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Assessment of the morphological composition of secondary construction waste from destruction

Abstract. The issues of post-war reconstruction of territories and settlements that suffered extensive damage as a result of hostilities are considered. Rational design and construction solutions are proposed that allow maximum use of the foundations of destroyed buildings for further reconstruction. It is determined that the planning solutions for the quarter development of industrial cities are imperfect and require updating in accordance with modern principles. A solution that significantly reduces the amount of work involved in dismantling the underground structures of buildings is to use them for the construction of new reconstruction objects. A combined solution is proposed for the joint use of the foundation array of a destroyed building and a monolithic grillage on bored piles. The use of diamond drilling technologies allows for the effective installation of piles in complex, swampy areas. It is proposed to construct the structure in the form of a system of soil foundation, artificial foundation, connected by a system of piles and foundation frames.

Keywords: region, secondary construction waste, destruction, morphological composition, recycling, utilization, processing, waste management
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Introduction.

The reuse of waste of all types is a pressing issue for most developed countries. Various factors contribute to the scale of secondary processing tasks. The process of urbanization concentrates the population in cities and agglomerations and makes them daily consumers of a multitude of goods. Solid domestic waste (SDW) is generated daily and has long been considered a complex urban planning problem. The market economy, with its objective laws, leads to the packaging of goods, products, and articles reaching 10-20% of the weight and volume of the actual item being sold. The industrial era produces a high density of artificial structures per unit area using a wide range of structural and building materials. The investment cycle of industry and the life cycle of buildings and structures are shortening, leading to the permanent renewal of fixed assets. In Ukraine, entire residential areas are subject to mass reconstruction. Some of the enterprises of the military-industrial complex of the USSR era have been transformed into industrial sites with buildings and structures for demolition. The construction industry is also a significant source of waste of various types. The war, which has been going on for four years, has greatly exacerbated the problem of secondary waste management in the country.

Another category is formed – secondary construction waste from the destruction of buildings and structures (SCWBS) caused by hostilities. This waste has its own characteristics, determined by the causes of destruction, time parameters, territorial localization, social and economic factors.

Review of the latest research sources and publications

Urbanization processes in developed countries and the formation of agglomerations have led to a significant increase in population density in cities. Industrialization and technical development contribute to the improvement of construction technologies and the emergence of new groups of building materials and structures. The resource intensity of construction is increasing. Development processes are shaping several different trends. The technogenic load on the territory is increasing, and the volume of construction is reaching landscape-level scales. At the same time, the life cycle of individual construction objects is coming to an end under the influence of various factors. Thus, cities concentrate huge amounts of artificial materials, a significant proportion of which require solutions for disposal, storage, recycling, and burial of waste. For basic characteristic groups, such as natural and artificial non-metallic or stone materials, research has been conducted for a long time on their secondary use in construction and beyond [1-9]. The durability of concrete, natural stone, and brick has led to a search for opportunities for their reuse. Scientific research into the recycling of concrete materials and structures continues [10-12]. A systematic approach to the reuse and recycling of a full range of construction and industrial waste of various morphologies is used in the work of domestic scientists [13]. One of the systemic factors in the majority of studies is the generalization of the continuity and duration of the process – the formation of waste and the processing of waste. In other words, secondary processing is a derivative of the overall process of economic functioning of cities. The factor of military action is only taken into account for countries in the Middle East with unstable political regimes. At this stage in Ukraine's recent history, when the scale of destruction from military operations totals millions of cubic meters, the task of managing and handling secondary construction waste generated by military operations is a nationwide challenge [14-17].

Problem statement

To determine the impact of the morphological composition of secondary construction waste from building demolition on rational options for its use. To develop a model for managing secondary construction waste from demolition that takes into account the significant initial heterogeneity of the material.

