New approaches to the development of construction technologies

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Abstract. The paper presents data on the volume of materials consumed by builders and the carbon dioxide emissions that occur during this process. The reasons for the formation and volume of construction debris are considered. Recycling technologies currently used in the demolition of buildings are associated with crushing. The resulting concrete mix is used only for filling low-level earthworks due to the rapid carbonation of concrete surfaces. The scrap metal formed during crushing is used for remelting, polluting the atmosphere and requiring a large amount of energy. It is proved that due to the low economic and environmental efficiency, this method of recycling is a dead end. Studies have found that the constant increase in the strength of concrete and the absence of a decrease in the strength characteristics of reinforcing steels, stone materials, bricks, which are operated for a long time in favorable temperature and humidity conditions, allows them to be reused. General approaches have been developed that require changes in the existing technologies for the renovation of urban areas, the demolition of individual buildings and structures that currently exist. To reduce CO2 emissions and construction debris, it is enough to increase the volume of gentrification, reconstruction, major repairs, and re-profiling of the existing residential and industrial stock. When demolishing buildings, it is necessary to abandon the method of collapse of building structures with their further fragmentation. The method of piecemeal dismantling with repeated use of materials, products and structures (after determining their strength indicators by specialists), allows you to dramatically reduce the problems of construction debris and carbon dioxide emissions.

1 Introduction

The Kyoto Protocol and the Paris Climate Agreement of the United Nations Framework Convention on Climate Change require a reduction in global greenhouse gas emissions. The construction industry uses cement, lime, steel, brick, glass. The production of these materials leads to direct emissions of carbon dioxide into the Earth's atmosphere. The constant need for the development of urban areas inevitably leads to the demolition of old buildings and structures, while forming huge amounts of construction debris. Each country that conducts renovation works strives to most effectively stimulate the process of demolishing old buildings and takes a number of measures to do this: the use of targeted programs that ensure the investment of projects through the provision of subsidies, the provision of benefits to individuals for lending and tax fees [1-9]. But during the renovation, one important and acute issue is raised - the disposal of construction waste [10-14]. Thus, studies conducted in European countries prove that construction waste makes up almost a third of all generated waste [5-7, 15]. According to the European Association for the Demolition of Buildings, more than 2.5 billion tons of construction debris are generated worldwide every year. Therefore, the rational use of construction waste is becoming one of the main directions for environmental protection. Mechanisms for the recycling and reuse of building materials began to be developed in the world about 20 years ago. To date, we can say that there is a whole industry of recycling of building materials. In developed countries, there is a policy to tighten the laws on burial sites and the formation of unauthorized landfills, creating conditions under which it becomes unprofitable to export waste to landfills. Therefore, recycling and reuse of old structures becomes not only environmentally beneficial, but also economically feasible [16-21]. The analysis of demolition technologies of buildings and structures shows the interdependence between the selected demolition technologies and the amount of waste generated. The most environmentally unsafe method is the removal of construction waste to landfills [22-29]. This method is most often used in mechanized and explosive demolition of buildings and structures, so it is now abandoned by most developed countries of the world [30-35]. The demolition of buildings leads to the formation of heterogeneous low-grade stone materials that do not have a uniform guaranteed strength [36-37]. The main volume of construction debris after the dismantling of the building is reinforced concrete, concrete and brick. Waste is sorted by special equipment. Large-sized blocks are crushed, and then processed in crushers installed directly on the site. The product of recycling of building materials is crushed stone, which is widely used for filling technological roads, filling the sinuses of pits, and drainage devices in swampy areas [38-44].

The proposed piecemeal disassembly of buildings using modern technology allowed us to reuse the resulting building structures and materials in the construction of low-rise buildings and the construction of the bases of intra-village roads, significantly reducing their cost [47]. Monolithic and precast-monolithic reinforced concrete structures, which were broken during the element-by-element disassembly, can be used as structural elements of foundations [45, 46].

Transportation of billions of tons of construction materials, including to landfills, leads to pollution of territories and the atmosphere. The reason for this situation is the conservatism of the use of traditional materials and technologies in construction. Therefore, the development of new approaches and construction technologies that contribute to sustainable development is an urgent task facing material scientists, technologists, and builders.

2 Materials and methods

The studies used statistical data on the production of building materials, demolition of buildings and structures, carbon dioxide emissions, and the formation of construction debris.

When determining the strength indicators, experimental data obtained during the survey of several buildings and structures that are in various operating conditions for a long time were used.

