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PROPERTIES OF RECYCLED SECONDARY AGGREGATES IN THE PRODUCTION OF RESOURCE-SAVING LOW-GRAVEL CONCRETE

Prof. Z. J. Pasieva
Prof. A. A. Pakhratdinov
Prof. J. Sh. Nizamtdinov
Karakalpak State University named after Berdakh

Abstract
This article examines the pressing issues of producing resource-saving, low-gravel concrete materials based on local Aral sand and utilizing secondary aggregates obtained from recycling concrete waste generated during public building construction, urban development, and landscaping projects. Considering the physical and mechanical properties of these secondary aggregates, the study highlights their potential application in concrete mixes, ways to reduce natural gravel consumption, and methods for improving the technological and operational performance of concrete mixtures.

Keywords. Fine-grained concrete, low-gravel concrete, Aral sand, secondary aggregates, recycled concrete waste, concrete mixture, resource-saving technology, physical and mechanical properties of concrete.

Introduction

Currently, concrete is one of the most widely used building materials in the global construction industry. The growing demand for concrete and reinforced concrete products in building construction, urban planning, and landscaping necessitates the rational use of natural raw materials, reduced production costs, and the development of new building materials based on the recycling of industrial waste. In this regard, the effective use of recycled aggregates obtained by processing defective and substandard concrete products in concrete production represents a pressing scientific and technical challenge. This approach reduces construction waste, conserves natural gravel and crushed stone resources, and enables the production of competitive, cost-effective building materials using local raw materials. The use of low-gravel concrete is particularly important in the manufacture of local decorative concrete materials and products, including cinder blocks, road curbs, paving slabs, and precast concrete pavement elements. In this process, the consumption of natural aggregates in concrete can be reduced by reusing coarse and fine recycled aggregates obtained by crushing and fractionating unusable concrete products [1-4].

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The physical, mechanical, and technological properties of recycled secondary aggregates differ from those of natural aggregates in several respects. In particular, the residual layer of old hardened cement paste on their surface, along with their porosity, water absorption, particle size distribution, and degree of crushing, directly affects the rheological properties of the concrete mix and the strength of the hardened concrete. Therefore, when using secondary aggregates, it is crucial to account for their fractional composition, density, water absorption, and crushing resistance, as well as to determine the optimal parameters for the recycling process. Another important aspect of research in this area involves expanding the potential use of local sand from the Aral Sea region. Producing low-gravel concrete using Aral sand reduces the consumption of natural coarse aggregates and enables the efficient use of local mineral raw materials. However, the particle size distribution, particle shape, packing arrangement of the Aral sand and recycled secondary aggregates, and their interfacial transition zone with the cement paste are critical factors that influence the structure and physical-mechanical properties of the concrete.

In this regard, the use of active organomineral additives, as well as the application of mechanochemical activation methods for cement and mineral components, holds particular scientific and practical importance for improving the technological properties of low-gravel concrete mixtures and enhancing the strength and operational performance of hardened concrete [5-8]. An analysis of domestic and foreign practices in recycling concrete waste reveals the feasibility of using recycled secondary aggregates in the preparation of concrete mixtures. In particular, it is important to take into account the quality indicators and technical requirements for aggregates used in concrete under GOST 26633-2015. Furthermore, the "All-Union Standards for the Technological Design of Enterprises Producing Reinforced Concrete Products" (ONTP-7-85) outline the technological requirements for recycling and utilizing concrete waste and defective reinforced concrete products [9-13].

1 – secondary fine aggregate belonging to the class of fine aggregates;

2 – secondary coarse aggregate belonging to the class of coarse aggregates;

Physical and mechanical properties of secondary aggregates obtained from recycling TMCH waste

Table 1Description of the secondary aggregate

Fractions	Average density, g/cm ^{3}	Bulk density, g/cm ^{3}	passing, %	voids, %
0-10	1.9 1	1.2 8	1 4	3 4
0-20	2. 9	1.3 3	15	3 7
5-20	2.1 8	1.3 2	1 3	4 3
10-40	2.2 5	1.3 1	1 1	4 1

Testing recycled aggregates obtained from processing CDW and determining their physical, mechanical, and granulometric properties play a vital role in improving the production technology of low-gravel concrete. In this context, assessing the particle size distribution,

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particle shape, porosity, and water absorption of recycled aggregates determines the feasibility of their effective use in concrete mixes. An analysis of domestic and international experience shows that insufficient attention to the content and properties of fine recycled aggregates derived from crushed concrete waste can lead to a decline in certain physical, mechanical, and performance characteristics of concrete [14-16]. Therefore, selecting the optimal fractional composition of recycled aggregates and experimentally substantiating their impact on the properties of both fresh and hardened concrete remains a pressing scientific task.

CDW recycling site and the technological process for producing recycled aggregates



Figure 1. Operation of the crushing and screening plant at the "Metan Ekspert Qo'ng'irot" private enterprise

a) - breaking down reinforced concrete structures; b) - general view of the crushing site; c) mobile crushing and screening plant; d) - dispatching finished products.

