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Use of recycled concrete and brick waste as aggregates in concrete

Gurbanova Rena Vagif, Mammadova Aygul Elsavar
Department of Chemistry and Technology of Inorganic Substances, Azerbaijan State Oil and Industry University, Baku, Azerbaijan

Abstract
Reuse of concrete and brick scrap as aggregates in concrete is a promising direction for sustainable construction and efficient management of construction waste. In the context of rapid growth in construction volumes and disposal of construction waste, the use of secondary materials can reduce the burden on natural resources, reduce waste disposal volumes and reduce carbon dioxide emissions. This paper discusses the physical and mechanical properties of secondary aggregates, the features of their preparation and processing, as well as their impact on the strength, durability and other characteristics of concrete. Analysis of domestic and foreign experience shows that, subject to technological requirements, concrete with secondary aggregates can be successfully used in various building structures. Improving environmental and economic efficiency makes the reuse of concrete and brick scrap a relevant and justified solution in modern conditions. This paper is devoted to the study of the possibility of reusing construction waste — concrete and brick scrap — as aggregates in concrete. In order to substantiate the feasibility of such an approach, a detailed analysis of existing scientific publications and engineering developments in this area was carried out. Based on the collected data, an experimental plan was drawn up, including the preparation of secondary crushed stone samples and the production of cement concrete with different proportions of recycled materials.
The experimental part determined the physical and mechanical characteristics of crushed stone obtained from concrete and brick scrap, as well as the main strength and density indicators of concrete samples made using it. A comparative analysis with traditional fillers was conducted. The results showed that, subject to certain technological conditions, secondary materials can be effectively used in the production of concrete without significant deterioration of its operational properties.
Conclusions are formulated on the prospects of using recycled concrete and brick scrap as fillers in concrete, which helps to reduce the environmental burden, save natural resources and develop sustainable construction.

Keywords: Fillers in concrete, concrete scrap, ceramic brick scrap, secondary crushed stone

Introduction

Modern construction is accompanied by a significant amount of construction waste, the bulk of which is made up of reinforced concrete and brick structures [1-5] In the context of growing demands for environmental safety and rational use of resources, the reuse of this waste in the construction industry is becoming an urgent task. One of the promising areas of recycling is the use of recycled concrete and brick scrap as fillers in concrete (Fig. 1).
The use of secondary fillers allows to reduce the load on natural quarries, reduce the volume of waste subject to disposal, and reduce the carbon footprint of construction production [6-8]. However, the introduction of such materials requires justification of their influence on the physical and mechanical properties of concrete, as well as the determination of maximum dosages at which it is possible to maintain operational characteristics. In recent decades, the problem of recycling construction waste has become increasingly relevant due to the intensive development of the construction industry and the limited natural resources. One of the promising directions for solving this problem is the use of recycled concrete and brick scrap as secondary fillers in concrete mixtures.
Research by foreign and domestic authors demonstrate that recycled concrete scrap can be effectively used in the composition of heavy concrete, possessing satisfactory physical and mechanical properties. Thus, in the literature [9-11] it was found that replacing natural crushed stone with recycled concrete crushed stone up to 30-50% leads to a slight decrease in the strength of concrete samples - within 10-15%. In the work [12] it is noted that the mechanical characteristics of concrete depend on the quality of the original concrete scrap, the technology of crushing and processing, as well as the correct selection of fractions.
An important aspect is also the influence of secondary filler on the durability of concrete. It has been established that an increase in concrete porosity due to the use of recycled concrete [13] can negatively affect the frost resistance and water resistance of the material, which requires the use of special additives and modifiers.
As for broken bricks, as studies show [14], this material is characterized by higher porosity and water absorption compared to concrete scrap. Therefore, the use of broken bricks is limited to non-structural or lightweight concrete, heat-insulating layers and pavement surfaces. At the same time, some works [15] demonstrate the possibility of using broken bricks in structural concretes, subject to additional processing and composition control.
In Russian conditions, Simonova and Kolesnikov [4] studied the use of secondary fillers in concrete mixtures and came to the conclusion that replacing natural crushed stone with recycled concrete and brick scrap up to 50% does not lead to a significant deterioration in strength characteristics, provided that the composition is correctly selected and modern plasticizers are used.
In addition to technical aspects, the economic and environmental effect of the introduction of secondary

aggregates is important. According to research [16], the use of recycled concrete allows for a significant reduction in waste volumes at landfills and a reduction in the extraction of natural crushed stone, which has a positive effect on the sustainable development of the construction industry.

