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EFFECTIVE USE OF RECYCLED CONCRETE AGGREGATES IN THE PRODUCTION OF CONCRETE AND REINFORCED CONCRETE PRODUCTS

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Abstract
This article examines promising approaches to recycling and reusing construction waste primarily concrete and reinforced concrete rubble to produce recycled building materials with specified physical, mechanical, and performance characteristics. Special attention is paid to the technological processes of crushing, sorting, and fractionating waste, as well as the potential for its reuse in the manufacturing of building materials.

Keywords: concrete and reinforced concrete rubble recycling; construction waste reuse technology; mechanical crushing method; electro-pulse concrete fragmentation method; sorting and fractionation of recycled aggregate; construction waste utilization; recycled building materials.

Introduction

The issue of recycling and reusing construction waste, primarily concrete and reinforced concrete rubble, is becoming increasingly urgent not only for Moscow and other major metropolitan areas in the CIS, but also for the Republic of Uzbekistan. This is driven by the need to address a range of environmental, economic, and resource-conservation challenges. First and foremost, recycling construction waste helps improve environmental conditions, reduce the volume of waste sent to landfills, decrease the demand for natural aggregates, and produce more affordable materials for new construction. Furthermore, reusing recycled materials makes it possible to optimize the traffic flows associated with delivering natural aggregates and cut transportation costs.

Under modern conditions, specialized organizations equipped for the dismantling of buildings and structures demolish built structures by first dismantling the structural elements and sorting the resulting waste. During this process, concrete and reinforced concrete rubble is separated from other types of construction waste and sent for further recycling. The main processing operations are performed at crushing and screening plants, which can be either stationary or mobile depending on operational conditions. An analysis of domestic and international

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practices in organizing construction waste recycling makes it possible to identify several efficient process flowsheets.

The first scheme involves transporting reinforced concrete debris from demolished buildings and structures to specialized stationary recycling facilities equipped with crushing, screening, and auxiliary processing equipment. The resulting recycled products crushed concrete and graded aggregate are sold to customers for subsequent use in construction. Given adequate production capacity and relatively modest capital investment, it is advisable to establish the manufacturing of technologically simple yet material-intensive building products alongside the main recycling operations. These products include foundation blocks, small-unit wall blocks, and other items made from recycled aggregates.

The second scheme is used when large volumes of building structures are being dismantled at a single construction site. In this case, mobile crushing and screening plants are located directly at the demolition site of the buildings and structures. The resulting recycled aggregates can be used directly on the same construction site, which significantly reduces transportation costs, lowers the demand for natural building materials, and improves the overall efficiency of construction operations. Depending on the nature of the force applied to the material being processed, the methods for breaking down scrap concrete are classified as either static or dynamic. Static methods rely on the application of splitting, crushing, and cutting forces. Dynamic methods involve breaking down concrete using impact, vibration, and explosive loads. The choice of a specific method is determined by the physical and mechanical properties of the source material, the composition of the reinforced concrete structures, the quality requirements for the recycled aggregate, and the technological conditions of the processing.

Thus, establishing specialized construction waste processing sites is a promising avenue for developing resource-saving technologies in the construction industry. The process of recycling and reusing concrete and reinforced concrete scrap is best illustrated by the processing of reinforced concrete products, the technological sequence of which is shown in Figure 1.

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Process flow diagram for recycling off-spec concrete and reinforced concrete