Experimental studies were conducted to determine the composition of particles of various sizes obtained from the secondary crushing of recycled concrete waste. This involved using a method to separate the original coarse and fine aggregates from the residual cement paste in the crushed material, as well as to determine their quantitative ratio. Coarse secondary aggregates were obtained by sorting the primary aggregate particles that had separated from the cement paste layer during the mechanical crushing process. To separate the original solid aggregates from the residual cement paste, the dry crushed mixture was passed through a 5 mm sieve. The mass of the coarse particles retained on the sieve was measured, and the pieces of cement paste adhering to them were carefully removed by mechanical means. As a result, the mass of the separated solid aggregates was determined. The material that passed through the sieve was collected separately as a mixture containing the fine fraction and residual cement paste.

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An ammonium nitrate solution was used to separate fine aggregate particles, namely sand, from cement paste residues and to determine their quantity. In this process, the fine-fraction mixture was treated with the solution, and the resulting suspension was separated by filtration. Because the particles retained on the filter could contain fine fractions of both sand and cement paste, they were subjected to further analysis. When identifying carbonate particles within the fine aggregates, the possibility of their partial dissolution due to the solution was also considered. Consequently, the experiments were conducted using parallel samples. Mass loss was observed during the chemical treatment of porous sand particles, and this factor was accounted for when evaluating the accuracy of the separation method.

The total cement content is determined by subtracting the combined mass of coarse and fine aggregates from the total mass of the concrete sample—specifically, the sum of the residues retained on all sieves, accounting for the proportion of pure sand at 0.14 mm, as indicated above; the experimental results are presented in Tables 2 and 3.

Table 2 Components and properties of recycled crushed concrete

Grain characteristics	Volume fraction content, %		
	5–10 mm	10–20 mm	20–40 mm
Secondary crushed stone grains, including crushed grains with fresh surfaces	23, 4 12, 4	26, 5 9, 8	42, 2 21, 3
Aggregates of crushed stone grains with hardened cement-sand mortar	8	1 4	27, 4
Aggregates of hardened cement-sand mortar	69, 6	58, 5	30, 5

Table 3 Second composition of crushed concrete, %

Crushed stone size, mm	Cement	Sand	Crushed stone
5-10	23.8	51.9	24.3
10-20	18.8	33.2	48
20-40	16.9	36.9	46.2

As shown in Table 3, the composition of the lime component obtained from recycled secondary aggregates of 10-20 mm and 20-40 mm in size is approximately the same, and its content corresponds to in conventional concrete. In the fine 5-10 mm fraction of cement-free concrete, the lime content increases, reaching 75%. In general, recycled secondary aggregates retain a greater amount of old cement paste residues compared to conventional natural crushed stone. This may negatively affect certain physical, mechanical, and operational properties of concrete produced using secondary aggregates.

The particle shape, surface texture, and quality of secondary aggregates differ from those of natural aggregates. Specifically, they may exhibit relatively low density, high water absorption, and lower resistance to environmental exposure. A higher degree of mass loss is also observed during mechanical testing and abrasion. These characteristics are primarily attributed to the

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porous layer of old cement paste retained on the surface of the secondary aggregates [8]. According to research data, the amount of cement paste residue adhering to the surface of recycled secondary aggregates can reach 36–39%. Furthermore, it has been noted that as the water-to-cement (W/C) ratio of the original concrete increases, the proportion of cement paste residue in the secondary aggregates decreases slightly.

Furthermore, as the particle size of recycled aggregates decreases, the relative proportion of residual cement paste within them changes. Specifically, in fine particles up to 0.3 mm in size, the content of old cement paste residue can reach approximately 50%, whereas in coarser recycled aggregates, this figure may be around 20–25%. This indicates the need for a dedicated study on the chemical and mineralogical composition of fine-fraction recycled aggregates, as well as their impact on the properties of the concrete mix.

Conclusion

Summarizing the results of the theoretical and experimental studies leads to the following conclusions. The comprehensive use of recycled fine and coarse aggregates obtained from processing concrete waste makes it possible to conserve natural mineral raw materials in the production of low-gravel concrete. Combining local Aral sand with recycled aggregates makes it possible to optimize the particle size distribution of the concrete and develop resource-efficient concrete mix designs. Improving the crushing, sorting, and fractionation processes for recycled aggregates enhances their quality indicators and broadens the potential for their effective use in concrete production. The developed technological solutions show promise for manufacturing local decorative concrete building materials and products, including road curbs, cinder blocks, paving slabs, and precast concrete road pavement elements. The proposed technology facilitates the recycling of construction waste, reduces the consumption of natural aggregates, ensures the efficient use of energy and material resources, and minimizes negative environmental impacts.

Final scientific conclusion: Improving the production technology of low-gravel concretes based on local Aral sand and recycled secondary aggregates is a key direction for ensuring resource efficiency in the construction materials industry, promoting the integrated use of technogenic waste, and developing environmentally sustainable production.

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