Thus, the review of scientific literature confirms the potential of using concrete and brick rubble as secondary fillers, but indicates the need for careful quality control of materials and optimization of the composition of concrete mixtures to ensure the required performance characteristics.

Fig 1: Recycled concrete and brick waste as fillers in concrete

Experimental Methodology

To assess the effect of secondary aggregates on the properties of concrete, several series of test samples were prepared with different proportions of natural crushed stone being replaced by concrete and brick rubble. In total, six types of concrete mixtures were produced.

- Control mixture without secondary fillers (0%)
- Mixtures with 25, 50, 75 and 100% concrete rubble as a replacement for natural crushed stone
- Mixture with combined filler: 25% concrete waste and 25% broken brick.

Secondary materials were pre-crushed and sieved to obtain a large fraction of 5–20 mm, similar to the natural crushed stone used. Particular attention was paid to cleaning and removing dust and foreign inclusions, which made it possible to minimize the impact of contaminants on the quality of concrete.

Concrete mixtures were prepared in a laboratory concrete mixer in accordance with the approved recipe, ensuring a constant ratio of cement, sand, water and aggregates. The mixtures were thoroughly mixed until a homogeneous mass was obtained.

The samples were made in the form of cubes measuring 100×100×100 mm and were subjected to vibration compaction to remove air voids. After molding, the cubes were stored in a chamber at a temperature of 20±2 °C and a relative humidity of about 95% for 28 days to fully gain strength.

For each type of mixture, at least five samples were prepared and tested, which allowed us to obtain statistically significant results (Table 1).

The following characteristics were determined

- Density of concrete
- Compressive strength according to GOST 10180
- Water absorption according to GOST 12730.3
- Frost resistance according to GOST 10060 (method of accelerated freezing and thawing)

Table 1: Composition of mixtures

Sample	Secondary filler	Share (%) of crushed stone mass
Control	—	0
Concrete 25	Concrete scrap	25
Concrete 50	Concrete scrap	50
Concrete 75	Concrete scrap	75
Concrete 100	Concrete scrap	100
Mixed 50	25% concrete + 25% brick	50

Experimental results and their discussion

1. Compressive strength

The most important indicator of concrete quality is its compressive strength.

The tests showed a natural decrease in concrete strength with an increase in the share of secondary aggregates. The control concrete, prepared using only natural crushed stone, demonstrated the highest strength - 45 MPa on the 28th day of hardening, which corresponds to class B30-B35. This value was taken as a standard when comparing the other mixtures.

Mixtures with 25% and 50% replacement of natural crushed stone with concrete scrap demonstrated strength of 42 MPa and 38 MPa, respectively. These values indicate that even with a significant content of secondary material, concrete retains sufficiently high strength characteristics and can be used for structural elements in civil and industrial construction.

With an increase in the concrete scrap content to 75%, the strength decreases to 34 MPa, and at 100% - to 30 MPa. This is already approaching the limit of permissible strength for structural concrete (B20-B22.5), especially if we take into account possible deviations in operating conditions.

The mixture with combined filler (25% concrete and 25% brick rubble) showed a strength of 36 MPa, which is 20% lower than the control, but still meets the requirements for class B25 concrete. This indicates the possibility of limited use of such mixtures in low-rise construction and elements without increased load-bearing function.

Table 2: Compressive strength of concrete mixtures with different proportions of secondary aggregates

No.	Composition of the mixture	Secondary filler content (%)	Type of secondary filler	Compressive strength, MPa
1	Control mixture	0	—	45
2	Mixture with concrete scrap	25	Concrete scrap	42
3	Mixture with concrete scrap	50	Concrete scrap	38
4	Mixture with concrete scrap	75	Concrete scrap	34
5	Mixture with concrete scrap	100	Concrete scrap	30
6	Mixed mixture (concrete + brick)	50 (25+25)	Concrete + Broken bricks	36

2. Density and water absorption

Density analysis showed a decrease in this indicator as the volume of secondary aggregates increased. Thus, the density of the control mixture was 2400 kg/m³, while the mixture with 50% secondary material was about 2320 kg/m³, and with the addition of broken bricks - 2250 kg/m³. The decrease in density is due to the lower bulk density and high porosity of recycled materials, especially brick.