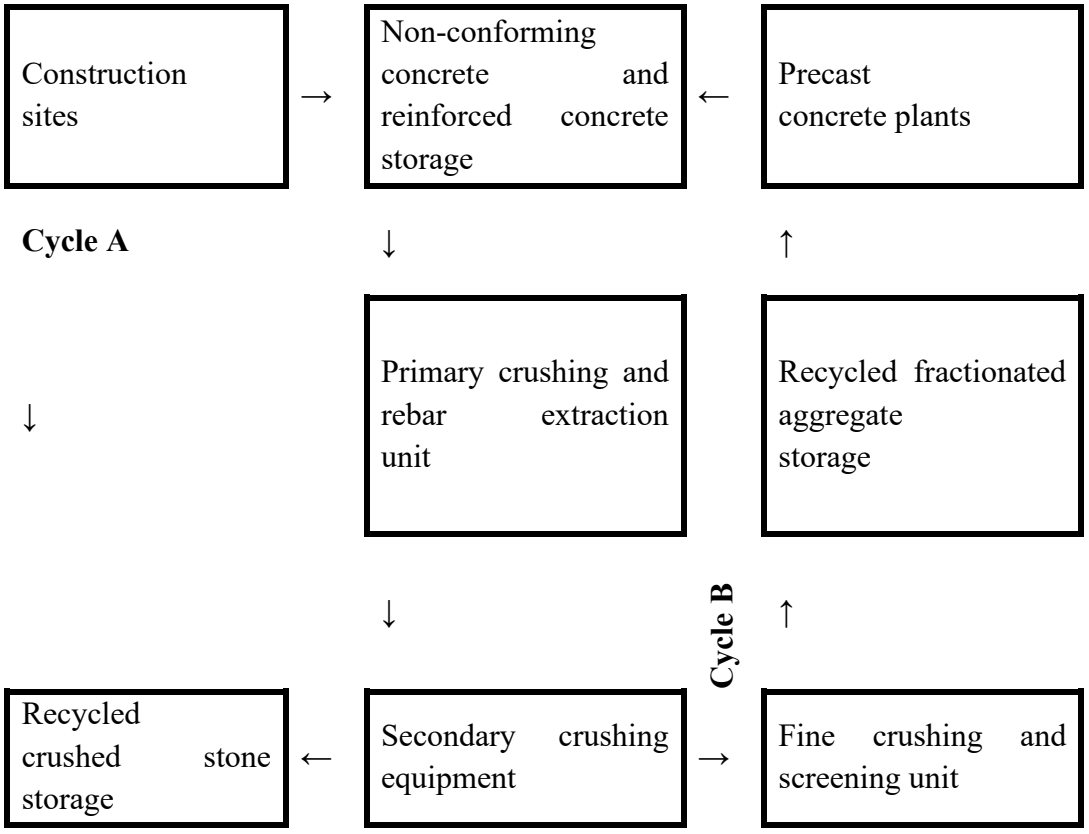

Figure 1 – Process flow diagram for recycling and reusing concrete and reinforced concrete rubble.

In Russian practice, the technology for recycling and reusing concrete rubble according to the second option of the regional scheme [1–3] (Cycle A) has become widespread. With this approach, the resulting recycled aggregate is primarily used for constructing crushed stone sub-bases, road bases, and other structural elements of road pavements. From the perspective of rational secondary resource management, the third option of the regional concrete rubble recycling scheme (Cycle B) is more effective. Under this technology, recycled crushed stone can be used as a coarse aggregate in the plant-based production of concrete with a compressive strength of 5 to 30 MPa. This expands the range of applications for recycled concrete products and reduces the consumption of natural mineral aggregates. Given the experience of international companies specializing in the recycling and reuse of concrete rubble, it is advisable to examine various process flow schemes for organizing these operations [4–7].

In Japan, the third option for recycling and reusing concrete has become widespread. To improve the cost-effectiveness of using waste concrete as recycled aggregate, it is advisable to process it directly at the construction site using compact crushing units and screens [8-11]. When implementing this technology on-site, the following operations are performed sequentially: crushing the waste concrete, sorting the resulting material into fractions, preparing a concrete mix using the recycled aggregate, and subsequently placing it to erect new building structures. This approach establishes a closed-loop process for utilizing construction

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waste, reduces transportation costs, and increases the efficiency of using secondary material resources.

A basic process flow diagram for recycling waste concrete, followed by the on-site preparation and placement of the concrete mix, is shown in Figure 2.

