Mechanochemical method for recycling construction industry waste

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Abstract The article deals with the use of metallurgical slag, which served as insulation in the floors of residential buildings, as a secondary technogenic raw materials. The principal possibility of creating components from it for reaction powder concrete using the method of Mechanochemistry has been shown.

1. Introduction
Russian Federal law No. 384 establishes the basic principles according to which construction waste, as well as waste from the dismantling of buildings and structures, must be safely disposed of. Construction waste in Russia is mainly stored in landfills, which negatively affects the ecology of the environment, and also leads to unjustified losses of raw materials [1]. On the other hand, major repairs and renovation of residential buildings lead to a significant increase in the amount of waste generated.

In the 60s of the 20th century, the insulation of attic floors of residential buildings was carried out by backfilling with slag of metallurgical industries. This material was included in the construction normative documents for construction heat engineering with a density of 400-800 kg/m³ and a thermal conductivity coefficient of 0.11-0.18 W/(m²*K). To date, the slag has crumpled, including as a result of regular humidification, and has ceased to function as a heat-insulating material.

Standard technologies for building reconstruction involve replacing the slag with its disposal at the landfill.

We have conducted research on application of backfill slag insulation and its use as a technogenic raw material for creating a functional product [2,12].

2. Result and discussion
The object of the study was backfill slag insulation, removed during the overhaul of the roof of a residential building in Yaroslavl. The characteristics of the investigated slag are shown in table 1 and figure 1. The true density of the initial slag was 3.8 g/cm³

Table 1. Fractional composition of the initial slag

| Specifications | Particle size, mkm / fraction of particles, % of mass. | Specific surface area, m² / g |
|----------------|-----------------------------------------------------|-------------------------------|
|                | >10       | 5-10       | 2.5-5     | 25-2.5    | 0.63-1.25 | 0.315-0.63 | 0.14-0.315 | <0.14 |
| Fractional composition | 9.5 | 14.5 | 5.5 | 15.5 | 13 | 12 | 19.5 | 10.5 | 8.57 |
Thus, waste is a polyfractal powder of 3-rd class of danger.

The derivatogram of the slag sample shown in figure 2 shows the presence of sorbed water, as well as organic and carbonate impurities with an annealing peak of about 500 °C.

Recycling of construction waste usually involves their grinding. Vibro-jaw crushers [3] and planetary ball mills [4] are used as grinders.

We proposed to use method of mechanochemistry and disintegrator technology for directed regulation of the properties of the recycled slag, and a universal disintegrator-activator (UDA) was chosen as the device that performs such a deliberate change. Disintegrator technology allows a wide range of physical and chemical properties of raw materials-particle size, reactivity, rheological characteristics [5].

It is known [11] that as a result of mechanical activation (table. 2) the transition of crystalline bodies to an amorphous state is possible. The aim of the study was to evaluate the possibility of obtaining a fine inorganic powder from the slag, which can be reactively active due to the amorphization of components.
Table 2 Influence of ultrafine grinding on the structure and properties of solids [11]

| Grinding                     | 1. The increase of surface |
|------------------------------|---------------------------|
| Mechanical activation       | 2. Increased surface activity |
|                              | 3. Changes in the structure of the lattice |
|                              | a) violations in the structure of the lattice |
|                              | b) transformation in the structure of the lattice |
|                              | C) transition of crystalline bodies to an amorphous state |
| Chemical-mechanical activation | 4. Chemical change |
|                              | 5. Formation of chemical compounds |
|                              | 6. Destruction of organic macromolecules |

In the inertial separation mode, the slag is crushed into a fine powder with particles less than 20 microns (table 2). The size of the specific surface determined by the BET method suggests that various compounds can be grafted onto the slag surface [9] to modify the resulting powder and transfer the required properties to it.

Table 3 Characteristics of powdered slag

| Mode of grinding | Particle size, mkm / fraction of particles, % of mass | Specific surface area, m2 / g |
|------------------|------------------------------------------------------|-----------------------------|
|                   | >63 | 40-63 | 30-40 | 20-30 | 10-20 | <10 |
| Inertial separation | -   | -     | -     | -     | 29.9  | 70.1 | 7.3 |

The study of the x-ray image of a sample of mechanically activated slag in the peak region 1. 3750, 2.2873, 2.7117 by their broadening allows us to confirm the previously proposed hypothesis about the amorphization of some compounds of mechanically activated slag.

![Figure 3](image_url)  
Figure 3. The radiograph of the slag after mechanochemistry activation
The slag obtained as a result of mechanochemical grinding was introduced as a filler in the composition of fine-grained low-grade concrete. The mobility of the mixtures was the same. Cone draft was 15 cm.

Table 4 Strength characteristics of concrete samples

| Mechanochemistry | Sample          | water-cement ratio | Bending strength, MPa | Design compressive strength, MPa | Actual compressive strength, MPa |
|------------------|-----------------|--------------------|-----------------------|----------------------------------|----------------------------------|
| Disintegration   | without additives | 0.76               | 2.24                  | 12.3                             | 12.3                             |
|                  | 10% slag         | 0.72               | 3.34                  | 13.4                             | 16.1                             |
|                  | 10% slag + plasticizer | 0.6               | 4.58                  | 17.5                             | 23.8                             |

The strength indicators of the tested samples not only do not decrease, but also there is a slight increase in them. This can be explained by the fact that due to the introduction of a fine component, the pores amount and, accordingly, defects of the concrete structure are reduced.

3. Conclusion
Mechanochemistry and disintegrator technology methods make it possible to have a regulating effect on the properties of the resulting materials. In addition, the principal possibility of using secondary technogenic raw materials (metallurgical slag) has been shown to create reactive components of concrete.

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