aggregates. This would enable one to ascertain if major savings in carbon emissions, resource depletion, and building waste creation outweigh the mechanical limitations noted. These initiatives will help to create ideal, ecologically sustainable, structurally sound mix designs suitable for different civil engineering uses by means of eco-efficient technologies.

In essence, upgraded concretes provide environmental advantages, but their mechanical trade-offs have to be properly handled. Further mix optimization, the use of supplemental cementitious ingredients, and external reinforcing procedures are summarized in the comparison table, demonstrating the mechanical qualities, physical attributes, and advised uses for RMC, PMC, and BMC concrete types as indicated in Table 6.

Table 6. Performance comparison of concrete types

Property	RMC	PMC	BMC
Compressive strength (MPa)	57	33.7	33.3
Tensile strength (MPa)	7.6	6.8	7.4
Modulus of elasticity ($\times 10^3$ MPa)	0.88	0.52	0.54
Dry density (kg/m2)	2550	1460	1700
Strain at peak load	0.0073	0.0075	0.008
Crack width (mm)	0.2	0.4	0.4
Load-bearing capacity (N)	4500	4000	4000

A limitation of this study is that microstructural investigation using methods such as Scanning

Electron Microscopy (SEM) or X-ray Diffraction (XRD) was not included, even as this work offers a thorough mechanical evaluation of RMC, PMC, and BMC combinations. Visualizing the interfacial transition zones (ITZs), microcrack propagation, and hydration product distribution, all of which greatly affect the mechanical performance of recycled aggregate concretes, requires these methods. Although resource limitations led to their absence from the present study, the authors highly advise their inclusion in future studies to link mechanical behavior with microstructural characteristics.

6. CONCLUSION

The structural behavior of three distinct concrete mixtures, conventional reinforced concrete (RMC), plastic-modified concrete (PMC), and brick-modified concrete (BMC), was assessed in this work using reinforced concrete short columns made from each. Each altered mixture was evaluated under axial loads and typical mechanical conditions using either crushed plastic or brick in a 50% replacement of coarse aggregate. Important results include qualitative as well as quantitative components. RMC had the maximum compressive strength of 57 MPa at 90 days, while PMC showed 33.7 MPa and BMC showed 33.3 MPa.

These findings support the better load resistance of traditional concrete. RMC obtained 7.6 MPa, followed by BMC (7.4 MPa) and PMC (6.8 MPa), showing that, because of greater interlocking, crushed brick gave superior tensile resistance than plastic. Under a 4500 N stress, RMC had the least strain (0.0073) and shortest fracture width (0.2 mm), whereas PMC and BMC reported broader cracks (0.4 mm) and higher strain values (0.0075 and 0.0080, respectively).

With a modulus of 0.880×10^3 MPa, RMC had the maximum stiffness and hence confirmed its great resistance to deformation. RMC resisted up to 4500 N, whereas PMC and BMC survived 4000 N but with more deformation, therefore suggesting less structural integrity. Qualitatively, the findings demonstrate that while brick and plastic trash may be utilized as coarse aggregate replacements, their usage influences the homogeneity, bonding efficiency, and resistance to cracking of the concrete.

Nonetheless, if sustainability is given top priority and non-load-bearing or secondary structural components are used, they have environmental benefits and could be appropriate. The relevance of this work is in its use of full-scale columns, high replacement ratios, and multi-faceted mechanical testing, therefore providing useful information for structural design incorporating recycled materials.

To improve the performance of modified concretes, further studies should look at optimal mix designs, usage of additional cementitious materials or admixtures, and long-term durability.

Although their strength, stiffness, and crack resistance make conventional reinforced concrete (RMC) still better for primary structural uses, this study shows that both plastic-modified concrete (PMC) and brick-modified concrete (BMC) provide structurally acceptable substitutes for non-critical elements. Engineers must consider inferior mechanical performance and increased strain when utilizing 50% recycled aggregates, but they gain from lower material weight, environmental sustainability, and cost savings. Proper mix design, quality control during curing, and targeted usage in partition walls, pavement subbases, or low-load columns may help field applications safely and effectively use recycled materials in structural systems.

