# OPTIMIZATION OF RESOURCE-EFFICIENT WALL BLOCK COMPOSITION BASED ON RECYCLED CONCRETE AGGREGATES AND INVESTIGATION OF THEIR PHYSICAL AND MECHANICAL PROPERTIES

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**Abstract** This article examines the possibility of producing resource-efficient wall blocks from recycled concrete aggregates obtained from construction and demolition waste. The main objective of the research was to develop an optimal wall-block composition using recycled concrete aggregates and to assess the principal physical and mechanical properties of the finished blocks. A technological sequence involving crushing, separation into fractions, and incorporation of recycled concrete aggregate into the concrete mixture was proposed. Particular attention was paid to the effect of recycled aggregate content on density, water absorption, and compressive strength. The model results show that increasing the proportion of recycled concrete aggregate decreases density, increases water absorption, and causes a moderate reduction in compressive strength. At 50% recycled aggregate content, a rational balance between strength and resource efficiency was observed. The use of recycled concrete aggregate can reduce the consumption of natural raw materials and promote the reuse of construction waste as a secondary resource.

**Keywords:** recycled concrete, recycled concrete aggregate, wall block, construction waste, density, water absorption, compressive strength, resource efficiency.

## 1. Introduction

The rapid development of the construction industry is increasing the demand for natural mineral raw materials. Large quantities of natural sand and gravel are traditionally used in concrete production, while a considerable amount of concrete waste is generated during the construction, reconstruction, and demolition of buildings and structures.

One of the promising ways to address these two issues simultaneously is to process concrete waste and use it as a secondary aggregate. Since aggregates occupy a significant volume of construction materials, partial replacement with recycled materials can reduce the consumption of natural resources and improve environmental sustainability.

Recycled concrete aggregate is commonly produced by crushing old concrete, separating reinforcing steel, screening, and fractionating the material. However, the properties of recycled aggregates differ from those of natural aggregates because of the adhered old mortar, which may decrease density and increase water absorption. These characteristics directly affect the water demand, workability, and physical-mechanical properties of hardened concrete.

Therefore, for wall blocks made with recycled concrete aggregate, it is important not only to replace natural aggregate but also to determine the optimum composition. The aim of this study was to develop resource-efficient wall blocks based on recycled concrete aggregate, determine the optimal replacement level, and evaluate the main physical and mechanical properties of the final product.



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**2. Materials and Methods**

Concrete waste generated during construction and demolition processes was considered as the main secondary raw material. Foreign materials such as metal, wood, plastic, and brick fragments were removed, after which the concrete pieces were mechanically crushed and separated into fractions. The proposed technological sequence was as follows: concrete waste → sorting → removal of metal and impurities → crushing → screening → fractionation → recycled concrete aggregate → concrete mixture → molding → compaction → curing → wall block.

The principal experimental factor was the degree of replacement of natural aggregate by recycled concrete aggregate (RCA). Five composition variants were considered: a control mixture and four mixtures containing 25, 50, 75, and 100% RCA. Because RCA usually has higher water absorption than natural aggregate, the water content of the mixture was adjusted accordingly.

**Table 1. Composition variants of wall blocks**

| Variant | Natural aggregate, % | RCA, % | Cement, kg/m³ | Water, l/m³ |
|---|---|---|---|---|
| Control | 100 | 0 | 320 | 170 |
| 25% RCA | 75 | 25 | 320 | 174 |
| 50% RCA | 50 | 50 | 320 | 179 |
| 75% RCA | 25 | 75 | 320 | 184 |
| 100% RCA | 0 | 100 | 320 | 190 |

The prepared concrete mixtures were placed into molds, compacted by vibration, subjected to initial hardening, and then cured under prescribed conditions. The quality of the finished blocks was assessed in terms of density, water absorption, and compressive strength. Density was determined from specimen mass and volume, water absorption was determined from the difference between dry and saturated mass, and compressive strength was calculated from the maximum failure load divided by the loaded area.

**3. Results**

The model results obtained for the main physical and mechanical properties of the wall blocks are presented in Table 2.

**Table 2. Influence of RCA content on the physical and mechanical properties of wall blocks**

| Variant | RCA, % | Density, kg/m³ | Water absorption, % | Compressive strength, MPa |
|---|---|---|---|---|
| Control | 0 | 1980 | 6.8 | 14.2 |
| 25% RCA | 25 | 1945 | 7.4 | 14.0 |
| 50% RCA | 50 | 1905 | 8.2 | 13.5 |
| 75% RCA | 75 | 1855 | 9.4 | 12.4 |
| 100% RCA | 100 | 1810 | 10.7 | 11.2 |

The results indicate that as the RCA content increased from 0 to 100%, block density decreased from 1980 to 1810 kg/m³, while water absorption increased from 6.8 to 10.7%. Compressive strength decreased from 14.2 MPa in the control sample to 11.2 MPa at full replacement. Nevertheless, the 25–50% replacement range maintained comparatively favorable strength values and may be considered technically acceptable for wall-block production.



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The evolution of strength with curing time is given in Table 3. The tendency remained similar at 7, 14, and 28 days: increasing RCA content slightly reduced strength, but the decline was moderate in the 25–50% replacement range.

**Table 3. Compressive strength of wall blocks at 7, 14, and 28 days**

| Variant | RCA, % | 7 days, MPa | 14 days, MPa | 28 days, MPa |
|---|---|---|---|---|
| Control | 0 | 10.3 | 12.7 | 14.2 |
| 25% RCA | 25 | 10.1 | 12.5 | 14.0 |
| 50% RCA | 50 | 9.8 | 12.1 | 13.5 |
| 75% RCA | 75 | 8.9 | 11.0 | 12.4 |
| 100% RCA | 100 | 8.0 | 9.9 | 11.2 |

A model resource-efficiency calculation showed that the use of 50% RCA could save 5.0 kg of natural aggregate per block, equivalent to about 50 t of natural aggregate per 10,000 blocks. This confirms the practical significance of recycled aggregate not only as a technological but also as a resource-saving solution.

**4. Discussion**

The results demonstrate that the incorporation of recycled concrete aggregate in wall blocks helps solve two important issues at the same time: reduction of natural aggregate consumption and utilization of construction and demolition waste. However, the physical properties of RCA are not identical to those of natural aggregate. The adhered old mortar increases porosity and water absorption, and this may adversely affect mixture water demand and block strength.

For this reason, increasing RCA content does not automatically improve product quality. Instead, the optimum replacement level should be established experimentally by considering particle-size distribution, moisture content, cement dosage, water-cement ratio, compaction method, and curing conditions. The model data indicate that 50% RCA provides a rational compromise between density, water absorption, compressive strength, and natural resource savings.

The findings are consistent with published studies that reported the feasibility of using recycled concrete aggregate in masonry units and vibro-compacted wall blocks. Nevertheless, optimal compositions are material- and technology-specific, and therefore final recommendations should be verified by full-scale laboratory and industrial testing.

**Conclusions**

1. Construction and demolition concrete waste can be processed into recycled aggregate suitable for wall-block production.
2. Recycled concrete aggregate has specific physical properties that influence mixture behavior and the final physical-mechanical properties of wall blocks.
3. The use of RCA in wall blocks reduces the demand for natural aggregates and promotes efficient waste utilization.
4. An increase in RCA content decreases density, increases water absorption, and moderately reduces compressive strength.
5. Based on the model evaluation, the 50% RCA mixture may be considered an optimal or near-optimal composition from the standpoint of strength and resource efficiency.
6. Final optimization should be confirmed by standardized laboratory testing under actual production conditions.



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