Analytical methods for selection of demolition technology

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Abstract. Demolition of buildings and structures, or their structural elements, is primarily aimed in designing stage – for the reconstruction or renovation of a building or complex of buildings, updating the appearance, design or philosophical meaning of an object. Therefore, demolition must be approached no less responsibly than the construction itself. The article deals with data on the economic feasibility of a correct approach to demolition, which allows the maximum extraction of raw materials from construction waste for further construction. The article provides a brief overview of the technologies for demolition structures to select the optimal and most effective. For the best use of the existing knowledge on this subject, and as a result – obtaining the greatest economic benefit, it is proposed to classify demolition technologies, their description and recommendations for use. For this, it was proposed to create a certain database that can, in an interactive form, help to choose the optimal technology for demolition a building or a separate structure.

1. Relevance
Nowadays, the relevance of topics related to the recycling and reuse of building structures and materials is becoming more valuable. This is mainly due to the end of the service life of residential buildings that were massively built in the 60s of the last century. These buildings are currently undergoing for reconstruction and modernization. In prestigious areas they are completely demolished. As a result of dismantling huge volumes of construction and demolition waste remain, which is expensive to dispose of and, moreover, is unfavourable for the environment. Considering the fact that the dismantling of a building is an expensive process, it becomes obvious the need for competent demolition so that the resulting raw materials can be sold or used and automatically solve the problem of waste disposal. There are many technologies for demolition of buildings and structures, which are more or less appropriate to apply. A competent approach to the choice of demolition technology will allow to reduce the cost of the process as much as possible and, as a result, to obtain the highest quality building materials from waste.

2. The main idea
The main potential reserves for saving material and energy resources in the construction industry is the use of waste concrete scrap, today in Ukraine the use of this resource is small. Analysis of indicators of waste disposal and their use as secondary raw materials indicates the economic attractiveness of this area. So, according to statistical reporting data for 53 types of resource-valuable construction waste, the volume of their use can be 58.5% of the total volume of this waste. Construction waste contains a large amount of metal and concrete scrap. In some cases, replacing natural resources by construction waste can save up to 50% of material [1].

Waste recycling, including construction and demolition waste, is a promising business, since the cost of recycled rubble is only 50 Euro per ton [2]. Secondary crushed stone from concrete constructions of demolished buildings is much cheaper than natural, since energy consumption for its production is 8 times less, and the cost of concrete with it is reduced by 25% [3]. Moreover, the absence of certain standards may allow manufacturers of secondary non-metallic building materials to sell almost all components. But, for example, the ingress of gypsum contained in finishing materials

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and partitions can lead to significant corrosion of new concrete, up to its destruction [3]. To obtain a high-quality product, it is necessary to strictly observe the technology of demolition buildings, sorting materials and preparing waste for recycling. Therefore, for the widespread introduction of complexes for the destruction of substandard concrete goods by a mechanical method and the production of crushed stone from crushed concrete, a number of issues should be resolved on its rational use in construction as a filler in the production of concrete work. It is especially important to choose the correct technology for demolition structures [4].

The problem of construction and demolition waste is of particular importance due to the fact that the service life of buildings massively erected in the 60s of the twentieth century is being exhausted. So, when a five-storey residential building is demolished, about 3 thousand cubic meters of construction and demolition waste are formed that needs to be processed, not stored. In the conditions of urban development, next problems arise: how to demolish a building, destroy a worn-out structure of a reinforced concrete or stone bridge or an industrial facility that has become unnecessary and where to subsequently use the resulting secondary resource. In general, the technological process of utilization of construction and demolition waste can be represented in two stages:

- preliminary disassembly or destruction of the most valuable and complex concrete and reinforced concrete structures.
- recycling waste into secondary crushed stone; removal and disposal of reinforced concrete and construction and demolition waste.

The advantages of processing reinforced concrete waste into secondary crushed stone include the following: at each construction site where structures are dismantled, crushed stone will soon be needed during the construction process (the presence of secondary crushed stone eliminates the need to purchase crushed stone, and pay the costs of its delivery, removal and storage).

The main components of reinforced concrete are rubble, sand, cement and metal reinforcement. These materials are relatively stable in the environment: their total volume and weight change little even after prolonged use. After crushing and separation of the metal, the obtained secondary aggregates compared to natural ones have lower density, bulk density and percentage of volume in a solid body, higher water absorption, weight loss in the test for resistance to weathering and losses due to abrasion. All these changes are associated with the presence of a mortar component in the concrete scrap. A great importance for predicting the behaviour of the aggregate in mixtures and in hardened concrete is the quantitative content of components in various fractions of concrete scrap. Knowledge of the patterns of changes in its component composition allows it to optimize the use of various fractions.

Today there are many methods of destruction of building structures – static (splitting, crushing, cutting and expansion) and dynamic (shock, vibration, explosive). Currently, the greatest results have been achieved in improving the technology of destruction of building structures by impact methods, splitting, cutting, crushing and expansion. However, at the same time, each of the methods has restrictions on the use, or vice versa, recommendations for use for the destruction of buildings and structures made of a certain material. In this regard, the issue of their classification remains relevant.

