Peculiarities of organizational and technological approaches to the post-war restoration of infrastructural objects in Ukraine

Mykola Savytskyi[1*], *Anatolyi* Radkevych[1], *Oleksandr* Savytskyi[1], *Maryna* Babenko[2], and *Tetyana* Shevchenko[1]

[1]Ukrainian State University of Science and Technologies, 49010, Dnipro, Ukraine
[2]Mendel University in Brno, Faculty of Forestry and Wood Technology, Wood Science and Wood Technology Dept., 61300, Brno, Czech Republic

Abstract. As a result of russia's insidious war against Ukraine, thousands of infrastructure facilities and energetical objects were destroyed or damaged. We are sure, Ukraine will win this war. Already today, the territories of the country freed from the occupiers with the destruction of residential and civilian buildings, infrastructure facilities need restoration. In Ukraine, the Government Plan for the Recovery of Ukraine has been developed. Ukraine's Recovery Plan is aimed at accelerating sustainable economic growth. But this Program outlines general approaches and directions for the recovery and development of Ukraine. Therefore, it is necessary to develop detailed local programs that contain organizational and technological approaches to the implementation of restoration works. The programs must to help local authorities, territorial communities in which housing and social infrastructure objects were damaged or destroyed as a result of russian armed aggression, to make decisions regarding the planning and implementation of restoration works and the development of territories. Purpose of the study: to develop detailed Local Program which specifies the National Programs of the Recovery Plan of Ukraine and contain organizational and technological approaches to the implementation of restoration works.

1 Ukraine war damage assessment

The war, insidiously unleashed by russia against Ukraine, continues. russian armed aggression against Ukraine includes: Russia's armed invasion of Crimea on February 20, 2014, the war in eastern Ukraine (Donbas) since April 2014, and the full-scale invasion of Ukraine by russia on February 24, 2022.

The extent of the destruction of civil infrastructure as of February 20, 2023 is estimated at 81305 destroyed and damaged objects. More than 44 million square meters of housing stock worth 39.3 billion dollars were destroyed. As a result of the russian armed aggression against Ukraine on June 1, 2022, Ukraine lost 35 percent of its GDP, and direct losses from

* Corresponding author: sav15@ukr.net

the war already exceed 600 billion dollars. The World Bank estimated Ukraine's losses from the war at 350 billion (as of June 1, 2022).

The large-scale russian armed aggression against Ukraine has led to a sharp increase in the volume of specific waste, including damaged and abandoned vehicles and equipment, shell fragments, construction debris, household and medical waste. Some of the waste is quite toxic, especially shell debris, medical waste, and construction debris containing asbestos and heavy metals.

According to the Ministry of environment, the volume of such waste has already acquired a scale that has not been observed on the European continent since the Second World War. More than 325 thousand tons of destroyed Russian equipment have been accumulated on the territory of Ukraine alone. In addition, huge amounts of waste from the destruction of Housing and transport infrastructure have been generated, which is a new challenge for our country [2].

According to the Ministry of Environmental Protection and natural resources, as of March 2024, Ukraine has already generated more than 600 thousand tons of destruction waste, that is, fragments of buildings and other objects destroyed by shelling. During the two years of the full-scale war, environmental damage caused by Russian aggression reached $63 billion [3].

The Russian invasion has affected the energy sector. 40% of the electricity transmission infrastructure and a significant portion of electricity generation capacity have been destroyed or severely damaged, causing serious disruptions in electricity, water, heating, etc.

As of October 2023, Ukraine's integrated power system has lost 44% of nuclear generation, 78% of TPP capacities (including occupied plants), 66% of block CHPs, 12% of HPPs, and 32% of PSPPs. 45% of distribution capacities were damaged [4].

But the war will still end with our victory and it will be necessary to rebuild the country. The construction industry will play a key role in the recovery of Ukraine. It is known that the level of development of construction speaks about the economic development of the country and the standard of living of its population. The share of construction in the GDP of Ukraine in 2010 was 8%, today it is slightly more than 2%. In EU countries, according to 2019 data, the industry provides 9% of GDP. Construction during the three months of the war was reduced by 70%, the cost of construction increased by 20% [5].

