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The possibility of secondary use of building materials in the framework of the residential buildings renovation program

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Abstract. The article is devoted to discussing the possibility of secondary use of building materials in the framework of the residential buildings renovation program. The viability of processing construction materials in contrast to their disposal at landfills is shown. A comparative analysis of prices for secondary building materials and their equivalents is carried out.

1. Introduction

The need to modernize housing stock, which becomes obsolete over time, is inevitable for all modern cities. The term "renovation", for civil engineering implying an innovative process of changing the functional purpose of the objects of reconstruction, in Russia is now associated primarily with Moscow. This is due to the adoption in 2017 of the Federal Law [1] and the Housing Stock Renovation Program [2], that among other tasks are aimed at constructing of energy-efficient houses with low operating costs, improving of the environmental situation, forming of a new structure of the urban environment, designed for the comfortable life of people. By now, reorganization of living space has taken place in cities of many countries – Japan, Czech Republic, France, Great Britain, China [3, 4]. But the greatest experience in this regard is accumulated in Germany. In the Eastern part of Berlin a comprehensive reconstruction of outdated bedroom districts was carried out, which completely changed their appearance. The quality of the living environment has also improved due to the insulation of floors, expansion of window openings, moving further away from streets, and landscaping.

Discussion of the residential buildings renovation program in Moscow naturally led to the idea of the need to extend the program to the whole country, because in most regions the housing stock is in a much worse condition. Thus, in the Irkutsk region a serious socio-economic problem is represented by houses of series 1-335. Houses of this series were mainly built in the Soviet Union in the early 1960s. Back then the authorities set the objective of providing the population with individual housing.

Structures for building houses of the 335th series were made at precast concrete plants from aerated concrete – a kind of cellular concrete made of a mixture of Portland cement, quick lime, fly ash from the CHP plant, aluminum powder and water with the addition of surfactants to regulate the setting process. Aerated concrete, in general, a fairly durable material, though inferior in this respect to brick, in Siberia proved to be fragile due to alternate freezing and thawing. Building material destruction was further promoted by the structural design of 335 series houses with incomplete framework, without columns on the outer longitudinal walls. The reason for this type of design is that the buildings were created as temporary structures with a service life of only 15 years. Later it was planned to disassemble and reassemble them in the form of one- and two-storey houses in small towns. In this form, these buildings could serve for about 150 years.

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2. Materials and methods

For research, data available today in the Irkutsk region on houses of the series 1-335 built in the 1960s-1970s were used. These are panel buildings with longitudinal bearing walls, uncoated. Distinctive features are four-fold large windows on stairwells and four-panel end walls with two windows.

3. Results

For the Baikal region, the problem of housing depreciation is particularly serious due to the seismic activity of the region. For Irkutsk seismic hazard is 8 points, while the buildings of the considered series were designed with the expectation of 5-7 points. There are two structural types of series 335 residential buildings [5]:

- the 1st type – with external load-bearing walls of aerated concrete without wall columns (years of construction 1960-1965);
- the 2nd type – with external walls made of aerated concrete with wall columns (built in 1965-1975).

In both types of houses the outer walls receive seismic loads in the longitudinal direction of the building. The difference between the two types of houses is that in the first case, the vertical load from girders and floor slabs is transmitted to the weakened exterior walls of aerated concrete. In the second type vertical loads are transferred to the wall columns made of heavy concrete.

Today, the number of 1-335 series houses in the Irkutsk region is 1.8 thousand objects, including 400 in Irkutsk, and 500 in Angarsk [5]. The total area is about 4.5 million m^2, the number of residents is 250 thousand people, or 10% of the population. The height of residential buildings is mainly 5 floors, there are also 4 and 3-storey buildings. From the point of view of seismic resistance and durability, the greatest risk of destruction exists for 5-storey houses of the first type.

There are three alternatives for the future of 1-335 series houses [5]:

- seismic reinforcement of buildings up to 7 points (option 1);
- preservation of the housing stock without reinforcement (option 2);
- demolition of 1-335 series houses in full and construction of new housing that will comply with current regulations (option 3).

Using the Angarsk case, scientists of the Institute of the Earth's Crust of SB RAS calculated the level of seismic risk for people living in houses of 335 series, for each of the alternative solutions [6]. According to the authors, the best strategy (risk 1.10-5, preference 50 %) is option 3, but its implementation is associated with significant financial costs. The cost of implementing option 3 in the Irkutsk region would be at least three and a half of its annual budgets. The worst strategy is alternative 2 (risk 2.10-4, preference level 15 %). This option does not guarantee residents safety in the event of an earthquake. Option 1 (level of preference 35 %, risk 2.10-5), according to the authors, is also quite acceptable, as well as option 3.

Still, for the Irkutsk region, where the probability of a 7-point earthquake before the year 2050, is almost one (the last 7-8 magnitude earthquake, Kultuk, happened in 2008), the best would be option 3, at least for the first house type, built in the period from 1960 to 1965. The chances that this alternative, impossible without the involvement of the Federal budget, will be affordable, have recently increased, bill No 550294-7 "On the renovation of the housing stock in the Russian Federation" was introduced to the State Duma on September 19, 2018. If it is supported, the regional authorities will be able to obtain funds for the implementation of a program similar to the one in Moscow. But then the authorities will face the question where to send the waste that will remain after the demolition of houses?