Basic material and results

Large-scale destruction caused by hostilities has led to the creation of a significant amount of construction waste, which complicates the restoration process. In this context, it is advisable to consider recycling options when developing concepts for the reconstruction and new development of damaged facilities. According to experts from the Kyiv School of Economics, as of early 2024, the amount of direct and documented damage caused by the war exceeded US$157 billion. As hostilities continue, this amount continues to grow. Approximately one-third of all direct losses are attributable to the housing stock: about 250,000 properties have been damaged or destroyed, of which 89% are private houses and 11% are apartment buildings. These losses cover about 9% of the total housing stock in Ukraine, with only 10% of the damaged buildings suffering minor damage. The Donetsk, Kharkiv, and Luhansk regions have suffered the greatest losses, accounting for more than 60% of the damaged or destroyed housing stock. As of 2024, the volume of construction waste throughout the country exceeds 670,000 tons. In this regard, the recycling of construction waste is becoming particularly relevant. Global experience in recycling construction waste, particularly in European countries, demonstrates a high level of recycling technology implementation. In the Netherlands, for example, over 90% of construction waste is recycled. In other countries, these figures are as follows: Belgium – 87%; Denmark – 81%; Great Britain – 45%; Finland – 43%; Austria – 41%; Canada – approximately 73%. These data confirm the high potential of construction recycling as an effective element of environmentally-oriented reconstruction.

Figure 1 – Example of secondary construction waste generated from the demolition of buildings and structures.

According to estimates, the demolition of a five-story industrial building generates up to 5,000 tons of waste, of which about 50% is concrete or reinforced concrete, and the rest is stone materials, glass, insulation, roofing materials, etc. Several groups of basic materials can be identified for reuse after sorting and processing: concrete and reinforced concrete can be crushed into fractions, allowing them to be used as aggregate for new concrete; as a base for road surfaces;

as filler in masonry mortars; low-ash binder for silicate products. Glass – used in the production of thermal insulation foam glass. Bricks – can be converted into construction rubble or decorative chips. Sorting waste is a complex problem, as the quality of recycled materials depends on the degree of purification from foreign inclusions (wood, reinforcement, debris). Secondary construction waste from the destruction of buildings and structures as a result of hostilities has characteristic differences, primarily due to the conditions of its origin. An additional factor is the influence of time, as destroyed buildings stand for years before they are dismantled and cleared away. Figure 1 illustrates the nature of secondary construction waste generated from the destruction of buildings and structures. There is no question of predictability, controllability, or orderliness in the formation of the array of destruction. Typological differences in the structural solutions of different types of objects should be taken into account.

Under normal conditions, the object of processing undergoes a stage of cleaning and removal of non-structural debris. A destroyed building concentrates inclusions that do not contribute to sorting or forming groups of recyclables with standardized indicators.

A multi-story residential building contains significant amounts of fragile lime-chalk-sand mixture, wood, paper, and fabric materials of varying degrees of metamorphism. There is plastic and bitumen roofing material. There are mineral wool slabs, foam plastic, and fragmented polystyrene foam facade insulation. Some of these materials were exposed to fire, forming soot, ash, and half-burnt remains. The remains of apartment furnishings, from furniture and clothing to books and household chemicals, pose a separate problem. External atmospheric and climatic influences lead to repeated prolonged soaking, rotting, efflorescence, and numerous cycles of freezing and thawing. In other words, the waste itself is constantly undergoing degradation processes. Figure 2 shows the actual state of cities and microdistricts destroyed by the war.

Sorting such a mass is almost impossible. There are technological solutions – manual sorting and cleaning of waste, recycling of secondary waste using either thermal burning or flotation (enrichment) methods. For obvious reasons, they are economically unfeasible. The task is to assess the impact of the morphological composition of secondary construction waste on the basic parameters of recyclate and to determine, taking into account typological classifications, the rational areas of its use.

The typological parameters of urban development of individual residential groups, neighborhoods, and microdistricts directly determine the structure of SCWBS. In other words, the former built-up area contains a full range of buildings and structures that have been 100% destroyed.

Figure 2 – Examples of the actual state of microdistricts and cities destroyed by hostilities.