2 Main features of the Program “Regenerative industrial construction (restoration of destroyed) objects of the social infrastructure of Ukraine using recycling and distributed energy technologies”

In Ukraine, the Government Plan for the Recovery of Ukraine has been developed [1]. Within the framework of the plan, a list of 17 National programs for achieving key results has been determined. Among the National programs, 5 of them directly affect the construction sector of the economy: Strengthening defense and security; Reconstruction of a clean and protected environment; Energy independence and the Green Course; Restoration and modernization of housing and infrastructure of the regions; Restoration and modernization of social infrastructure.

We have developed the Program “Regenerative industrial construction (restoration of destroyed) objects of the social infrastructure of Ukraine using recycling and distributed energy technologies”, which specifies the National Programs of the Recovery Plan of Ukraine. The program is designed to help local authorities, territorial communities in which housing and social infrastructure objects were damaged or destroyed as a result of Russian armed aggression, to make decisions regarding the planning and implementation of

restoration works and the development of territories. The program includes technologies and organization of restoration works of infrastructure objects of Ukraine.

Main features of the Program:

1. Consideration of modern threats to humanity and global development trends.
2. New urban planning principles for the development of territories (taking into account war threats, new urbanism, balanced development of territories)
3. New types of buildings, providing safety, accessibility, energy-efficency. Focus on low-rise construction. Energy-efficient reconstruction. Three zero buildings − zero energy, zero emissions, zero waste.
4. Industrial (factory-made) architectural-constructive-technological systems of buildings to ensure high rates of construction.
5. Creation of a network of distributed small industrial productions, close to the places of destruction areas and construction sites for the rationalization of transport costs.
6. Use of distributed (decentralized) energy systems using renewable energy sources to ensure autonomous production.
7. Technologies of recycling (reusing) materials of destroyed buildings and structures.

2.1 Modern threats to humanity and global development trends

There are various interpretations about the main threats to humanity. The most comprehensive analysis of threats is contained in [6]. The most important world threats to humanity are: 1) war threats; 2) climate change; 3) the pandemics; 4) threat of hunger; 5) didgitalization that limit the freedom and sovereignty of both an individual and entire states.

The war threat has turned from virtual to real, which has been happening in Ukraine since 2014 thanks to the aggressive policy of the russian federation. How to confront this existential challenge in the future will be discussed further.

Climate change. The first in terms of consequences for mankind is the problem of climate change. Climate change refers to long-term shifts in temperatures and weather patterns. The main emitters: generating power, manufacturing goods, cutting down forests, using transportation, producing food, powering buildings, consuming too much. Impacts of climate change: hotter temperatures; more severe storms; increased drought; a warming, rising ocean; loss of species; not enough food; more health risks; poverty and displacement.

Postwar reconstruction will create an opportunity to accelerate the “greening” of the economy. Ukraine's economy and fulfill Ukraine's obligations under the Nationally Determined Contribution (Nationally Determined Contribution − NDC). As Ukraine has become a candidate for accession to the European Union, it will eventually be required to fulfill obligations to fulfill the commitments common to the EU in this area (Copenhagen criteria). Green recovery is crucial for Ukraine's membership prospects in the European Union.

The EU is introducing a carbon tax (CBAM). If an exporter does not “prove” that its products are climate-neutral, it will have to pay a carbon tax at the border [7]. Ukraine needs to revise the NDC-2 targets (Nationally Determined Contribution under the Paris Agreement). CBAM conditions are becoming more stringent. Ukraine needs special conditions because CBAM can destroy the Ukrainian industry that survived the war [8].

The water-energy-food (WEF) Nexus. Ukraine is an industrial and agricultural country. The agricultural sector is an extremely important sector of Ukraine's economy. The sustainability of water, energy, and food systems is one of the grand challenges of the 21st century. The water-energy-food (WEF) Nexus is a prominent approach for addressing today's sustainable development challenges. The water-energy-food (WEF) Nexus provides a framework and an approach to help address these multifaceted issues [9].

We propose the concept Regenerative Buildings. The term “regenerative” describes processes that restore, renew or revitalize their own sources of energy and materials. The concept Regenerative Buildings involves the creation of Bioenergy complex − an ecologically closed system for the organic waste recycling with the production of energy, food, feed, fertilizers and irrigation water.

