Technologies of reusing materials obtained during step-by-step demolition of buildings

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Abstract. Nowadays scientists are required to create closed-cycle technologies for handling the waste; they have to reduce the waste amounts and the anthropogenic carbonic trace on the Earth, and they are supposed to use the recycled materials. The main amounts of the construction waste at the landfills of solid domestic waste appear after using the explosion method and the mechanical way of destruction, which are used for the demolition of buildings. Smart demolition, used during the renovation in Moscow, assumes crushing the obtained stone materials for their reuse. However, technologically crushing is not always possible, and economically it is cost-based. The research of the durability characteristics of load-bearing elements of the demolished buildings and existing regulatory documents allow reusing of these materials.

1. Introduction

The growth of land prices in the city centres, the modernization of the industrial factories, obsolescence of buildings require the renovation of the city territories and reallocation of the areas for new construction. The technologies, mostly used nowadays while demolishing different objects, lead to the obtaining of construction waste, which is one of the reasons for the solid domestic waste landfills constant growth, and also lead to the ecological problems.

The elimination of the negative consequences of the mentioned above problems in the EU is achieved by creating the closed-cycle economy for waste management, which requires the prevention of waste formation and material reuse [German law on the closed-cycle economy for waste management dated February 24, 2012]. In 2012, 30th April, in the Russian Federation there was adopted a programme “The Fundamentals of the Government Policy in the Sphere of the Russian Federation Ecological Development in the period till 2030” (approved by the President of the Russian Federation) where it is indicated that “the main tendency of managing the wastes is the prevention and reduction of waste generation, and step-by-step introduction of imposing a ban on waste burial”. That is why the development of the technologies aimed at reusing materials, items and constructions, obtained during the building demolition, is an urgent task set to the scientists in the construction sphere.

2. Aims and objectives of the research

The development of the technology for reusing materials, items, and constructions, obtained during step-by-step building demolition:

The assessment of the possibility to reuse materials, items and constructions, obtained during step-by-step dismantling of the industrial buildings.

The practice of adopting technology of step-by-step building dismantling with the further reuse of the obtained materials in building low-rise constructions.
3. Materials and the research methods

The following methods were used: systematization, comparative analysis, theoretical generalization of the data, obtained during the detailed analysis of the scientific resources.

The research of the concrete durability was carried out according to the requirements of State Standard 28570-2019 Concretes. Methods of determining durability by the samples, chosen from the constructions; State Standard 22690-2015 Concretes. Determining the durability by the non-destructive control methods; State Standard 17624-2012 Concretes. The ultrasound method of durability determining; State Standards P 53231-2008 Concretes. Rules of control and durability evaluation.

The research of the reinforcement durability was done according to State Standard P 57349-2016 Brick and blocks. Method of determining the durability for compression. The research of the reinforcement durability was carried out according to State Standard 12004-81. Reinforcing steel. Method of tension testing (with Amendments N 1, 2), State Standard 1497-84. Metals. Methods of tension testing (with Amendments N 1, 2, 3).

4. Results and discussions

The main methods of dismantling buildings and constructions in the world practice are explosion and mechanized methods. The special ways of crushing objects and their constructions are hydroexplosive, thermal, electrohydraulic and hydrosplitting, which are used rarely [7]. The explosion method is used to demolish multistoried buildings in America, China, Great Britain, Germany [1-7].

The explosion method has the following disadvantages:
1. Dynamic loads of the neighboring buildings.
2. Formation of a huge amount of dust during the explosion.
3. Heterogeneity of the obtained materials; this complicated the loading of the materials onto vehicles and labour-intensiveness of further processing.
4. Ecological problems of the obtained construction waste utilization.

The mechanized method of demolishing is used while dismantling building up to 9 stories. The advantage of this method is high efficiency, achieved by using special equipment.

Obvious advantages of these methods are high speed of work execution on dismantling and its low cost.

The disadvantages of the explosion method and mechanized method are difficulties during loading, low efficiency of transportation, as it is difficult to provide a full loading of broken ferroconcrete constructions; this increases the cost price of work execution, causes ecological problems or recycling and utilizing the obtained waste.

Nowadays during renovation in Moscow they use the technology of “smart demolition”. “Smart demolition” is the works, executed at several stages [8, 9]. At the first stage such elements as faience, ceramics, glass and woodwork are taken off. Then they are transported to specialized landfills with the aim of reuse.

At the second stage the mechanized method of demolition is used, the remnants of the construction are crushed and recycled. After crushing metal scrap is separated and sent for remelting.

The main material, obtained after recycling, is crushed stone which is used for filling the technological roads, filling the foundation pit pockets, making drainage in boggy areas [10-16].

The advantages of the “smart demolition” recycling are:
- reduction of the construction waste amounts which require burial at the solid domestic waste landfills;
- reuse of stone materials;
- solution to ecological problems due to production of the initial materials.

The disadvantage of this method is high cost of the obtained stone materials, their low homogeneity and durability [17-24].

The analysis of the maintenance and real longevity term of the load-bearing constructions of the buildings which are being demolished shows that they were exploited only 40-70 years while the regulatory terms of maintaining buildings from brick and ferroconcrete is 150-175 years according to MPP-3.2.23-97 [Methodological recommendations on economic basis for using constructive elements and technologies, providing the improvement of the investments efficiency due to reduction of operational costs, improvement of longevity of buildings and constructions, reduction of construction duration, and other effective decisions at increase of one-time costs while projecting and constructing and simultaneous growth of the estimate costs. / Economical efficiency of project solutions./ Part 1, item 1.3. Longevity of buildings, constructions and constructive elements and the estimation of longevity influence.
on maintenance costs. Approved by the first Vice-Prime Minister of Moscow Government V. I. Resin, Moscow 1997].

