Application of Household Waste as Aggregates for Concrete

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Abstract. The use of recycled materials as a product of household waste recycling to reduce environmental pollution, as well as to obtain cheap aggregate for the manufacture of concrete is considered. During the laboratory tests, the strength of concrete was found by a non-destructive method of controlling the strength of materials - by the method of a shock pulse using an electronic strength meter IPS-MG4.01. The uniformity and class of concrete are determined on the basis of measuring the time and speed of propagation of ultrasound in them. Compression tests were carried out on parallelepiped samples of 390x190x188 mm in size, consisting of Portland cement, sand and household garbage. Significant differences were found from the indicators of the considered analogues, such as relatively low values of strength and frost resistance of the samples; but at the same time, the low cost of finished products due to the actually free aggregate, as well as the relatively low weight of the samples. Recommendations are given on the selection of the ratio of aggregate components to improve the properties of concrete as a whole. Areas of application for concrete blocks from household waste are offered.

1. Introduction

Recycle materials are nothing but household garbage, which often finds a place in landfills [1-3], or is simply burned [4-6]. Both applications (burning or storage) lead to environmental pollution, which is a pressing problem of our time [7-10]. In addition, household waste (HW) has virtually no cost, and recycling it in recyclables will not only effectively get rid of garbage, but also receives economic benefits from recycling for the products produced [11-16]. Thus, the use of recycled materials as aggregate for concrete instead of more expensive aggregate is an important scientific task.

The use of recycled materials as a concrete aggregate currently has several versions. For more than few dozen years, man has thought about the recycling of industrial waste [17-21]; construction debris, which occurs as a result of the destruction of buildings and structures that are unsuitable [22-26]; and other waste [27-31]. For example, new concretes are produced using crushed concrete [32], asphalt concrete [33] and bricks of the former use, the process of so-called recycling [34]. Also for the manufacture of concrete, it is proposed to use fly ash [35], broken glass [36], sawdust [37] and shavings, as well as metal shot [38].

The purpose of the article is to compare the developed concrete samples with previously obtained and investigated analogues for the selected indicators: compressive strength, frost resistance; and the development of recommendations for possible applications it in construction. To achieve the purpose, the following tasks were solved:

- testing of samples for strength (by two complementary methods) and frost resistance;
- comparison of obtained indicators with indicators of analogues and identification of competitiveness;
- formulation of recommendations on the use of samples in construction.

2. Materials and methods

2.1. Materials
A building block was made of Portland cement CEM II A-S 32.5 (Spasskcement), silica sand of a fraction of 0.5-1.0 from quarries of the Primorsky Territory (Russia), household waste and water (Fig. 1). The mass of the block is 24 kg.

![Figure 1. Sorting solid waste.](image1)

The mixture for the blocks is prepared in the following proportion: sand, cement and garbage in a ratio of 3: 1: 5. Adding water - 0.5 of the amount of cement.

2.2. Methods
Measurement of the strength of the samples was carried out by the method of non-destructive testing using the device IPS-MG 4.03 (Stroypribor, Russia) (Fig. 2). This method is designed for operational non-destructive testing of the strength and homogeneity of concrete and mortar using the shock pulse method. The testing procedure was carried out in accordance with EN 12504-2: 2001.
3. Results and discussion

Manufacturing technology consisted of disinfection by using disinfectants, and sorting household waste, which after processing becomes one of the aggregates for the building blocks. The HW was fed to the conveyor, then went to the shredder, which crushed it to fine crumb size 5×5 mm. Further, it was mixed into a homogeneous mass and in the next tank mixed with chemical reagents that completely disinfect the garbage. After processing, this consistency was mixed with sand and cement and fed into the unit producing the blocks. The blocks were dried until the product completely hardened for 28 days at a humidity of 90-95% and a temperature of 20°C.

As a result of measuring the strength by non-destructive testing using the device IPS-MG 4.03, the average values for each face were obtained from 15 measurements (Table 1).

| Face no. | Strength, MPa | Face no. | Strength, MPa | Average strength, MPa |
|----------|---------------|----------|---------------|-----------------------|
| 1        | 12.7          | 4        | 12.5          |                       |
| 2        | 14.0          | 5        | 14.2          | 13.4                  |
| 3        | 13.4          | 6        | 13.8          |                       |

In order to confirm obtained in Table 1 results by the press total 3 samples of the same size and characteristics were tested. The measurement results are listed in Table 2.

| Specimen no. | Compressive strength, MPa | Average compressive strength, MPa |
|--------------|---------------------------|----------------------------------|
| 1            | 13.25                     |                                   |
| 2            | 12.97                     | 13.5                              |
| 3            | 14.15                     |                                   |

Comparing the results of compressive strength obtained by various complementary methods (Table 1 and Table 2), it was found the similarity of the results obtained, which confirms these results.
The test results for frost resistance are listed in Table 3.

**Table 3.** The test results for frost resistance.

| Face no. | Number of freeze / thaw cycles | Face no. | Number of freeze / thaw cycles | Frost resistance class |
|----------|-------------------------------|----------|-------------------------------|------------------------|
| 1        | 12.7                          | 4        | 12.5                          |                        |
| 2        | 14.0                          | 5        | 14.2                          | 13.4                   |
| 3        | 13.4                          | 6        | 13.8                          |                        |

Table 4 lists the results of the comparison of the tested sample with similar samples, which also includes various wastes: concrete scrap, fly ash, cullet, sawdust.

**Table 4.** The test results for frost resistance.

| Specifications       | Aggregates                                      |
|----------------------|-------------------------------------------------|
| Use of waste, %      | HW [2] concrete scrap [2] fly ash [3] cullet [4] sawdust [9] |
| Compressive strength, MPa | 13.5  51.2  32  51.3  25.6 |
| Frost resistance     | F25  F200  F100  F100  F150 |
| Water resistant      | W2  W12  W12  W12  W6 |
| Density, kg/m³       | 1500  2500  1700  1900  2600 |
| Cost, $ per 1 m³     | 32  98  67  29  40 |

From Table 4, it can be seen that blocks with HW are inferior to analogues in compressive strength, frost resistance, water resistance and density. But there are a number of advantages: the cost is 1.5-3 lower, and waste disposal reaches 50%. At the same time, given the low density of the resulting blocks, labor costs for their manufacture, transportation and construction itself are reduced. As a way for further research, it is proposed to study the dependence of the low density of blocks and heat and sound insulation characteristics.

4. **Conclusions**

The ability to manufacture concrete blocks of garbage with the desired properties allows the use of this material for the construction of low-rise buildings, and the resulting concrete can be used for the improvement of urban areas. As part of solving important environmental and economic problems, it is necessary to use local secondary waste products to ensure the required properties of building blocks with the minimum required amount of cement. The use of waste contributes to the solution of environmental problems and the creation of waste-free production, provides industrial enterprises with cheap raw materials, simplifies and intensifies technological processes. Building blocks may successfully compete in the market of building materials, as their price is 1.5-3 times lower than their counterparts.

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