Fourth industrial revolution. Ukrainian industry will change dramatically due to the risks associated with the war. Soviet methods of locating and building industrial facilities are being adapted to modern realities. 30 to 35 years ago, the location of large industrial enterprises on the left bank of the Dnipro River was quite logical from a strategic point of view. Now it is advisable to change their location. The old industry will become history. The industry that existed in Ukraine until recently will mostly disappear. That's because the concentration of production that was used in the twentieth century is giving way to dispersed schemes of capacity allocation. Given the current crisis, it is necessary to build the industry from scratch, taking into account protection against external aggressive actions of the enemy [10].

Today, the world is developing in the direction of the fourth industrial revolution [11, 12]. Ukraine should not stand aside from these processes. The Fourth Industrial Revolution (4IR) describes how modern technologies like artificial intelligence, big data, robotics, virtual reality, and 3D printing bridge the gap between the human experience and its digital counterpart. It’s a dramatic leap in manufacturing and productivity, changing the way we work, live, and interact with one another in real time through software, analytics, connectivity, and human-machine interaction. The Fourth Industrial Revolution is creating a world of smart machines, advanced robotics, autonomous systems, and pervasive networks. At its core are the following technologies: Faster Computer Processing; Big Data Analytics; Artificial Intelligence (AI); Robotics; 3D Printing; Blockchain; Web3; Nanotechnology; Connectivity, Internet of Things (IoT), and 5G; Virtual Reality (VR) and Augmented Reality (AR).

2.2 New urban planning principles for the development of territories

Specialization of the region. An important place in the system of regional relations is occupied by the issues of identifying the branches of the established specialization of the region and justifying the direction of its effective specialization.

To determine the branches of specialization of the region, a system of theoretically grounded indicators, closely interrelated with other indicators of the territorial division of labor, should be used. Since the market specialization of the region is based on the territorial division of social labor, the definition of specialized industries should be based on the identification of the region's participation in the social division of labor [13].

Natural resource potential is an important structural element of the geographical environment. An important condition in rationalizing the use of natural resource potential is to determine the economic valuation of natural resources and natural services. The geographic environment performs three main functions: provision of natural resources; assimilation of waste and pollution; providing people with natural services, such as recreation, aesthetic pleasure, etc.

Among the available approaches to determining the economic value of natural resources and natural services, which allow us to obtain a specific assessment, we can distinguish those based on: a) market valuation; b) rent; c) cost approach; d) alternative value; e) total economic value (cost).

In order to rationally place the products of each branch of production on the territory of the country, taking into account the raw material resources available in the regions, the existing system of transportation communications, ensuring the integrated development of

productive forces within economic production, the inter-sectoral balance of the region is used [14].

Learning from the experience of war. Global knowledge and experience of specialists will need to be directed taking into account the following main aspects [15]:

1 - Planning the directions of the main and adjacent roads / highways and bridges, which on the one hand will provide for heavy traffic in the cities of the future, and on the other, if necessary, will provide for the possibility of protecting cities from the aggression of the neighboring state and the safe supply of humanitarian aid and intensive evacuation of a large number of citizens. creation of bypass roads near overpasses, entrances to rivers in order to create crossings, etc.

2 - Development of road infrastructure - without direct wide avenues. The construction of wide highways, where the road is a continuous platform for military equipment, should be limited. Instead, we should give preference to the principle of multimodality. Where one lane is for private transport, the other for public transport, as well as a tram line, bicycle paths and pedestrian zones on both sides. All of this should be divided into zones by means of landscaping, curbs, relief differences, or fences. This makes the city simply unsuitable for the movement of military equipment and combat operations.

3 - Design of military structures for defensive purposes in possible areas of military aggression.

4 - Zoning of cities should provide for a separate location of military and industrial infrastructure enterprises: military units, military warehouses and storage facilities, oil storage facilities, energy and municipal infrastructure facilities, chemical enterprises and other objects – targets of possible priority enemy bombing. Identifying such sectors will help reduce the impact and harmful impact on the civilian population of these cities in the event of an attack.

5 - Foresight of Civil Defense engineering measures for a peaceful and special period, design of Housing and other public and social facilities, taking into account the experience of construction in countries that are under constant threat (civil protection shelters, residential buildings protected from progressive destruction, etc.).