Our research showed that durability characteristics of brick, concrete (figure 1, figure 2), reinforcing steel (figure 3), being in the body of the ferroconcrete item, and being exploited under favourable temperature-humidity conditions (plus temperatures and the presence of humid surrounding) and the absence of factors, which contribute to the destruction of these materials (chemically aggressive environment, washing-out of the cement stone from the concrete structure by precipitation, or freezing and thawing of the materials in the water-saturated state) do not sink, the durability characteristics of the reinforcing steel is higher than the ones guaranteed by the producing factories by 3-5%, and concrete durability even increases by 20-200 %.

According to [25, 26] an average durability limit at compression of brick batch aged more than 150 years equals to 6.8 MPa, the brick brand is M50. According to the scheme of projecting the development of concrete durability in time [26], with time the durability of concrete will grow up to 112.7 years.

Table 1 shows the results of testing durability characteristics of the main construction materials, obtained by the staff of VSTU by destructive and non-destructive methods of control.

| Durability under compression (MPa) | Concrete | Silicate brick | Ceramic brick |
|-----------------------------------|----------|----------------|--------------|
|                                    | 20-100   | 7.5-10         | 3.5-10       |

The analysis of the following documents [State Standard P 57678-2017 Resource-saving, waste management, construction waste destruction. Moscow, Standartinform, 2017, STO NOSTRA 2.33.53.2011. Demolition (dismantling) of buildings and constructions. The National Association of Builders. Moscow 2012, TCP 45-01.03-186-2009 (02250) Products, materials, equipment. The regulations of reuse. RUE “Stroytechnorm”. Ministry of architecture and building of the Republic of
Belarus, Minsk 2010] shows that almost all the materials, products and constructions, obtained during demolition have to be reused according to their intended purpose.

From all the mentioned above, we may conclude that the temporal factor of exploiting construction materials, products and constructions often does not lead to the decrease of their durability, and they may be reused and have to be reused, and crushing of these constructions, having huge durability resources, is economically unreasonable.

The practice of step-by-step dismantling technology, supervised by the professionals of the chairs of the VSTU construction departments, shows that reuse of brick, foundation blocks, timber and breakage of building stone does not lead to psychological problems of private customers, who are the main consumers of these items and materials during low-rise construction, and these items are widely used during constructing low-rise buildings. However, the disassembling of ferroconcrete carcasses due to getting defects in the areas of concreting during step-by-step dismantling causes significant problems during their reuse for their intended purposes. That is why the scientists of VSTU have elaborated the technologies of reusing ferroconcrete columns, crossbars (figure 4), plates of coverings and bridgings, both cavitated (figure 5) and ribbed (figure 6), in the foundation constructions of the low-rise buildings.

The reuse, especially of the ribbed plates, obtained during step-by-step dismantling, allows reducing by 4-5 times the weight of foundation constructions, the loads onto foundation soils and the cost of strip foundation constructions in comparison with the new ones from monolithic concrete with an equal support area. And construction of box-like section foundations from these plates is possible while constructing under complicated ground conditions, and allows using them even while constructing on gliding slopes (figure 7) [27].

Figure 4. Construction of strip foundation using ferroconcrete crossbars and columns.

Figure 5. Construction of foundation using cavitated plates of bridging.

Figure 6. Construction of foundation reusing ribbed plates of bridging, obtained at step-by-step buildings dismantling.

Figure 7. Construction of breastwalls from ribbed ferroconcrete plates.
Figure 8. The use of stone construction materials breakage for strengthening the soils of foundations while building on the impound territories.

In 2019, according to the National project “Dwelling and urban environment” (approved on 24th December, 2018, by the decision of the presidium of the Russian Federation President Council for Strategic Development and National Projects), the amount of settled unfit available housing apart was 0.14 mln m², and in 2021-2024 this figure is supposed to reach 2.14 and 9.54 mln m² respectively. A great amount of two-storied buildings from slag stone have to be demolished; during dismantling such buildings a huge amount of construction waste is obtained, which was reused to strengthen clayey soils on the impound territories (figure 8) [28].

The novelty of the developed technologies is confirmed by patents [29, 30] of the Russian Federation and implemented during constructing dozens of buildings and constructions in Voronezh and Voronezh region. The implementation of the developed technologies allowed reducing by 40% the amount of the construction waste transported to the solid domestic waste landfills in Voronezh. The amount of the implementation of the reuse technology is constantly growing and improving along with the training of architects, designers, planners, organizations involved into step-by-step dismantling, engineers who control the quality of the materials obtained during the demolition, builders, constructing low-rise buildings and constructions. Even without the support of the government bodies it is planned that in 5-7 years the construction waste in Voronezh will not be transported to the solid domestic waste landfills.

The technologies of adamantine cutting [7] during step-by-step buildings and constructions dismantling allow avoiding the breach of ferroconcrete constructions integrity; this will allow using the technologies with the reuse of ferroconcrete carcasses wider in the process of constructing low-rise buildings and constructions.

5. Conclusions
The main reason for the formation of the construction waste is the demolishing technologies used by the builders nowadays.

The researches prove that construction materials and reusable constructions under favourable exploiting conditions do not yield to new materials by their durability characteristics; that is why such materials may be reused and have to be reused.

The technologies of step-by-step dismantling of building constructions allow obtaining construction materials, items and constructions for their reuse.

The implementation of step-by-step building dismantling technologies with the reuse of the obtained materials in the low-rise building showed high efficiency of the trend of these technologies development.

The reuse, especially of ribbed plates in the construction of breastwall foundations, in low-rise construction has a high economical reasonability.

Russia has a significant potential for the rational use of construction materials, items and constructions, obtained during demolition of buildings and constructions, due to the development of the closed-cycle innovative technologies implemented in building.

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