### 2.1. Impact methods

The most widespread are hydraulic and pneumatic hammers on self-propelled units, which are characterized by high productivity, mobility and the ability to accurately apply a blow. Compared to pneumatic hammers, hydraulic hammers have less noise, vibration and dust generation. The best proven hydraulic hammers with a single impact energy of 9000 J and hydropneumatic installations with a load of up to 3000 J. Pneumatic breakers with an impact energy of 80-90 J are used for dismantling concrete and reinforced concrete structures and rubble, rubble concrete and brick structures and semi-rocky rocks. For disassembly and destruction of various types of structures, they are supplied with replaceable working bodies (lance and shovel). Pneumatic jackhammers with an impact energy of 30-45 J are used for demolition concrete and asphalt concrete pavements, brick walls. During operation, pneumatic manual machines are turned on by pressing the handle with a
certain effort and turned off when the effort is removed from the handle. To provide energy to manual pneumatic machines, stationary compressor units and air distribution networks of the reconstructed enterprise are used. In the absence of such a possibility, portable compressors are used. Electric manual impact machines have a lower energy of a single blow compared to pneumatic ones, however, during their operation, the noise level is significantly lower, which leads to a decrease in fatigue of workers.

It is advisable to use electric hand hammers and concrete breakers for element-wise disassembly of a structure of medium and low strength, as well as when working at height, where, in cases of using pneumatic manual machines, workers need to make additional efforts to lift and hold the air hose, which leads to rapid fatigue and, accordingly, decreased productivity. Pneumatic manual impact machines are effectively used to dismantle more durable concrete, reinforced concrete and brick structures.

2.2. Cracking
When concrete and reinforced concrete structures are destroyed by splitting, hydraulic wedges are used, which allow working without harmful effects of vibration, noise and dust formation. The hydraulic wedge consists of a hydraulic cylinder and a propping device inserted into the drilled hole and creating a force of up to 130 tons, as well as a pumping station that creates pressure in the hydraulic cylinder. The average performance of hydraulic wedges is approximately 510 times higher than manual breakers.

For splitting concrete foundations, installations are used, consisting of an oil pump station and several (up to 5) wedge devices. To separate parts of concrete, boreholes are drilled in it with a pitch that depends on the strength of the concrete and is 400-800 mm. The diameter of the holes is 3-5 mm larger than the diameter of the working body. The working body is introduced into the hole, then pressurized oil into the hydraulic cylinder. Chipping off pieces of concrete occurs without the scattering of fragments, accompanied by a weak crack. Installation performance 0,25-0,5 m³/h.

2.3. Cutting
When structures are destroyed, cutting methods are used, which make it possible to dismember a structure into separate elements (blocks) suitable for reuse. In this case, diamond cutting wheels and thermal cutting using oxygen blast, plasma or electric arc are used. Modern machines with diamond wheels allow cutting reinforced concrete to a depth of 400 mm and a mechanical feed rate of up to 2 m/min.

2.4. Splitting up
Crushing is carried out using teeth that are installed on the concrete breaker or separately mounted on the excavator. Replaceable working equipment allows crushing reinforced concrete structures up to 700 mm thick and foundations up to 1200 mm thick. One of the main advantages of a crushing plant is the ability to use it directly at the site of construction and demolition waste generation. In this case, the mobile crushing and screening complex is delivered to the construction site, where it immediately starts to work.

2.5. Destruction by expanding compositions
For the destruction of building structures with the help of expansion, cartridges of liquid carbon dioxide (cardox) are most often used, the action of which is based on an increase in volume as a result of the transition of carbon dioxide from a liquid to a gaseous state, while the developed pressure varies from 125 to 275 MPa. Recently, other expanding compounds have appeared, the action of which is based on various chemical processes that take from several hours to 30 minutes. The destruction of structures occurs as a result of the expansion of the mixture of powder and water poured into the drilled holes, but the resulting pressure is much lower than when using a frame (within 30-40 MPa). Therefore, with the help of this, as a rule, light reinforced concrete structures are destroyed.
When all production processes are carried out near the demolished building, a mobile or self-propelled recycling equipment is used, placed on a mobile construction and demolition waste recycling site. The set of equipment includes: a tower crane (when building is demolished), which forms stacks of building elements with different characteristics; excavator with removable working equipment (bucket, hydraulic hammer and hydraulic shears); a loader for removing destroyed elements of buildings prepared for primary crushing from a stack, moving these elements to the primary crushing unit and loading the unit's primary device (a bulldozer can be used in these processes); units for primary and secondary crushing; screen for separating crushing products by size; conveyors for placing products of several fractions, processing waste and reinforcement, feeding into stacks. Loading of products and waste is carried out by loaders, and valves by excavators, less often by loaders.