6 - Release small rivers from collectors. Rivers are natural obstacles to the enemy's path. We need to change the approach to the life of small rivers - not to ignore them, but, on the contrary, to make them more full-flowing so that wetlands can develop next to them. This is important both for increasing the recreation area for people and for the sustainability of the ecological system. And, as it turned out, it is important for defense. So, open rivers are a kind of fortification, a natural defense.

New Urbanism. The restoration of territories and settlements should be carried out taking into account the principles of New Urbanism. New Urbanism is a form of sustainable urban development that creates inclusive, walkable communities while reducing dependence on cars. It is intended to create livable, walkable communities that reduce dependence on cars and promote a more sustainable lifestyle. By combining residential, commercial, and recreational spaces nearby, New Urbanism aims to create vibrant, sustainable neighborhoods that prioritize human needs and environmental preservation [16]. New Urbanism is a movement of practices and principles that promote walkable, mixed-use, diverse, and highly dense neighborhoods. The goal of New Urbanism design is to create places where communities can meet and interact in public spaces or on the street. Through reduced car use, walking and cycling to destinations can foster interaction while reducing negative environmental and traffic effects [17].

We want to learn from the war to make our lives better. According to Jan Gehl [18], cities are designed for life, not war. The new urbanism should inspire planners and designers to implement smart growth policies throughout Ukraine.

2.3 New types of buildings, providing safety, accessibility, energy efficiency

Safety. Now we will have the opportunity to abandon our past habits and design based on the European approach to architecture and the basics of urbanism. This means, first of all, a comfortable environment for human activity.

After the war, Ukraine will revise the principles of designing residential buildings based on the experience of the war [19]. The security function may become a key one in the new Ukrainian architecture. It is not only about basic bomb shelters that should be comfortable, but also about rethinking construction technologies that would ensure greater resilience of buildings.

Provide homes with apartment or collective shelters. This requirement has become mandatory for design and new construction.

Provide a room with two walls in the apartment. During shelling, Ukrainians are advised to use the "two walls" rule. The first wall should take the brunt of the explosion, and the second wall should take shell fragments, broken glass, or pieces of furniture.

Design escape ladders without going outside. It is necessary to make the basic staircase H4 – these are smoke-free stairs that are placed in the body of the building. Such stairs are more technologically advanced and more expensive.

Ensure the reliability and stability of buildings. Experience shows that the most reliable buildings are those with a monolithic reinforced concrete frame. Then Panel prefabricated buildings. And the least reliable are brick buildings.

Establish mandatory standards for performing safe glazing. The glass should be in triplex − these are several layers of glass glued together with a film. So, when the glass breaks, it freezes. Or there is another option for safe glazing – tempered glass. When tempered glass breaks, it does not break into sharp pieces, but into cubes that are less traumatic.

Limit the height of buildings. It is worth designing houses of medium storeys – up to 6 floors. This is the optimal acidity for a comfortable density of living in an urban environment and the ability to evacuate. Dutch urbanist Jan Gehl says that it is necessary to design up to 6 floors. It is believed that average vision capabilities provide for recognizing a person from a height up to and including the 6th floor. Psychologists believe that this is important. Because if you live higher up, you are disconnected from the life around the House. The more communication between residents, the more cohesive the society. This communication and cohesion should be facilitated by the architecture itself.

More compact buildings. If a missile hits a yard, the houses surrounding it are damaged. At the same time, the next ones remain intact. Thus, the houses are a cushioning of the explosion for each other. And there is a chance that more buildings will survive. Therefore, the distances between the houses will be reduced, the yards will have a square of about 40 by 40 meters, according to the European model.

Accessibility. The next thing we need to consider in urban planning and architectural design is accessibility for people with limited mobility. In the civilized world, the health of a society or the face of a state is primarily determined by the attitude towards people with disabilities and those in need of assistance. According to the World Health Organization, about 10% of Ukraine's population has a disability [20]. By the end of the war, this number will increase significantly. The realization of their rights is impossible until a real barrier-free space is created in Ukraine.

When we talk about ensuring accessibility, we mean access to: public and civil facilities; amenity facilities; transport infrastructure and transportation; road services, information and communication. Universal design can help solve these problems [21].