In such cases, the task of managing and dealing with SCWBS is combined with the tasks of urban redevelopment of the area, with changes or preservation of the functions and form of city districts. Industrial cities in eastern Ukraine are characterized by the presence of urban development zones with typical features of the corresponding style and time. For such areas, it is possible to develop concepts for the management of SCWBS that take into account rational options for urban reconstruction solutions (Fig. 3).

The working hypothesis is the duration and scale of land clearing. WEEE management should be combined with urban redevelopment tasks. Traditionally tested processing methods – sorting, recycling, disposal, and burial of waste – should be supplemented with additional options. The possibilities of using WEEE in landscape projects are being considered, including the expansion of roads, the collapse of flooded areas, and the formation of industrial sites and plots. The mineral component of waste can be used to adapt design and construction solutions in densely built-up areas. The waste management model needs to be supplemented with a matrix of alternative solutions that specifies the potential volumes of waste, the linear and area parameters of the sites, and the concepts and recommendations for reconstruction.

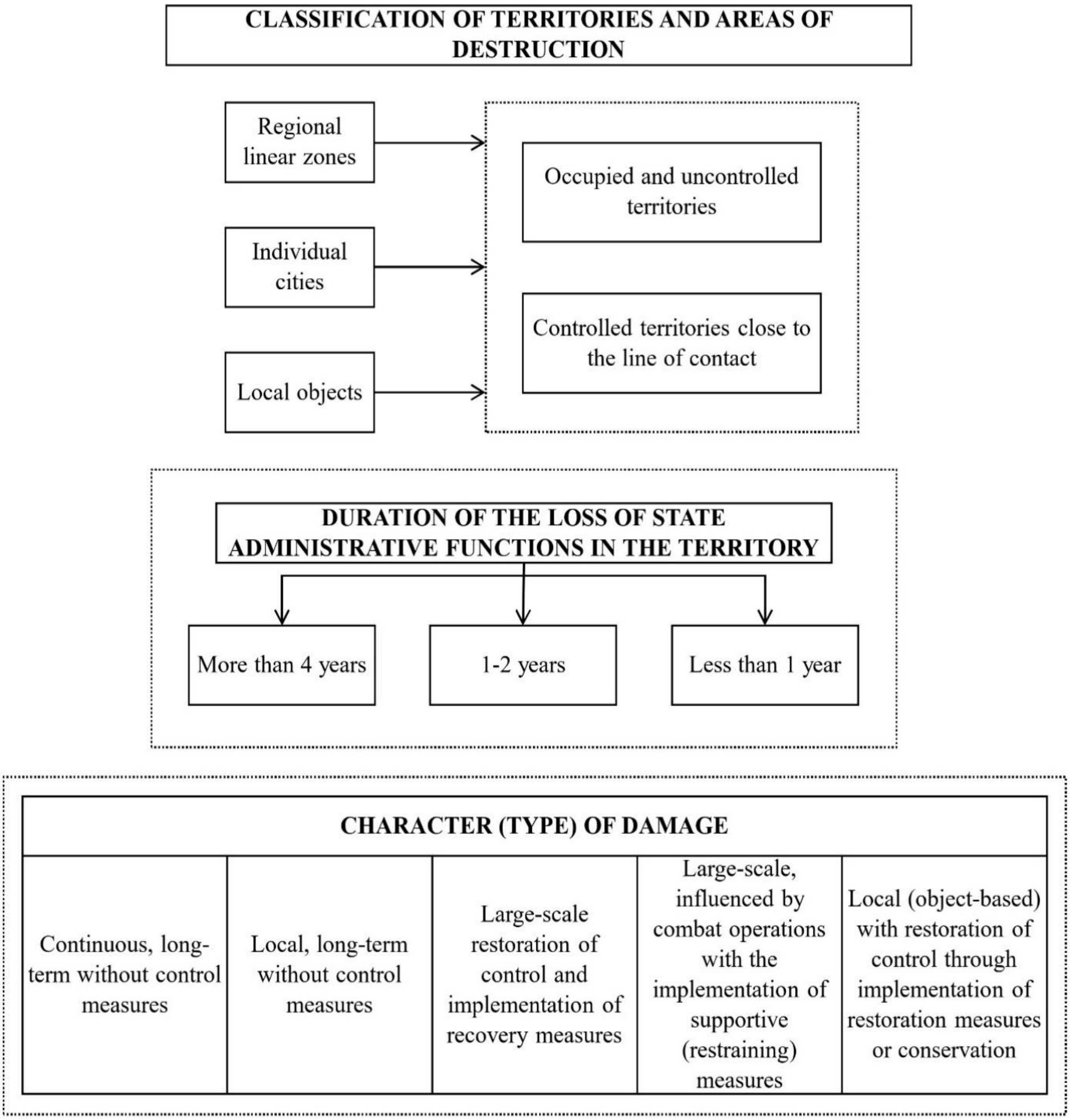

Figure 3 – Model for developing concepts and recommendations for managing SCWBS

Conclusions

When addressing issues related to the management of secondary construction waste from the demolition of buildings and structures, one of the main factors is the territorial scale, significant areas and sections of territories that have been affected. Thus, the problem of SCWBS management forms an urban planning task, and not just an object type. The morphological composition of secondary construction waste is largely determined by the typology of development and the influence of external factors (fire, climatic factors). The task is to develop a concept for handling secondary construction waste, feasible options for disposal and reuse, and a system for handling secondary construction waste.

System analysis determines the main parameters, factors, and trends of the regional situation. A characteristic feature of the so-called gray zone in eastern Ukraine is the formation of a large-scale zone of destruction, the restoration of which is a complex task at the state level. The basis of the region is complemented by the formation of a border strip, which means dependence on external conditions in the tasks of developing concepts and strategies for reconstruction. The territorial scale of urban destruction creates an urgent problem in the development of an effective SCWBS management model. Proven options for dealing with destruction waste are proposed – recycling and processing, disposal or burial, and landscape use of waste arrays.