2.6. Electro-hydraulic method of destruction of structures
It is carried out without the formation of a blast wave and scattering of fragments, which is a fundamental factor when performing work in places with the release of dust or the likely appearance of gas. This method is completely safe for people working near people and installed equipment, so it can be successfully applied not only on open construction sites, but also inside industrial premises. The use of the installation of the electrohydraulic effect for the destruction of stone and concrete massifs, rubble concrete and brickwork make it possible to increase labour productivity tenfold and even completely exclude the use of physical labour in these works.

2.7. Drilling and blasting method of destruction
The method uses the energy of an explosion generated when an initial impulse from a spark or impact is applied to an explosive. This method has long been used in construction; therefore, it is considered one of the first. In justified cases of destruction of structures by this method, blasthole charges and camouflage explosions are used. To reduce the scattering of pieces, explosion localizers of various designs are used. Their advantages over other means are the absence of fragments and noise, a large number of simultaneously filled boreholes, which in a day cause cracking of massifs unlimited in volume. Destruction of concrete blocks of grade 300 and more, as well as densely reinforced blocks is carried out with preliminary drilling of vertical or inclined boreholes. The disadvantages of explosion generators are the large spread of fragments, significant noise (up to 108 dB in a radius of 50 m) and the release of toxic gases.

An analytical comparison experiment was carried out of all methods of demolition structures to establish a correspondence between building structures and technology in order to obtain the most efficient extraction of raw materials. It was found that it is impossible to strictly envisage the regulations for the selection of demolition technology. This is due to the fact that even the slightest changes in the design feature or its environment can change the efficiency of using the demolition technology, compared to other similar structures. However, for all buildings and structures, for the most efficient extraction of high-quality raw materials from construction and demolition waste, it is important to perform a phased demolition of structures and coatings made of different materials. It is especially important to separate materials that could subsequently cause corrosion of concrete made from the raw materials obtained.

For the most efficient and rational use of existing knowledge about demolition of buildings, structures and their individual structures and, as a result, to obtain the greatest economic benefit, we propose a classification of demolition technologies, their description and recommendations for use in tabular form (Table 1). This will make it possible to help in a convenient form to choose the optimal technology for demolition of a building or a separate structure.
Table 1. Recommendations for the selection of demolition technology.

| Name of technology                        | Used equipment                                                                 | Recommendations for use                                                                                                                                 |
|-------------------------------------------|-------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------|
| **Impact methods**                        | Self-propelled hydraulic and pneumatic hammers, hand hammers                  | For demolition of concrete and reinforced concrete structures, rubble concrete and brick structures, semi-rock and asphalt pavements                    |
| **Cracking**                              | Hydraulic wedges                                                              | Used in situations where the harmful effects of vibration, noise and dust formation are unacceptable                                                  |
| **Cutting**                               | Saws with diamond cutting discs, thermal cutting devices using oxygen blast, plasma or electric arc 23.9 | If necessary, to dismember a structure into separate elements suitable for reuse                                                                    |
| **Splitting up**                          | Teeth that are mounted on concrete breakers or separately mounted on an excavator | Used when it is necessary to crush and process concrete scrap directly at the place of formation                                                        |
| **Destruction by expanding compositions**  | Cartridges of liquid carbon dioxide (cardox)                                  | For the destruction of light reinforced concrete structures                                                                                           |
| **Electro-hydraulic method of destruction of structures** | Installation of electrohydraulic effect                                       | Can be used inside industrial premises, where the use of a blast wave and scattering of fragments, dust and gas excretion is unacceptable. The method is safe for people working near and installed equipment. |
| **Drilling and blasting method of destruction** | Initial impulse explosive (blasthole charges and camouflage explosion)        | The method is effective for quickly demolition a large volume of structures.                                                                          |

3. Conclusions and results

Effective demolition of buildings and structures allows performing a number of tasks, namely: elimination of landfills and burials of construction and demolition waste; creation of resource-saving technologies for the processing of construction and demolition waste, allowing to save building materials; reducing the cost of building structures, saving natural resources. For the most efficient extraction of useful resources from construction and demolition waste, it is important to choose the right technology or a set of technologies for demolition structures. To do this, it is necessary to analyse the above technologies for dismantling structures and select the optimal one based on the recommendations. When choosing methods for disassembling and destroying structures, one of the main indicators is the labour intensity and timing of work, however, the effectiveness of using one or another method also significantly depends on the yield of materials ready for reuse. The use of a competent approach to the choice of demolition technology will allow a responsible and most rational approach to the task of demolition of old, morally and physically obsolete buildings. The proposed
classification of technologies for demolition buildings and structures and their individual parts and recommendations for use will make it possible to competently and most efficiently selection of optimal technology. This will maximize the benefit of the generated waste and to save money.

The classification of technologies for demolition buildings and structures and their individual parts in a tabular form should be regarded as the basis for the further creation of a database in a more interactive form.

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