Universal design in architecture, provision of services or information, and development of modern technologies take into account seven principles to the maximum extent possible: equality and accessibility of use; flexibility of use; simplicity and intuitiveness of use;

accessibly presented information; tolerance for errors; low physical effort; availability of the required size, place, and space.

Energy efficiency. Buildings are the largest source of energy consumption and the construction sector is fundamental to reducing carbon emissions. Therefore, when reconstructing and constructing new buildings, it is necessary to focus on modern standards of energy efficiency of buildings. Energy efficiency classification of buildings in Europe by specific energy consumption, kW/(m^2 year): ordinary – 161-300, standart – 101-160, with redused consumption – 61-100, with low consumption – 36-60, with ultralow consumption – 16-35, passive < 15, zero consumption (Zero energy building - ZEB) – 0, energy plus – generates energy.

To stimulate the market to innovate and adapt to low carbon technologies, measures to promote zero energy building (ZEB) and zero carbon building (ZCB) projects are useful.

2.4 Industrial (factory-made) architectural-constructive-technological systems of buildings

To ensure high rates of construction, it is necessary to use industrial, i.e. factory-made architectural, structural and technological systems (an Industrialised Building System (IBS) [22]). At one time, such systems were widely used in Ukraine and largely provided a solution to the housing problem in the post-war (after World War II) reconstruction. Today, such systems are used in Europe, America, China, etc.

Industrialization technologies introduce production processes that can simplify production, increase labor productivity, and reduce production costs to make the final construction products in the form of buildings and structures affordable for the vast majority of people.

Overall, there is no single best building system in the world, and there are many variants of industrial systems. IBS types are emerging from five main categories of task distribution between the factory and the site: prefabricated 3D modules, kit-of-parts for assembly on the construction site, hybrid or combined kit-of-parts and 3D modules, and precast - monolithic systems, 3D printing system.

Given the need to ensure the stability and durability of building structures in the face of military operations, high construction rates, and a reduction in the cost of construction products, we believe that prefabricated-monolithic architectural, structural, and technological systems should be preferred.

We have developed and implemented the following architectural, structural and technological systems of industrial production in Ukraine: a system of construction from small-sized elements, a system of construction with prefabricated - monolithic flat floors and prefabricated columns for 2-3 floors, a system of factory production of structural elements by 3D printing. These systems can be used for both low-rise and high-rise buildings, civil defense and military facilities, and have high technical and economic performance.

2.5 Creation of a network of distributed small industrial productions

Localization. There are several types of localization (location) of manufacturing enterprises: centralized, decentralized and distributed. In the past, Ukraine mostly used a centralized production system with concentrated capacities. The concentration of production that was used in the twentieth century is giving way to distributed schemes of capacity allocation.

This approach is also appropriate when locating IBS production facilities close to large-scale destruction sites and construction or reconstruction sites of damaged buildings and structures. This will significantly reduce the cost of the transportation component of the production cost. The proximity to the sites of large-scale destruction will allow us to use the

materials of destroyed buildings using recycling technology to reuse them as aggregates for concrete.

Cluster development. It is advisable to create such manufacturing enterprises on the basis of innovative cluster development. A cluster is a sectoral, territorial, and voluntary association of organizations that closely cooperate with each other and other entities in the value chain to increase the competitiveness of their products and exports, reduce transaction and economic costs, and promote economic development in the region.

In 2020, the Industry4Ukraine Platform presented the draft National Cluster Development Program until 2027 [28]. The document argued for the need to accelerate cluster development, outlined the main principles and benchmarks for development until 2025, and contains a number of recommendations for executive authorities at the national and regional levels, as well as for cluster leaders.

Given that the agricultural sector of Ukraine's economy is one of the leading sectors, it is advisable to create agricultural and construction clusters in rural areas. Sustainable development of rural areas is characterized by the development of various sectors of the economy with the following types of integral clusters: construction and agriculture; construction, processing industry and agriculture, rural tourism; construction, processing industry and agriculture; construction, recreation and health industry, and agriculture.

The most important feature of clusters is that they stimulate innovation. The concentration of companies in an industry within a single region promotes the spread of tacit knowledge. This is the effect of the enriched information environment that emerges in clusters. That is why the innovation economy exists only in the form of clusters.

