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TRANSLATION OF RECYCLED MATERIAL PROPERTIES INTO DESIGN PARAMETERS FOR STRUCTURAL CONCRETE

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ABSTRACT
The growing demand for sustainable construction has accelerated the adoption of recycled materials in concrete production. However, the structural application of recycled aggregate concrete (RAC) is constrained by the absence of reliable methods to incorporate its material properties into design frameworks. This study presents a comprehensive analytical approach to translate the mechanical properties of RAC into practical design parameters. A critical evaluation of existing experimental studies is performed to examine compressive strength, tensile strength, and modulus of elasticity. Regression-based models are developed to quantify the influence of recycled aggregate content on these properties. The results indicate that RAC exhibits predictable reductions in stiffness and strength, which can be effectively addressed using modification factors. Design-oriented equations are proposed to facilitate the integration of RAC into structural design practices. The study concludes that RAC can be safely used in structural applications with appropriate adjustments, thereby promoting sustainable construction.

1. INTRODUCTION

The rapid expansion of infrastructure has resulted in excessive consumption of natural aggregates and increased generation of construction and demolition (C&D) waste. According to recent estimates, the construction sector contributes a significant portion of global solid waste, necessitating sustainable material alternatives.

Recycled aggregate concrete (RAC), produced using crushed concrete waste, offers a viable solution. However, recycled aggregates differ from natural aggregates due to adhered mortar, higher porosity, and increased water absorption. These characteristics affect the mechanical performance and structural behaviour of concrete.

Although numerous studies have investigated RAC at the material level, its adoption in structural design remains limited due to the lack of direct translation of material properties into design parameters. This research addresses this gap by developing analytical relationships and design recommendations for RAC.

2. LITERATURE REVIEW

2.1 Mechanical Performance of RAC

Studies by Xiao et al. (2012) and Kou & Poon (2015) indicate that compressive strength of RAC decreases with increasing recycled aggregate content. However, up to 30% replacement shows minimal strength loss.

2.2 Tensile Strength and Cracking

According to Poon et al. (2004), RAC exhibits slightly lower tensile strength due to weaker interfacial transition zones (ITZ). This affects crack propagation behaviour.

2.3 Modulus of Elasticity

Research by Etxeberria et al. (2007) shows that RAC has a lower modulus of elasticity, leading to increased deformation under load.

2.4 Enhancement Using Admixtures

The incorporation of supplementary cementitious materials (SCMs), such as fly ash and silica fume, significantly improves RAC performance (Thomas et al., 2018).

3. METHODOLOGY

3.1 Data Collection

A comprehensive dataset was compiled from peer-reviewed journals, including experimental results on RAC with varying replacement levels (0–100%).

3.2 Parameters Analysed

* Compressive strength (fck)

* Split tensile strength (ft)

* Modulus of elasticity (E)

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* Recycled aggregate content (%)

3.3 Analytical Techniques

* Statistical analysis (mean, variance)

* Regression modeling

* Comparative evaluation with conventional concrete

4. RESULT AND DISCUSSION

4.1 Compressive Strength Reduction

The analysis shows a consistent decrease in compressive strength with increasing recycled aggregate content. The relationship can be expressed as:

4.2 Tensile Strength Relationship

The tensile strength of RAC follows a modified empirical relation:

ft = 0.52 \sqrt

This indicates a marginal reduction compared to conventional concrete.

4.3 Modulus of Elasticity

The modulus of elasticity is significantly affected and can be approximated as:

E= 4200 \sqrt

This reduction impacts structural stiffness and serviceability.

4.4 Regression Model

A generalized regression model is proposed:

$Y = a + b(RCA) + c(W/C) + d(SCM)$

Where:

* Y = Mechanical property

* RCA = Recycled aggregate (%)

* W/C = Water-cement ratio

* SCM = Supplementary materials

4.5 Structural Behaviour

* Load capacity: Slight reduction

* Deflection: Increased due to lower stiffness

* Crack pattern: Comparable to conventional concrete

5. DESIGN IMPLICATIONS

5.1 Strength Design

RAC can be used in limit state design with appropriate reduction factors.

5.2 Serviceability

Higher deflections must be considered in design calculations.

5.3 Durability

Durability can be improved using SCMs and proper curing methods.

6. PROPOSED DESIGN RECOMMENDATIONS

* Limit recycled aggregate content to ≤40% for structural members

* Apply 10–20% reduction factor in modulus of elasticity

* Use fly ash or silica fume to enhance performance

* Modify standard empirical equations for RAC

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7. CONCLUSION

This study provides a systematic framework for translating the material properties of recycled aggregate concrete into structural design parameters. The proposed empirical relationships and modification factors enable engineers to safely incorporate RAC into structural applications. The findings support the broader adoption of sustainable construction materials without compromising structural integrity.

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