Management of the waste of construction and demolition

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Abstract. The problem of accumulation, transport and disposal of waste is currently the cause of environmental degradation of territories, so it is relevant. The main method of waste disposal in Russia is landfill disposal without additional disposal methods, including recycling. In recent years, technologies for handling construction and demolition waste have been developed so that they can be recycled after processing as raw materials, for example, in the construction industry or in road repairs. This will save primary natural resources and energy. The article uses the example of a specific project for the reconstruction of the building in Moscow to present the technology for handling of the construction and demolition waste during the dismantling of a building with the preservation of the facade wall. The classification of waste according to the Federal classification catalog of waste is given, the volume of waste generated is calculated, the term and organization of their temporary storage on the construction site is given, and the possibility and options for secondary use of this waste are analyzed. Based on the comparison of options, the route scheme for transportation of the construction and demolition waste outside the construction site to the landfill, where the recovery complex and the crushing complex are located. There the waste will be prepared for recycling.

1. Introduction

Environmental degradation as a result of anthropogenic pressure, the intensity of pollution increases faster than the population of the planet. As the academician V.I. Vernadsky wrote: "Humanity in its impact on nature has become the greatest geological force." By the amount of extracted and processed natural resources (100 Gt/year) 10 years ago, economic activity approached the activity of the biota of the biosphere (1000 Gt/year) and surpassed volcanic activity (10 Gt/year) [1].

The role of secondary resources in the economy of different countries has significantly increased in the last 15-20 years [2]. This is due to the increased consumption and increasing restrictions in providing the industry with primary raw materials and energy (figure 1), as well as significant progress in the field of waste recycling technologies, including construction materials [3-6]. The number of the Earth's population, anthropogenic impact, in particular, the volume of industrial products and waste y increases in time t exponentially with the coefficient A:

\[ y = e^{tA}, \]

where A is a coefficient that reflects the degree of growth of the value y.
The amount of waste increases every year, and this is affecting on the safety of people's lives and worsening their health negatively.

In Russia, of only 2 to 50% of primary natural raw materials (primary material resources) is used in industrial production, the rest is used for recycling, in our country, most often – for burial. Today in Russia, the total area of landfills for solid municipal waste is huge, it occupies about 4 million hectares, which is comparable to the area of Switzerland or the Netherlands, and increases every year by 0.4 million hectares annually. The number of landfills in Russia today is about 1,000, authorized landfills – about 15,000, unauthorized landfills – about 17,000. The number of incineration plants - 40, the number of waste processing plants – 243, and 53 waste sorting complexes. Municipal solid waste occupies 2.3 % of all landfills.

Increasing the economic efficiency of production in order to increase the volume of national income with minimal capital investment is possible by reducing material costs in the total cost of creating the final product. The use of recycled materials – production waste in different industries – in different industries in order to replace similar necessary raw materials contributes to this. The world is already implementing a strategy to minimize the cost of material and energy resources, including the volume of waste generation at all stages of the product life cycle – during design, production, operation, processing, disposal and storage. The legislative framework and incentive system for the development of waste processing (recycling) facilities are constantly being improved.

Waste is a valuable resource – raw materials for secondary use, in particular, construction and demolition waste is used in the construction materials and technology industry. Recycling of waste with its subsequent secondary use in various fields, utilization of the remaining amount of waste from construction and demolition of buildings and structures is becoming one of the significant "socio-economic, environmental, and technological challenges in the development of social production in the modern world" [9]. This determines the policy of saving materials and reducing energy costs for industrial production of building materials, which, in turn, increases the environmental friendliness of both industrial processes and the environmental and social security of territories. According to various sources [3], the volume of use of secondary raw materials in production can be increased to 10-15 % or more of the global demand of world production for raw materials.

Today, in some countries, such as Sweden, up to 98% of waste is disposed of by incineration and recycling. In the United States, about 50% of ferrous metal consumption is made up of secondary materials, more than 40% of copper and nickel, about 30 % of tin and titanium, and up to 28% of aluminum and paper. Practical experience in the use of secondary material resources – secondary raw materials (construction, wood, polymer, etc.); costs for reconstruction and major repairs of complex industrial facilities indicates a reduction of 10-12%. These costs include both material and energy costs, as well as saving natural and primary resources, reducing the volume of construction and demolition waste disposed of, and improving the environmental situation by reducing the amount of waste to be disposed of. Currently, less material-intensive and energy-intensive industrial products are
being produced, and research is being conducted on the use of secondary resources for obtaining alternative energy sources.