Clusters are the first step in a long process of replacing market-based economic mechanisms (which are resource-intensive and often prone to crises) with a new type of economic mechanism − econocenosis. Just as in the wild, animals, plants and microorganisms that make up a biocenosis (an interconnected community living together) are fundamentally interdependent and cannot survive without each other, so in an econocenosis, enterprises form a viable structure only together − but such a structure is incredibly stable and flexible in relation to any external influences.

High-tech socio-ecological complexes can be a form of organization of agricultural and construction clusters. The term “high-tech socio-ecological complex” refers to a created living environment in which human scientific, educational, and production activities are safely and harmoniously integrated into the natural environment in a way that supports free, healthy, comprehensive human development, is responsible for future generations, and can be successfully sustained indefinitely.

The socio-ecological complex creates conditions for solving environmental, economic, social and cultural problems of society, being the basic model of sustainable development of the ecosystem, including humans, nature and society. The main idea behind the creation of an eco-complex is to create a habitat in which comprehensive human development and personal freedom are achieved through organizing life in harmony with nature, with oneself and the people around one.

2.6 Distributed energy systems using renewable energy sources

Before the full-scale war, Ukraine's energy system was largely dependent on fossil and nuclear fuels. The electricity sector is highly concentrated. Electricity markets consist of dominant national actors in the production of electricity from coal (privately owned DTEK), hydro resources (state-owned Ukrhydroenergo), and a nuclear monopoly (state-owned Energoatom).

To ensure energy security, it is necessary to develop distributed energy. The range of technologies used for distributed generation described by the International Energy Agency

(2002) includes: reciprocating engines, gas turbines, microturbines, fuel cells, renewable sources [24]. The main drivers listed in the literature are summarized below: transmission and distribution costs; rural electrification; energy efficiency; security and reliability; environmental impact.

The strategic goals in the energy sector for these years are, in particular, to support the "green" transition and promote an increase in the share of renewable energy, which should be accompanied by increased decentralization of the energy system and simultaneously improve energy security and resilience of the energy system [4].

In October 2021, the Ministry of Energy of Ukraine announced that it is developing a new system to support small-scale generation, which will replace the current feed-in tariff program and stimulate further development of renewable energy sources in Ukraine. Earlier, the State Agency on Energy Efficiency and Energy Saving presented the concept of introducing two new mechanisms - Net Billing and Net Metering [25].

Net Metering is a system whereby a household uses the generated energy from alternative sources for its own consumption and transfers the surplus to the general grid. Then, when the amount of "clean" energy is less than the amount of consumption, the household takes it back from the grid. This is especially true at night or in winter, when the solar plant cannot generate enough electricity due to short daylight hours and cloudy weather.

Net Billing works according to the same scheme, where the generated energy is transmitted to the general grid, but for it, the producer of energy from renewable sources (prosumer) is returned not in kW, but in cash. Unlike the "green" tariff, this money cannot be cashed out - it accumulates on the balance sheet of the solar station owner. Therefore, when the generated energy is not enough to cover the household's consumption, the prosumer will be able to buy energy from the general grid for the money accumulated.

The new system of state support will apply only to new owners of solar power plants and will cover both private households and businesses. At the same time, the old feed-in tariff agreements will continue to be valid until 2030.

2.7 Recycling (reusing) materials of destroyed buildings and structures

Law of Ukraine "On waste management" dated June 20, 2022 No. 2320-IX provides for harmonization of the waste classification procedure with European requirements, given, in particular, in Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and European Commission decision 2000/532 / EC dated May 03, 2000, which approved the EU waste list [2].

The current EU waste list does not contain the types and types of waste that they are formed as a result of war. At the same time, the resolution of the Cabinet of Ministers of Ukraine from September 27, 2022 No. 1073 "On approval of the procedure for waste management, formed in connection with damage (destruction) of buildings and structures as a result of military operations, terrorist acts, sabotage or carrying out work to eliminate them amendments to certain resolutions of the Cabinet of Ministers of Ukraine" defines the list and types of such waste, as well as the procedure for handling them.