7. ACKNOWLEDGMENTS

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8. REFERENCES

[1] Rashid SP and Bahrami A, Structural performance of infilled steel–concrete composite thin-walled columns combined with FRP and CFRP: A comprehensive review. Materials, Vol. 16, No. 4, 2023, p. 1564. DOI: 10.3390/ma16041564.

[2] Brütting J., De Wolf C., and Fivet C., The reuse of load-bearing components. IOP Conference Series: Earth and Environmental Science, Vol. 225, 2019, p. 012025. DOI: 10.1088/1755-1315/225/1/012025.

[3] Wang J., Cui M., Jiao Y., and Fang X., Axial stress-strain characteristics, and confinement mechanism of concrete-encased steel composite columns: An analytical model. Journal of Building Engineering, Vol. 72, 2023, p. 106656.DOI: 10.1016/j.jobe.2023.106656.

[4] Shewale M., Bahrami A., Murthi P., and Chidambaram RS, Enhancing Load-Carrying Capacity of Reinforced Concrete Columns with High Aspect Ratio Using Textile-Reinforced Mortar Systems. Buildings, Vol. 14, No. 7, 2024. DOI: 10.3390/buildings14072050.

[5] Wen C., Zhang P., Wang J., and Hu S., Influence of fibers on the mechanical properties and durability of ultra-high-performance concrete: A review. Journal of Building Engineering, Vol. 52, 2022, p. 104370. DOI: 10.1016/j.jobe.2022.104370.

[6] Xu J., Wu C., Xiang H., Su Y., Li Z. X., Fang Q., and Li J., Behavior of ultra high-performance fiber reinforced concrete columns subjected to