Recycled aggregate production flow diagram

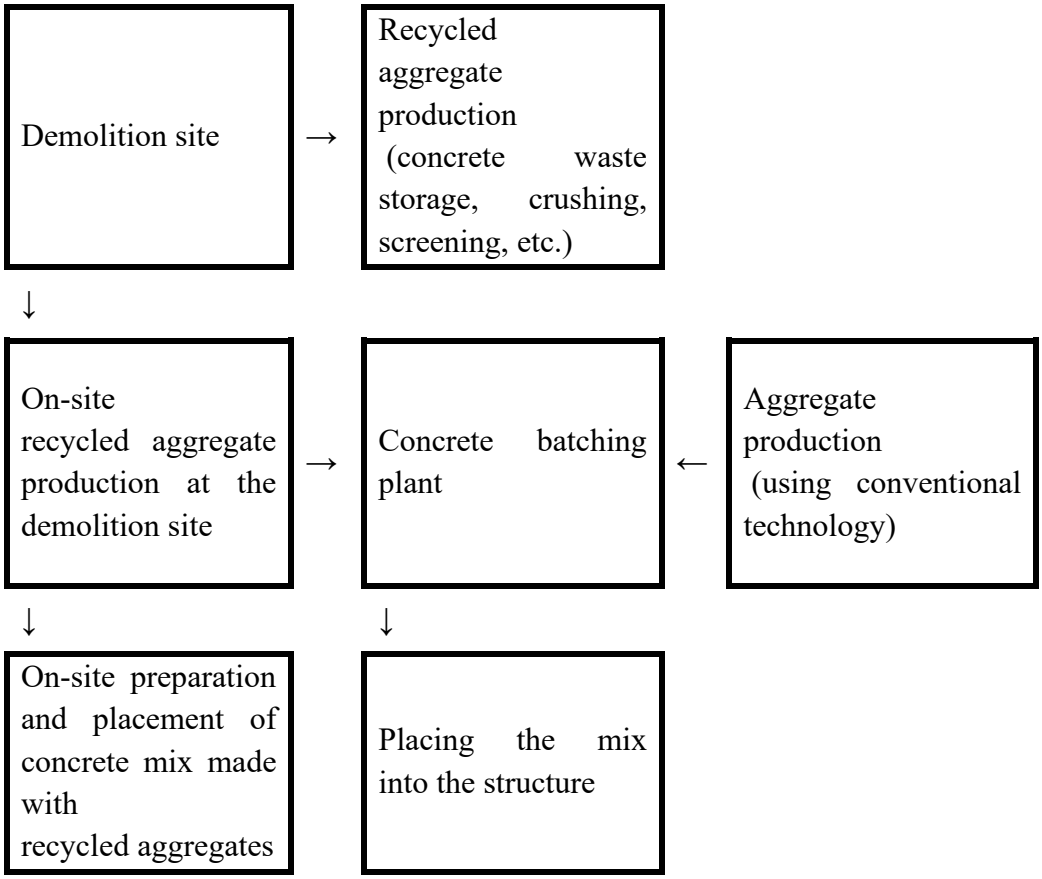

Figure 2 – Process flow diagram for concrete scrap recycling and the on-site reuse of recycled aggregate.

Reinforced concrete scrap generated during the demolition and dismantling of buildings and structures is transported to specialized yards (processing sites), where it is stockpiled in preparation for primary crushing. Currently, reinforced concrete scrap is recycled primarily using two main methods: mechanical and electro-pulse.

Mechanical recycling involves several sequential process operations. Following the demolition of buildings and structures, the reinforced concrete scrap is delivered to a crushing and screening yard. In the first stage, oversized reinforced concrete structures are broken down into individual fragments measuring 1.0-1.5 m, which are then fed into the crushing and screening plant. In the next stage, the pre-crushed fragments enter a primary (coarse) crusher before being routed to secondary crushing equipment for further size reduction. During the crushing process, magnetic separators are used to extract metal inclusions and residual rebar. Once the metal

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components are removed, the material is screened, sorted into distinct fractions, and stockpiled as a finished product.

Processing yields recycled crushed stone in the following size fractions: 0–10, 10–20, 20–40, and 40–70 mm. These fractions can be used as recycled aggregate in the production of various construction materials and for construction work. It should be noted that recycled aggregates obtained by crushing reinforced concrete waste and removing metal inclusions exhibit several distinct physical and mechanical properties compared to natural aggregates. In particular, they are characterized by lower average density, higher water absorption, greater mass loss in weathering tests, and increased abrasion loss. The main reason for these altered characteristics is the presence of residual cement mortar on the surface of the recycled aggregate particles, which remains after the concrete waste is crushed. The amount and properties of this mortar component significantly affect both the quality of the recycled aggregate and the performance of concrete produced with it[12–15]. The main reason for the change in the specified characteristics is the presence of old cement mortar residues on the surface of the secondary filler grains, which are retained during the crushing of concrete scrap.

Conclusion

Thus, an analysis of the technological processes for recycling concrete and reinforced concrete scrap indicates that using crushed recycled aggregate in the production of heavy-weight concrete is a promising approach. Using recycled crushed stone makes it possible to produce concrete mixes and hardened concretes with the required strength and deformation characteristics, provided that the aggregate meets quality standards and the concrete mix design is optimized.

The use of recycled aggregates in the production of concrete and reinforced concrete products and structures promotes the efficient use of material resources, reduces the consumption of natural raw materials, and decreases the volume of construction waste. At the same time, ensuring the required physical, mechanical, and performance characteristics of concrete is essential for manufacturing durable and reliable building structures capable of performing effectively under demanding operating conditions.

Consequently, advancing technologies for recycling concrete and reinforced concrete scrap and expanding the applications of recycled aggregates are promising avenues for improving the resource and environmental efficiency of the construction industry.

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