Each Russian region has developed programs for the management of municipal solid waste, as well as construction waste, based on Federal legislative documents [10-12].

Management of the waste includes collection, removal, disposal and including recycling. Waste management is now the most urgent problem, since the decision on the allocation of sites for landfills for the waste disposal raises many questions in every locality, especially near and on the territories of megacities. At the same time, in our country today, approximately 90-95% of all waste is buried only in official landfills. In contrast, in other countries, much less of the household, industrial and other waste in Russia is sent for recycling and goes through the recycling stage. The waste recycling refers to the processing of industrial waste for its secondary use or return to production.

Construction waste according to GOST R 57678-2017 is the waste generated during demolition, disassembly, reconstruction, repair (including capital) or construction of buildings, structures, industrial facilities, roads, engineering and other communications. In the same document, the term "construction and demolition waste" is interpreted similarly, but "with the exception of highly and extremely hazardous waste", in accordance with the Decree of the government of Moscow No. 469 of June 25, 2002. Construction and demolition waste includes the following materials: broken bricks, old tiles, pieces of concrete, plaster, scraps of wallpaper, old linoleum, doors, scraps and remnants of other construction and finishing materials.

Unlike solid municipal waste, the construction and demolition waste has a more uniform composition and is easier to dispose of and recycle. Construction and demolition waste can be reused in the construction industry or other industries [13-19]. Below we list the areas of secondary use of the construction and demolition waste and technology:

1. as a filler in the production of concrete and reinforced concrete products [20-21],
2. in the production of ceramic bricks [22],
3. in road construction in the production of aggregate for road surfaces,
4. as part of composite materials for various purposes.

The classification of construction and repair waste is reflected in the Federal waste classification catalog, block 8 and includes:

- waste from preparation of the construction site, disassembly and demolition of buildings,
- waste from construction of buildings and structures,
- waste during dismantling and repair of road surfaces,
- waste during dismantling and repair of railway track facilities,
- waste from construction and repair of radiation-hazardous facilities,
- other construction and repair waste.

In total, as of 19.01.2020, 115 types of construction and demolition waste are included in the Federal waste classification catalog.

There are five hazard classes for waste. Low-hazard and non-hazardous construction waste belong to hazard classes 4 and 5, the first of them decompose in about 3 years. These classes include construction waste, including waste from repairing apartments and houses. These classes also include municipal solid waste.

Unfortunately, in Russia there is still no systematic, mandatory use of secondary materials in industrial production, fixed by law, although there are numerous individual examples of recycling, for example, dismantled building structures during capital repairs and reconstruction of buildings and structures, and followed by disassembly and sending for recycling for secondary use, which increase the efficiency of construction and installation production.

2. Material and Methods
As the example of the handling of the construction and demolition waste is the following reconstruction of the building at the address Moscow, 1st Spasonalivkovsky lane, 9, p. 2. The building reconstruction area is located in the Yakimanka district, in the block bounded by Bolshaya Polyanka
street, Kazansky, 1st and 2nd Spasonalivkovsky lanes (figure 2). As a result of the reconstruction, it is planned to place a multi-apartment single-section residential building on the site. Figure 3 shows a plan of the building being dismantled (demolished) with the preserved facade wall (a), the section shows a zone of manual dismantling and demolition (b).

![Figure 2. The situation plan (a) and the general view (b) of the reconstructed building.](image)

3. Results

It was proposed to preserve the facade wall during reconstruction, strengthening it with a special metal structure in this project. The foundation is supposed to be reinforced with jet-piles. Dismantling of the old building was carried out in a mechanized way, but some of the structures were disassembled manually. Since the topic of the article concerns only construction and demolition waste and does not concern the description of the technology of reconstruction work, we will focus in detail on the organization and technology of accumulation, transport and disposal of construction and demolition waste.
To reduce environmental pollution, construction waste from the dismantling of the building was collected on the construction site in containers that were located in a specially designated place and taken to the industrial waste landfill for further disposal.

The removal of construction debris from the site was carried out evenly throughout the entire period of dismantling work. Materials from disassembly were removed daily from the construction site by the organization, preventing the accumulation of dismantling waste on the site. The remaining materials after dismantling were sorted and crushed to transport dimensions by an excavator for subsequent loading and removal by vehicles to the designated place. Materials were loaded into vehicles using an excavator. Garbage was transported in dump trucks with a closed canvas top. Construction materials and structures suitable for secondary use were sorted and exported to a special enterprise for preparation for secondary use.