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Оцінка морфологічного складу вторинних будівельних відходів від руйнації

Аннотація. Проаналізовано чинники що визначають особливості формування масиву вторинних будівельних відходів від руйнації будівель та споруд. Визначено, що вторинні будівельні відходи мають свої характеристичні особливості зумовлені причинами руйнування, часовими параметрами, територіальною локалізацією. Обсяг та масштаб масивів руйнувань формує проблему загально національного рівня. Немає мови про прогнозованість, керованість або упорядкованість формування масиву руйнувань. Доведено, що фактор часу здійснює негативний вплив на стан масиву руйнування. Під впливом природно-кліматичних чинників деградація матеріалів, що складають масиви руйнувань тільки збільшується. Сформульовано робочу гіпотезу щодо впливу морфологічного складу вторинних будівельних відходів від руйнації будівель та споруд на доцільні варіанти їх утилізації, що спираються на містобудівні задачі відбудови. Запропоновано модель розробки концептів та рекомендацій по управлінню вторинними будівельними відходами від руйнації будівель та споруд в контексті містобудівного відновлення. Залежно від масштабу руйнування містобудівне відновлення території може передбачати зміну або збереження функцій та форми ділянок міст. Запропоновано шляхи повторного використання у будівництві окремих компонентів будівельних відходів. Пропонуються апробовані варіанти поводження з відходами від руйнування – рециклінг та переробка, утилізація або поховання, ландшафтне використання масиву відходів. Результати, що досягаються – зменшення обсягів поховання та відповідно територій полігонів, зменшення витрат природних ресурсів, створення нових робочих місць. Відновлення інфраструктури зруйнованих міст утворює цикл: розчищення – містобудівний концепт – переробка – план детальної забудови окремих мікрорайонів та кварталів. Зроблено висновок, що модель поводження з відходами необхідно доповнити матрицею варіативних рішень, яка конкретизує потенційні обсяги відходів, лінійні та площинні параметри ділянок, концепти та рекомендації відбудови.

Ключові слова: регіон, вторинні будівельні відходи, руйнування, морфологічний склад, рециклінг, утилізація, переробка, управління відходами.

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