Water absorption also increased with the increase in the proportion of secondary components. The control concrete demonstrated water absorption at the level of 5.2%, while in mixtures with 50% secondary crushed stone it reached 6.1%, and in the case of using broken bricks - 7.0%. This is due to the open pore structure of secondary aggregates, which promotes intensive water absorption, especially with porous ceramics.

Increased water absorption potentially reduces the water resistance of concrete and can accelerate the corrosion processes of reinforcement in reinforced structures in the absence of appropriate protective measures.

Table 3: Density and water absorption of concrete mixtures

No.	Composition of the mixture	Density, kg/m³	Water absorption, %
1	Control mixture	2400	5.2
2	Mixture with 50% concrete debris	2320	6.1
3	Mixed mixture (concrete + brick)	2250	7.0

3. Frost resistance

Frost resistance tests showed that control samples withstand up to 200 freeze-thaw cycles without signs of destruction, corresponding to the F200 grade. Mixtures with 50% concrete debris showed frost resistance of F150, and mixtures with broken bricks - about F100.

The decrease in frost resistance is directly related to the increase in capillary porosity of concrete and the decrease in its water resistance. Broken bricks have the most pronounced negative impact, since they have high water saturation and an unstable structure with repeated temperature fluctuations.

Table 4: Frost resistance of concrete mixtures

No.	Composition of the mixture	Frost resistance grade (F)	Comment
1	Control mixture	F200	High stability
2	Mixture with 50% concrete debris	F150	Suitable for moderate climates
3	Mixed mixture (concrete + brick)	F100	Requires limited use

Overall, the data obtained allow us to formulate the following conclusions

- When replacing up to 50% of natural crushed stone with recycled concrete scrap, the concrete retains satisfactory strength characteristics that meet the GOST requirements for structural concrete classes B25–B30.
- At higher substitution levels (75–100%), there is a significant reduction in strength, density and durability, limiting the use of such mixtures in critical structures.
- The combination of concrete and brick fillers allows for the recycling of several types of construction waste at once, but requires caution due to the deterioration of a number of characteristics, especially frost resistance and water absorption.
- Increased porosity of secondary materials requires additional processing: fractionation, washing, and in some cases, treatment with water repellents or the addition of special plasticizers and sealing additives.

Practical recommendations

- Concrete with up to 50% secondary filler can be used in the construction of foundations for low-rise buildings, paving slabs, enclosing structures and internal elements of buildings.
- If it is necessary to increase frost resistance, it is recommended to use air-entraining additives and modify the surface of secondary fillers.
- It is advisable to use broken bricks in structures that are not subject to moisture saturation and cyclic freezing.

Abstract

The reuse of concrete and brick debris as aggregate in concrete production represents a promising direction for sustainable construction and efficient management of construction waste. In the context of rapidly growing construction volumes and increasing amounts of demolition debris, the use of recycled materials helps reduce the pressure on natural resources, decreasing landfill volumes, and lower greenhouse gas emissions.

This study examines the physical and mechanical properties of recycled aggregates, the specifics of their processing and preparation, and their impact on the strength, durability, density, frost resistance, and other key characteristics of concrete. A review of domestic and international research confirms that, when technological requirements are met, concrete with recycled aggregates can be successfully used in both structural and non-structural elements.

To justify the feasibility of this approach, an in-depth analysis of scientific literature, regulatory documents, and engineering developments was conducted. Based on the gathered data, an experimental plan was developed, which included the preparation of recycled aggregates from crushed concrete and brick waste, and the production of cement concrete with varying proportions of recycled content.

During the experimental phase, the physical and mechanical characteristics of the recycled materials were determined, along with compressive strength, density, water absorption, and frost resistance of the resulting concrete samples. The results were compared with those of traditional mixtures based on natural aggregates.

The experimental findings demonstrate that, with proper preparation and quality control, recycled concrete and brick waste can be effectively used in concrete production without significant deterioration of its performance characteristics.

The study concludes that the use of recycled construction waste as aggregate in concrete is both environmentally and economically justified, supporting the transition to more sustainable construction practices.

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