Today they are of particular importance scientific research aimed at creating favorable conditions for implementation effective directions and technologies for recycling war waste for their re-use usage.

In general, all construction waste consists of such products as: concrete and reinforced concrete, brick, metal, soil, sand contaminated with clay, sanitary ceramics, wood, glass, drywall, plastic, asphalt concrete. According to researchers, the mass content of 52% of construction waste is concrete and reinforced concrete, 32% – stone wall materials (bricks, wall blocks, foam and aerated concrete), 8% – asphalt and mortar waste, 4% - metal waste,

2% – wood waste and plastics, 1% − ceramic products (sanitary ceramics, ceramic tiles), 1% – drywall, glass and other waste.

The process of processing construction waste is quite expensive. According to calculations specialists in wear and tear, removal and processing of construction waste are in the following areas: on average, 80…100 USD per 1 m^3. However, it should be borne in mind that, in addition to the costs of processing them, you can make a profit in the form of secondary materials: crushed stone, scrap metal, small silicate screening, high-calorie organic raw materials. It is established that during the extraction of natural crushed stone, energy is consumed 8 times more than when you get it from crushed old concrete. Cost of concrete obtained from secondary crushed stone, 30% lower than concrete based on natural crushed stone. When using secondary crushed stone increases the physical and mechanical parameters of concrete, and cement consumption decrease. Crushed stone made of concrete scrap has an active surface, which contributes to the formation of a strong contact layer with cement stone.

Taking into account the experience of construction companies volume construction scrap after the demolition of one five-story four-entrance building is about 5 thousand tons. After processing construction scrap, the following percentage is mainly obtained materials: crushed stone, fractional concrete, granite screening approximately 70%; fragments of brick and stone approximately 25%; scrap metal approximately 5%. In the world practice, about 90% of construction waste is recycled and reuse.

3 Program composition

1. Assessment of the extent of destruction of social infrastructure in Ukraine as a result of the war with russia.

2. Analysis of the state of the industry of building products and structures for housing construction.

3. System engineering for diagnosing and assessing the local scale of destruction using robotic and IT technologies.

4. Methodology for diagnosing and assessing the technical condition of damaged buildings and structures.

5. Generalization and development of methods for restoring damaged buildings and structures to a non-emergency technical condition (overhaul, reinforcement, reconstruction).

5.1. Large panel residential buildings.

5.2. Frame residential buildings.

5.3. Large block residential buildings.

5.4. Brick residential buildings.

6. Technology and organization of dismantling of buildings and structures in emergency technical condition and completely destroyed.

7. Technological design of crushing and sorting lines.

7.1. Stationary crushing and sorting technological lines.

7.2. Mobile crushing and screening technological lines.

8. Substantiation of modern technologies for the production of concrete.

8.1. Development of compositions and study of the properties of heavy concrete from recycled and local materials.

8.2. Development of compositions and production technology of heat-insulating concrete.

8.3. Development of compositions and study of concrete properties for 3D printing technologies.

8.4. Design of mobile technological lines for concrete production.

8.5. Design of stationary concrete production lines.

8.6. Design of technological equipment for the method of zone injection for ground concrete products from local materials.

8.7. Design of technological equipment for 3D printing technologies.

9. Architectural, structural and technological systems (ASTS) of residential and public buildings of industrial production with safety, energy efficiency and barrier-free.

9.1. ACTS of large-sized elements.

9.2. ACTS of small-sized elements.

9.3. Automatic telephone exchanges using 3D printing technology.

9.4. ACTS from local materials.

9.5. ACTS of frame and wooden buildings.

10. Technological solutions for distributed production of industrial elements and structures of residential buildings.

10.1. Technology of production of large-sized elements.

10.2. Technology of production of small-sized elements.

10.3. Production technology using 3D printing.

10.4. Production technologies from local materials.

10.5. Production technologies for frame and wood construction.

11. Distributed energy systems for the production, transformation, storage and use of energy for the production process.

11.1. Technologies for the production of renewable electricity.

11.2. Technologies for the production of renewable thermal energy.

11.3. Technologies of energy transformation and storage.

11.4. Gray water recovery system.

12. Technical, economic and environmental indicators of housing production and construction technologies.

12.1. Technical, economic and environmental indicators of ACTS from large-sized elements.

12.2. Technical, economic and environmental indicators of ACTS from small-sized elements.

12.3. Technical, economic and environmental indicators of ACTS using 3D printing technology.

12.4. Technical, economic and environmental performance of ACTS from local materials.

12.5. Technical, economic and environmental indicators of the technology of frame and wood house building.

4 Stages of program implementation

1. Establishment of an International Fund for financing and controlling regenerative construction (restoration of destroyed) social infrastructure facilities in Ukraine.