The strength of concrete and bricks in load-bearing building structures was determined by the impact pulse method according to GOST 22690-2015 " Concrete. Determination of strength by mechanical methods of non-destructive testing" (impact-pulse strength meter " Onyx-2.6). Foundation slabs, concrete foundation blocks, reinforced concrete columns, crossbars, floor slabs and silicate bricks were subjected to tests. The concrete test sites for determining the strength were located:

- in places of the lowest concrete strength, previously determined by the expert method;
- in zones and elements that determine their load-bearing capacity;
- in places with defects and damage that may indicate a reduced strength of the concrete.

To determine the steel grade of construction trusses, metal samples were selected for mechanical testing and chemical analysis. The mechanical properties of the steel were determined by testing the surface layer of the metal samples for Rockwell hardness using the TK-2 device in accordance with GOST 9013-59 "Rockwell hardness test". The chemical analysis of the steel was carried out in accordance with GOST 22762-77 " Metals and alloys. Method for measuring the yield strength by pressing the ball".

Tests of strength and deformation characteristics of reinforcing steel were carried out in accordance with GOST 1497-84. " Metals. Methods of tensile testing" on the Instron 5982 universal electromechanical test system with a load error of ± 0.5%

3 Results

The result of statistical studies shows:

1) of the total carbon dioxide emissions (35 - 50 billion US dollars). m3 of man-made CO2 emissions) the construction industry emits up to 15 billion tons annually. In addition, the construction industry consumes more than 5 billion tons of clean water and 800 million m3 of wood;

2) a big problem in the construction industry is the demolition of buildings and structures, which leads annually to the formation of more than 2.5 billion tons of construction debris according to the European Association for the Demolition of Buildings [48].

Studies of the strength indicators of materials and structures of buildings that fall under demolition are given below.

The results of determining the class of concrete with a service life of 52 years in terms of strength are presented in Table 1

Table 1. Results of determining the concrete strength class.

Name of the structural element	Actual grade of concrete kg / cm2 / Mpa	Mean square deviation	Coefficient of variation	Concrete class
Prefabricated reinforced concrete foundation plate (quantity 30 pcs.)	206 / 20.7	2.187	10.6	15
Precast concrete foundation blocks (quantity 30 pcs)	143 / 14.4	1.344	12.1	10
reinforced concrete column (quantity 30 pcs)	267 / 26.8	2.85	10.6	20
Prefabricated reinforced concrete floor crossbar (quantity 30 pcs)	217 / 21.7	2.433	11.2	15
Prefabricated multi-cavity reinforced concrete floor slab (quantity 30 pcs)	253 / 25.3	2.771	10.9	20

The actual physical and mechanical characteristics of the masonry of the load-bearing wall of the building with a service life of 52 years are given in Table 2.

Table 2. Results of the control of the strength and uniformity of the masonry materials of the load-bearing walls of the building.

The name of the structural element	Average arithmetic, Xsr, kgf / cm2	Average square deviation, kgf/cm2	Coefficient of variation, %
Silicate brick	128	14	11.7

The actual physical and mechanical characteristics of steel structures with a service life of 71 years are given in Table 3.

Table 3. Mechanical properties of steel.

Countings on the indicator	Average value of hardness HR	Number of hardness HR, reduced to hardness HB, kgf/mm2
89.6 – 90.5	90.1	179.4

The strength and deformation characteristics of reinforcing steel that has begun to corrode, with a service life of 64 years, are presented in Table 4.

Table 4. Strength and deformation characteristics of reinforcing steel.

Yield strength (0.2 %), MPa	Tensile stress, MPa	Elongation, %
341.00	503.76	20.68

3 Discussion

The main reasons for the formation of the carbon footprint in the construction industry is the carbon dioxide emissions arising from the production of cement, lime, steel, glass, ceramics, where the emission occurs as a result of chemical reaction of decomposition of calcium carbonates in the firing:

$$CaCO_3 = CaO + CO_2 \uparrow, \Delta H > 0.$$

In the production of gypsum binders that can replace cement, carbon emissions do not exist, the technological chain of production of less energy-intensive.

The analysis of the strength indicators given in Tables 1-4 and the data given in [49, 50] shows that the strength of concrete of reinforced concrete structures, bricks, reinforced steel of reinforced concrete structures and steel structures operated in favorable temperature and humidity conditions does not fall, and concrete even increases. Based on the above, we can draw the following conclusions.