Among the main targets of the renovation program, environmental friendliness and environmental protection are not the last on the list. Removal of dismantled panels and construction waste to landfills does not meet the principles of sustainable environmental management. The amount of waste during the demolition of one 5-storey building amounts to 3 thousand m^3 [7]. Dismantling 1,800 houses, respectively, will lead to the formation of more than 5 million m^3. Within the framework of Irkutsk alone, the volume of construction waste from dismantling of 400 residential buildings will amount to 1.2 million m^3. Since the design capacity of the solid municipal waste (MSW) landfill is calculated

taking into account the specific generalized annual rate of accumulation of MSW per inhabitant, and the period of decomposition of concrete is about 100 years, the existing landfill in five kilometers from the city will soon be filled. It is possible that part of the construction waste will end up at other unauthorized landfills, resulting in littering and pollution of the environment, and catastrophic destruction of natural ecosystems in the waste storage area. Therefore, the most reasonable way is to recycle waste generated by dismantling buildings. It will not only prevent the negative environmental consequences of their placement in landfills, but also reduce losses, both direct, associated with the maintenance of landfills and the elimination of unauthorized landfills, and indirect from the irrational use of potential secondary raw materials.

When demolishing residential buildings, whole structural elements (slabs, panels, blocks) can be reused in construction, unusable elements can be recycled into rubble and sand, it is easy to dispose of metal and wood, and only construction waste, is normally taken to the dump [8]. In the Irkutsk region, the problem of production and consumption waste is very acute due to the lack of waste processing, waste transshipment and waste sorting complexes and the presence of 948 unauthorized locations for the placement of MSW on an area of more than 1.4 thousand hectares, with a volume of 12,237 thousand m^3 [9]. Constructing a waste recycling, especially for construction waste, in the case of the adoption of the law on the renovation of the whole of Russia, would solve a lot of problems. Let's investigate the problem in greater detail.

4. Discussion

On average, a 335 series house consists of the following materials (the ratio will vary depending on the type of building): 70-80% – concrete and reinforced concrete, 15-25% – stone wall materials and bricks, 9-7 % – waste wood, metals (rebar, partition profiles, railings), plastic, glass, gypsum, 1 % – other waste. All these wastes are inexpensive feedstock for secondary materials, which can be further used in construction.

The areas of using secondary materials formed from houses demolition are given in table 1.

Table 1. The possibility of using secondary materials obtained from dismantled buildings.

Name of waste	Waste recycling process / name of secondary material	Field of use
Crushed concrete products, waste concrete in lump form	Production of secondary crushed stone with division into fractions	As a filler for concrete, for construction and filling of low-speed gravel roads, foundations in individual construction, for landscape works, etc.
Crushed reinforced concrete products, waste of reinforced concrete in lump form		
Crushed brick	Production of brick rubble	For the production of large-porous concrete blocks; facade ceramics, facing facade tiles, sanitary products [7]
Scrap and waste of ferrous metals	Ferrous metal	In the automotive industry, housing construction
Scrap glass	Crushed glass	In the form of granulated foam glass for the production of plates, for the production of glass and ceramics [10]
	Scrap glass powder	Production of heat- and sound-insulating glass fiber, heat-insulating material-foam glass (cellular glass)
Construction timber waste	Lump waste, chips, sawdust, chips	Production of building materials, as fuel in natural and briquetted form

These data show a wide range of uses of secondary materials obtained from dismantled buildings. Their cost is lower than the cost of respective new building materials. In order to understand whether it is feasible to use the resulting materials from an economic point of view, we consider the prices offer for secondary resources in Irkutsk and compare them with the prices for the replaced material.

The results of the analysis (table 2) are evident: the price of secondary materials is much lower than the material they replace, so the use of waste will reduce the cost of construction products as a whole. Also, one should not forget about the prevented environmental damage – processing of construction waste ensures rational use of natural resources and significantly reduces pollution of the environment. The latter is especially important for the Irkutsk region: of the twenty cities included in the Priority list of cities with the highest level of pollution, five (a quarter of the total) are located here [11].

Table 2. Comparative analysis of material prices.

Secondary material name	Field of use	Unit	The average price on the market, RUR.	Replaced material	The average price on the market, RUR.
Brick rubble	Backfilling of local roads	m^3	377	Rubble 40-70, 20-40	900
Concrete crushed stone	In road construction. As coarse aggregate for concrete in the construction of low-rise buildings	m^3	750	Crushed stone of different fractions	1100

Special machines and mechanisms ensure dismantling of large-panel buildings. Except load-lifting cranes various hoisting devices, mechanical equipment, rigging for temporary fixing of structural elements are used [8]. If panels and slabs are not intended to be re-used, over-sized pieces of reinforced concrete or parts of the building itself are first destroyed by a hydraulic press or shears (figure 1). The prepared fragments are crushed in a crushing plant to pieces about 20 cm in size, then the mixture is divided into metal and concrete components. After further grinding of the concrete pieces, the gravel is separated from the sand by means of a screen. All work can be carried out either on the territory of the processing plant using permanently installed mechanisms or by mobile crushing and screening complexes. Production lines for processing large elements of building structures are available not only abroad, but also domestically.



Figure 1. Mechanisms for the destruction of building elements.

5. Conclusion

Thus, it can be concluded that the use of secondary materials obtained by processing waste generated during dismantling of 1-335c series buildings in the Irkutsk region is more appropriate than their disposal at landfills. This helps reduce anthropogenic impact on the environment, sustainably use natural resources, and is economically more profitable.

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