During the operation of construction machines, mechanisms, vehicles and other equipment, it was not allowed to pollute the construction site with fuel and lubricants, incinerate garbage, and bury defective structures and products. To combat the impact of harmful effects on the environment, work technologies (polluting factors – dust, harmful gases, sewage, vibration, noise, electromagnetic radiation, etc.) were used, technological schemes and equipment that exclude these effects and do not exceed the maximum permissible levels established by state standards.

The types of waste generated at the site from dismantling, the volume of their formation and the period of temporary storage (number of days from the moment of formation) of waste after dismantling are shown in table 1. Table 1 also contains the code and hazard class of each waste forming according to the Federal waste classification catalog (FWCC).

| №  | Waste code according to the FWCC | Name of generated construction waste                                    | Quantity (tons) | The period of temporary storage | Waste hazard class according to the FWCC |
|----|---------------------------------|--------------------------------------------------------------------------|-----------------|---------------------------------|------------------------------------------|
| 1  | 81210101724                     | Wood waste from demolition and disassembly of buildings                   | 60.812          | Export 2 times a day            | IV                                       |
| 2  | 8129010174                      | Garbage from demolition and disassembly of buildings unsorted             | 0.089           | Export 1 time in 7 days         | IV                                       |
| 3  | 15211002215                     | Waste of twigs, branches, vertexes from logging                          | 0.090           | 0 calendar days                 | V                                        |
| 4  | 15211001215                     | Stump uprooting waste                                                   | 0.068           | Export 6 times a day            | V                                        |
| 5  | 15411001215                     | Waste of low-value wood (brushwood, dead wood, fragments of trunks)      | 0.185           | Export 1 time per day           | V                                        |
| 6  | 46101001205                     | Scrap and waste containing uncontaminated ferrous metals in the form of articles, pieces, unsorted | 17.700          | Export 1 time in 3 days         | V                                        |
| 7  | 81210101215                     | Scrap brickwork from demolition and disassembly of buildings              | 1776.60         | Export 20 times a day           | V                                        |
| 8  | 82110101215                     | Scrap of side stones, paving stones, cobblestones and other waste products made of natural stone | 38.280          | Export 6 times a day            | V                                        |
| 9  | 82210101215                     | Scrap concrete products, concrete waste in lump form                      | 41.580          | Export 1 time per day           | V                                        |
| 10 | 82230101215                     | Scrap of reinforced concrete products, waste of reinforced concrete in lump form | 44.220          | Export 1 time per day           | V                                        |
The table shows that the greatest amount of waste during dismantling of the building is formed from scrap masonry and wood products, followed by waste the scrap concrete products, concrete waste in lump form and scrap concrete products, and scrap of side stones, pavers, cobblestones stones and other waste from natural stone. Waste from stone scrap can be crushed and reused as a raw material – aggregate for concrete or as a roadside fill, wood waste can also be crushed, for example, into shavings or briquettes and used, for example, in the production of fuel or go to incineration.

Other construction and demolition waste generated during the dismantling of the building is planned to be transported, placed and disposed of at the landfill, including at the waste recovery facility.

For each type of hazard class IV waste generated during the dismantling of a building, a passport must be drawn up based on data on the composition and properties of this waste, and an assessment of their hazard. A passport is not required for waste of hazard class V generated during work at this facility.

A detailed description of the places of temporary storage of waste after the dismantling of the building and waste products after the dismantling of the building are presented in table 2.