1. To reduce CO2 emissions and reduce the amount of construction debris, it is sufficient to increase the volume of reconstruction, major repairs, repurposing, existing residential and industrial stock, as well as industrial buildings and structures.

2. The collapse method used in the demolition of emergency facilities after determining the strength and environmental characteristics of materials, products and structures must be abandoned.

3. Crushing of concrete and reinforced concrete structures is inefficient, energy-consuming and unecological due to the following factors:

- when crushing reinforced concrete and remelting steel reinforcement, a significant amount of energy is consumed;
- the concrete rubble undergoes rapid carbonization of the newly formed concrete surfaces, as a result of which the resulting materials have reduced water resistance;
- when melting 1 ton of steel, 1.5 tons of carbon dioxide is emitted.

Research conducted at the Voronezh State Technical University shows a constant increase in the strength of cement concretes of building structures during its operation under normal conditions.

At the same time, the service life of demolished buildings ranges from 30 to 70 years, although, according to various reference literature, their service life should be 100-175 years. The actual service life of Roman concrete and brick is thousands of years.

It is easy to assume that the dismantled structures and materials can be reused without crushing after inspection and appropriate justification. This will allow, given the volume of demolition, dramatically improve the environmental problem and reduce the cost of building low-rise buildings.

Demolition of buildings should be carried out using a new approach, which includes the following steps.

The first stage: piecemeal dismantling of buildings with separate storage of the resulting building materials, products and structures.

The second stage: determination by specialists of the residual strength characteristics of products and structures with rejection and subsequent justification of the possibility of their reuse as various elements of low-rise buildings and structures: foundations, wall materials, floor slabs, coatings, fixed formwork for stone, concrete and reinforced concrete structures.

The third stage: designing buildings with reusable products and structures.

The fourth stage: management of the construction of such structures and constant engineering control of the quality and technology of construction.

As noted earlier, the demolition of buildings is accompanied by the appearance of crushed stone materials in the form of brick, concrete, reinforced concrete, cinder blocks. After conducting research on the selection of compositions and technologies, we proposed to use these materials to strengthen clay soils in construction under difficult hydrogeological conditions using bulk cementation of soils, where they are often used as an active porous aggregate [51].

In recent years, the authors have obtained patents of the Russian Federation for methods of constructing stepped foundations, solid box-section slab foundations, and ribbon foundations using ribbed floor slabs that appeared during the element-by-element dismantling of industrial buildings and volumetric soil reinforcement [52-54]. The results of the patent developments were used in practice in strengthening the soil of the bases, flooded areas, and the construction of dozens of foundations of low-rise buildings, which led to a 4-6-fold reduction in the cost of foundation construction. Thousands of tons of construction debris did not fall into landfills, but carbon dioxide emissions-into the earth's atmosphere.

4 Conclusion

The main reasons for the formation of carbon dioxide emissions generated during the production of basic building materials are analyzed. The volume of construction debris generated by traditional methods of demolition of buildings and structures is determined. A number of areas have been identified that allow us to use new approaches to the construction industry. These approaches will make it possible to create construction waste-free technologies that ensure the sustainable development of urban areas by reducing the volume of demolition and switching to the piecemeal dismantling of buildings, replacing technologies using cement with gypsum materials, including those obtained using non-burning technologies.

Studies of the strength of bricks, concrete, reinforced concrete structures, and reinforcing steels made of reinforced concrete structures that have been used in favorable conditions for 40 years or more have shown a certain increase in the strength of concrete and bricks.

Reinforced concrete structures that are obtained during the piecemeal dismantling of buildings can and should be used as load-bearing structures for their intended purpose, and structures that have received defects should be used in the construction of foundations and other structures of low-rise buildings (with appropriate justification).

The novelty of this technology is confirmed by patents of the Russian Federation.

The use of the technologies discussed above leads to a reduction in the cost of construction work due to the reuse of materials and structures, as well as an improvement in the environmental situation.

5 Recommendations

The conducted research shows the need to increase the volume of gentrification, reconstruction, and major repairs of the residential and industrial stock. In the case of new construction, it is necessary to replace, where possible, cement materials, products and structures with gypsum, including those obtained by non-firing technology from multi-tonnage construction waste.

It is necessary to continue research on non-burning technologies with the reuse of materials formed during the demolition of buildings. It is necessary to increase the volume of piecemeal dismantling of buildings with the sorting of the resulting materials, products and structures and their re-use in the construction of low-rise objects.

There was a need for the emergence and teaching of new disciplines at different levels of education of construction specialties.

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