blast loading. DOI: 10.1016/j.engstruct.2016.03.048.
[7] Mander JB, Priestley MJN, and Park R (1988). "Theoretical stress-strain model for confined concrete." J. Struct. Engrg., ASCE, 114(8), 1804-1826. DOI: 10.1061/(ASCE)0733-9445(1988)114:8(1804).
[8] Paultre P. and Légeron F., Confinement reinforcement design for reinforced concrete columns. Journal of Structural Engineering, Vol. 134, No. 5, 2008, pp. 738-749. DOI: 10.1061/(ASCE)0733-9445(2008)134:5(738).
[9] Onyelowe K. C., Jagan J., Kontoni D. P. N., Moghal A. A. B., Onuoha I. C., Viswanathan R., and Soni D. K., Utilization of GEP and ANN for predicting the net-zero compressive strength of fly ash concrete toward carbon neutrality infrastructure regime. International Journal of Low-Carbon Technologies, Vol. 18, 2023, pp. 902-914. DOI: 10.1093/ijlct/ctad081.
[10] Suksiripattanapong C., Phetprapai T., Singsang W., Phetchuay C., Thumrongvut J., and Tabyang W., Utilization of recycled plastic waste in fiber reinforced concrete for eco-friendly footpath and pavement applications. Sustainability, Vol. 14, No. 11, 2022, p. 6839. DOI: 10.3390/su14116839.
[11] Baciu AM, Kiss I., Desnica E., and Sárosi J., Reinforcing concrete with recycled plastic wastes. Journal of Physics: Conference Series, Vol. 2212, No. 1, 2022, p. 012031. DOI: 10.1088/1742-6596/2212/1/012031
[12] Neville AM, Properties of Concrete, 5th ed., Pearson Education, 2011.
[13] Kintingu S. H., Design of interlocking bricks for enhanced wall construction, flexibility, alignment accuracy and load bearing. PhD Dissertation, University of Warwick, 2009.
[14] Pacheco-Torgal F. and Ding Y., Eds., Handbook of Recycled Concrete and Demolition Waste, Elsevier, 2013.
[15] Kou S. C. and Poon CS, Properties of self-compacting concrete prepared with coarse and fine recycled concrete aggregates. Cement and Concrete Composites, Vol. 31, No. 9, 2009, pp. 622-627. DOI: 10.1016/j.cemconcomp.2009.06.005
[16] Monteiro P., Concrete*:* Microstructure, Properties, and Materials, McGraw-Hill Publishing, 2006.
[17] Evangelista L. and de Brito J., Mechanical behaviour of concrete made with fine recycled concrete aggregates. Cement and Concrete Composites, Vol. 29, No. 5, 2007, pp. 397-401. DOI: 10.1016/j.cemconcomp.2006.12.004.
[18] Paul S. C. and Van Zijl G. P. A. G., Mechanical properties of concrete containing recycled concrete aggregate. Proceeding of Concrete for a Sustained Environment, Johannesburg, South Africa, 2010.
[19] Alexander M., Bentur A., and Mindess S., Durability of Concrete: Design and Construction, CRC Press, 2017.
[20] Silva R. V., De Brito J., and Dhir R. K., Properties and composition of recycled aggregates from construction and demolition waste suitable for concrete production. Construction and Building Materials, Vol. 65, 2014, pp. 201-217. DOI: 10.1016/j.conbuildmat.2014.04.117.
[21] Omary S., Ghorbel E., and Wardeh G., Relationships between recycled concrete aggregates characteristics and recycled aggregates concretes properties. Construction and Building Materials, Vol. 108, 2016, pp. 163-174. DOI: 10.1016/j.conbuildmat.2016.01.042.
[22] Esmaeily A. and Xiao Y., Behavior of reinforced concrete columns under variable axial loads: analysis. ACI Structural Journal, Vol. 102, No. 5, 2005, p. 736.
[23] de Brito J., Evangelista L., and Thomas C., Multirecycled concrete aggregates in concrete production. Waste and Byproducts in Cement-Based Materials, Woodhead Publishing, 2021, pp. 387-411. DOI: 10.1016/B978-0-12-820549-5.00018-8.
[24] Zhang B., Yu T., and Teng J. G., Behavior of concrete-filled FRP tubes under cyclic axial compression. Journal of Composites for Construction, Vol. 19, No. 3, 2015, pp. 401-406.DOI: 10.1061/(ASCE)CC.1943-5614.0000523.
[25] Sonawane T. R. and Pimplikar S. S., Use of recycled aggregate concrete. IOSR Journal of Mechanical and Civil Engineering, Vol. 52, 2013, pp. 59-62.
[26] Tam V. W., Soomro M., Evangelista A. C. J., and Haddad A., Deformation and permeability of recycled aggregate concrete—A comprehensive review. Journal of Building Engineering, Vol. 44, 2021, p. 103393.DOI: 10.1016/j.jobe.2021.103393.
[27] Kong F. K. and Evans R. H., Reinforced and Prestressed Concrete, CRC Press, 2017.
[28] Chang T. P., Lin H. C., Chang W. T., and Hsiao J. F., Engineering properties of lightweight aggregate concrete assessed by stress wave propagation methods. Cement and Concrete Composites, Vol. 28, No. 1, 2006, pp. 57-68. DOI: 10.1016/j.cemconcomp.2005.07.002.
[29] Wu X., Yan Q., Hedayat A., and Wang X., The influence law of concrete aggregate particle size on acoustic emission wave attenuation. Scientific Reports, Vol. 11, No. 1, 2021, p. 22685. DOI: 10.1038/s41598-021-02234-x
[30] Marinković S., Radonjanin V., Malešev M., and Ignjatović I., Comparative environmental assessment of natural and recycled aggregate

concrete. Waste Management, Vol. 30, No. 11, 2010, pp. 2255-2264. DOI: 10.1016/j.wasman.2010.04.012.

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