2. Establishment of the “International Expert and Technical Center for Regenerative Construction” with the involvement of foreign and Ukrainian specialists for technical support of the Program.

3. Assessment of the amount of destruction of social infrastructure objects of a separate region or city of Ukraine as a result of the war.

4. Diagnosis and evaluation of the local scale of the destruction of social infrastructure objects by robotic and IT technologies for the selection of machines and mechanisms for the dismantling of destroyed objects.

5. Diagnostics and assessment of the technical condition of damaged buildings and structures for the development of capital repair technologies, strengthening, and reconstruction of structural elements of structures.

6. Development of detailed local programs for the restoration of destroyed social infrastructure facilities with the involvement of local authorities and territorial communities.

7. Development of detailed area plans (DPT) − urban planning documentation of the local level and land management documentation, which determines the planning organization and development of the territory.

8. Design of objects of housing and social infrastructure with the development of estimate documentation to determine the necessary amounts of financing.

9. Restoration of damaged buildings and structures in non-emergency technical condition (overhaul, strengthening, reconstruction).

10. Dismantling of buildings and structures that are in an emergency technical condition and completely destroyed.

11. Creation of distributed energy systems of production, transformation, storage and use of energy for the production process.

12. Construction of local technological lines for the production of industrial elements and building structures.

13. Determination of construction organizations for construction works.

14. Restorative construction (restoration of destroyed) objects of social infrastructure

5 Necessary equipment for the Program implementation

1. Equipment for diagnostics of building structures.

2. Equipment for repair and reinforcement of structures.

3. Equipment for dismantling of structures

4. Equipment for reinforcement extraction, crushing, screening, washing of recycled aggregates.

5. Laboratory equipment for the selection of compositions and research of concrete.

6. Equipment for concrete preparation.

7. Technological equipment for precast concrete with intelligent control systems.

8. Prefabricated production facilities.

9. Mobile power plants for energy generation, transformation, storage.

10. Computer equipment and software products for geospatial and volumetric design of buildings and structures, network and building engineering life support systems.

11. Geodetic equipment for georeferencing of buildings and structures on the ground.

12. Construction equipment for construction works.

Reconstruction of the country after the war will be a great challenge for our state in its history. The restoration of Ukraine is not the reconstruction of Ukraine to the pre-war state, it is a comprehensive transformation, a deep modernization of the country. That is why the construction industry of Ukraine should be the locomotive of innovative reconstruction of infrastructure facilities. The main criteria for evaluating this process will be the quality and speed of reconstruction. It is possible to achieve this through the introduction of modern construction methods using construction products of industrial (factory) manufacture in combination with the most modern design approaches based on BIM technologies.

6 Conclusions

Russia's large-scale armed aggression against Ukraine has resulted in massive destruction of residential and public buildings, infrastructure, and energy facilities. After the end of the war, Ukraine's destroyed and damaged infrastructure needs to be restored on a large scale. In Ukraine, the Government Plan for the Recovery of Ukraine has been developed. Ukraine's Recovery Plan is aimed at accelerating sustainable economic growth. But this Program outlines general approaches and directions for the recovery and development of Ukraine. There fore we are developed detailed Programs that contain organizational and technological

approaches to the implementation of restoration works. The Program are developed with consideration of modern threats to humanity and global development trends, new urban planning principles, new types of buildings, the need to industrialize construction, the need to create distributed production and energy systems, using technologies of recycling materials of destroyed buildings and structures. The composition and stages implementation of the Program have been developed. The equipment, machines and mechanisms required to carry out the work under the Program have been identified. The programs must to help local authorities, territorial communities in which housing and social infrastructure objects were damaged or destroyed as a result of russian armed aggression, to make decisions regarding the planning and implementation of restoration works and the development of territories.

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