| №  | Types of dismantling waste                              | Detailed description of temporary storage locations                                                                 | The waste products                                                                 |
|----|----------------------------------------------------------|------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------|
| 1  | Wood waste from demolition and disassembly of buildings  | Waste storage in a standard storage bin for large-size waste of 6 m$^3$ located on the construction site. The bunker is located with the expectation that it will not interfere with the passage of vehicles | Raw materials for the manufacture of wood-fiber boards and chipboards             |
| 2  | Garbage from demolition and disassembly of buildings unsorted | Waste storage in a standard storage bin for large-sized waste of 0.8 m$^3$ located on the construction site. The bunker is located with the expectation that it will not interfere with the passage of vehicles | Various types of recycled waste                                                  |
| 3  | Waste of twigs, branches, vertexes from logging          | Waste storage is not provided. Waste from cutting down green spaces is collected from the wheels at the place of formation. Cutting is accompanied by a car with a container of 8 m$^3$, as the container is filled, it is taken out | Raw materials for the manufacture of wood-fiber boards and chipboards             |
| 4  | Stump uprooting waste                                   | Waste of low-value wood (brushwood, dead wood)                                                               |                                                                                   |
| 5  | Scrap and waste containing uncontaminated ferrous metals in the form of articles, pieces | A separate site for collecting and sorting metals, temporary accumulation of waste in a storage bin for large-sized waste of 6 m$^3$ is organized | Recycled metal                                                                  |
| 6  |                                                          |                                                                                                                 |                                                                                  |
Scrap brickwork from demolition and disassembly of buildings | Waste storage in a standard storage bin for large-size waste of 8 m³ located on the construction site. The bunker is located with the expectation that it will not interfere with the passage of vehicles | Recycled crushed stone of different fractions
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Scrap of side stones, paving stones, cobblestones and other waste products made of natural stone | Accumulation of waste in a standard storage bin for large-sized waste of 6 m³, the Bin is located with the expectation that it will not interfere with the passage of vehicles | Recycled crushed stone of different fractions
Scrap concrete products, concrete waste in lump form | Waste accumulation in a standard storage bin for large-sized waste of 6 m³, the Bin is positioned so that it will not interfere with the passage of vehicles | Recycled crushed stone of different fractions
Scrap of reinforced concrete products, waste of reinforced concrete in lump form | Accumulation of waste in a standard storage bin for large-sized waste of 6 m³, the Bin is located with the expectation that it will not interfere with the passage of vehicles | Recycled metal

In accordance with the construction master plan, an area of 70.2 m² (15.6×4.5 m) is provided for the accumulation of waste from the dismantling of the building (figure 4).

Standards for waste generation were calculated using existing methods, but they are not given in this article.

**Figure 4.** Scheme of the layout of temporary waste storage sites for the period of dismantling works.
The route of removal of the waste from the object located at the address: Moscow, 1st Spasonalivkovsky lane, property 9, structure 2, to the territory of the owner of the waste landfill "VIVA TRANS", where the waste recovery complex and crushing complex is located, at the address: Moscow, Khovanskaya industrial zone, village Sosenskoe, was selected based on a comparison of several options and presented on figure 5. The distance from the object to the location of the landfill is 22 km. A possible alternative waste disposal route is shown in figure 6. In the compared building, waste disposal during construction work was selected from several options. In addition to the description of the collection scheme and the selected option for transporting and disposing of waste from the dismantling of this building, for comparison, we present the option for removing waste from a building under construction in the same area of the city. During construction work in the compared building, waste disposal was selected from several options, the alternative option is shown in figure 6, its length is 36 km.

Figure 5. The route scheme for the removal of construction and demolition waste during the dismantling of the building to the waste recovery complex and crushing complex.

Figure 6. The alternative route for removal of construction and demolition waste.

The route chosen for the removal of the construction and demolition waste during the dismantling of the building has a length of 22 km, it runs along 1st Spasonalivkovsky lane, Bolshaya Polyanka street, Zhitnaya street, garden ring, Bolshaya Yakimanka street, Leninsky prospekt, Kiev highway, Admiral Kornilov street.

Based on the study of domestic literature, it is assumed that construction and demolition waste will be processed in an amount of up to 50-80 % of the original volume.

4. Discussions and Conclusions
The considered scheme of construction and demolition waste management during the reconstruction of the building is developed in accordance with legislative and regulatory documents, which allows not to accumulate waste on the construction site. The scheme of construction and demolition waste disposal is optimal for this project.

Specific scientific and practical data on the topic of construction and demolition waste management are published for the first time. Available publications on the topic of construction and demolition waste management available in domestic and foreign publications mainly analyze the General situation in the field of waste management, existing legislative documents and organizational and legal aspects. The authors did not find any publications that consider the handling of construction and demolition waste on the example of a specific project for dismantling a building. The relevance is
proved, the review of Russian and foreign works on the topic under consideration is made, examples of secondary use of construction and demolition waste are given.

The option of handling of the construction and demolition waste is determined by the organizational and technological features of the dismantling process. As a result of mechanical and partially manual dismantling, the facade wall of the building was preserved. Based on this, a certain amount of waste was generated, which was taken out for recovery and could later be reused in road construction and the production of building materials. On the example of reconstruction of a building in Moscow at the stage of dismantling, the scheme of waste management of construction and demolition is shown.

The article describes the collection scheme and selects the option for transporting and disposing of waste from the dismantling of the building. For comparison, the option of waste removal from a nearby building in the same area of the city is given.

Thus, the proposed option for handling construction and demolition waste allows you to justify the collection and removal of waste at the optimal distance, and use the waste management method for such projects of dismantling buildings in urban development. The article shows the possibility of secondary use of construction and demolition waste of danger classes IV-V.

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