ISSN 2522-4182

DOI: 10.32347/2522-4182.17.2025.131-140
UDC 624.04: 69.059.1:338.45:69

TECOREP TECHNOLOGY AND POSSIBILITIES OF ITS ADAPTATION FOR POST-WAR UKRAINE

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Abstract. The article examines modern technologies for dismantling high-rise buildings in the context of the transition of world megacities to the principles of a circular economy and increasing requirements for the environmental safety of construction processes. The article provides an extensive review of the history of the development of dismantling methods. Particular attention is paid to the innovative Japanese technology for internal dismantling of skyscrapers TECOREP (Taisei Ecological Reproduction System), developed by Taisei Corporation for the conditions of ultra-dense urban development. The method involves the gradual internal dismantling of floors using temporary metal supports and jacking systems, which ensures a controlled reduction in the height of the building without the use of external heavy equipment or blasting. The study analyzed the features of the technological process, the advantages of TECOREP in terms of reducing emissions, noise and dust, the possibility of recovering and reusing building materials, as well as the limitations associated with the geometry of facades and the structural system of buildings.

Separately, the potential for applying TECOREP technology in Ukraine in the context of post-war urban reconstruction, where a significant number of high-rise buildings were partially or completely destroyed as a result of hostilities, is considered. It has been shown that internal dismantling allows work to be carried out in dense buildings, minimizing the danger to the population, transport infrastructure, and buildings that have survived nearby. Given the scale of the destruction and the need to recycle millions of tons of construction waste, it is reasonable to believe that the introduction of such technologies will contribute to the formation of an environmentally friendly urban reconstruction system, reducing anthropogenic load, and developing the market for secondary construction materials.

The results of the study may be useful for specialists in the field of construction, urban planning, environmental engineering, and for government agencies dealing with issues of restoration and modernization of urban areas.

Keywords: demolition of buildings; TECOREP technology; recycling of materials; post-war reconstruction; energy efficiency of demolition; innovative construction technologies.

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PROBLEM STATEMENT

The problem of dismantling dilapidated or outdated high-rise buildings is becoming increasingly urgent for countries with rapid urban development.

Such structures, built in the 1960s–1990s, often no longer meet modern standards for earthquake resistance, energy efficiency, and safety. In addition, many cities around the world are faced with the need to update urban infrastructure, reconstruct old areas, and modernize the building stock [3].

In Ukraine, the problem of dismantling has gained particular importance due to the war. In 2022–2024 alone, hundreds of high-rise residential complexes in Mariupol, Kharkiv, Bakhmut, Irpen, Borodyanka, Chernihiv, and other cities were seriously damaged or destroyed. Some of these buildings are in a condition that makes it impossible to restore their load-bearing capacity. Traditional demolition methods are generally not suitable for dense construction conditions, especially where intact buildings remain next to the damaged structures [4].

Current trends in construction and demolition reflect the global economy's shift towards sustainability and circularity. The use of environmentally friendly, low-noise, and safe demolition methods is becoming not only desirable, but also economically viable. Japanese TECOREP technology is one of the most progressive in world practice, and its adaptation to Ukrainian conditions can play an important role in post-war reconstruction.

TRADITIONAL DEMOLITION METHODS

Usually, demolishing a building is almost as difficult as building it – especially if it is a skyscraper located in a densely built-up area. The standard method of destruction used by construction workers has always been to demolish a building using heavy machinery or a controlled explosion. Observers enjoyed the “spectacular” demolition of the 165-meter towers of the Mina Plaza complex in Abu Dhabi in 2020, which entered the Guinness Book of Records as the demolition of the tallest building using explosives, for a full 10 seconds. However, the time to lay 18,000 explosive charges on 144 floors and clear the area of construction debris and dust was over 2 months, with over a thousand specialists working simultaneously.

The most common methods of demolishing tall buildings include:

1. Controlled explosion (implosion). As a result of correct calculations, the building collapses inside its own perimeter. The method is fast, but environmentally and technologically problematic. First, it is an increased noise level. Second, it is a huge dust plume that affects the environment: a high concentration of harmful substances in the air, limited visibility, a layer of solid precipitation that will settle around the site for a long time. Thirdly, the destruction of a significant part of building materials, which makes their secondary use impossible. All these factors sometimes simply make it impossible to use in dense development.

2. Mechanical dismantling using heavy equipment. During the work, hydraulic shears, hydraulic hammers and excavators with extended booms are used. However, this method has a number of disadvantages. The main disadvantage is the duration of the work. Also, a significant amount of free space is required at the construction site. There is also a high risk of collapses, high noise levels, which as a result has a negative impact on the population of the surrounding area.

Such methods have been dominant for decades, but in a world where the quality of the urban environment is becoming increasingly important, they are gradually giving way to innovative technologies.

It should be borne in mind that modern cities are densely built up, and the buildings that need to be demolished are sometimes over 100 m high. Their demolition in the traditional way can lead to serious consequences. In addition, today the world is moving towards a circular economy, the main postulate of which is recycling. Therefore, there has been a trend when demolishing buildings not to destroy building materials, but to reuse them. In 2010-2020, many EU and Asian countries introduced construction waste management programs that encourage: reuse of materials, on-site waste sorting, reduction of construction

waste, reduction of emissions and energy consumption.

In this structure, dismantling ceases to be “demolition” and becomes a technological process of “dismantling,” that is, the controlled, careful removal of materials for reuse.

Therefore, the Japanese construction company Taisei Corporation from Tokyo has developed an unusual technology for the demolition of high-rise buildings, in which the destruction of the building occurs internally [1].

TECOREP technology meets the above requirements as much as possible.

GENERAL CHARACTERISTICS OF THE TECHNOLOGY

As the world's most populous capital, Tokyo currently has nearly 800 buildings over 100 meters tall. Under a modernization program to comply with Japanese building safety regulations, nearly a hundred of the oldest skyscrapers are to be demolished within 10 years [2]. The method, called Tecorep (Taisei Ecological Reproduction System), is relevant and looks very unusual - looking at a building being dismantled, a decrease in its overall height becomes noticeable over time.

The technology involves the preliminary dismantling of all interior elements and non-load-bearing structures. Compact special equipment and special metal structures are delivered to the skyscraper on its top floor. These metal “rods” are installed inside the building, playing the role of columns and giant jacks. Then the “hat” of the building (the upper floors and roof) is fixed on temporary columns. After that, special equipment begins to remove all the load-bearing walls and floors, thus destroying layer by layer. And the building itself “slides” down on metal scaffolding, decreasing by one upper floor. At the same time, workers calmly dismantle the walls from the inside in comfortable conditions even in bad weather, without fear of harming residents of neighboring houses and passersby. The roof and floor themselves are removed last.

The dismantled structures are lowered through internal elevators and shafts, from where they are removed from the construction site by dump trucks. It should be noted that when lowering materials down, energy is generated on the internal elevator, which is used to power the equipment and tools for dismantling work.

TECOREP technology provides full control over the dismantling process, minimizes environmental impact, reduces noise and dust levels outside, and, which is especially important for dense Tokyo, makes it possible to work in extremely cramped conditions.

What is the main difference in the dismantling technology offered by Taisei Corporation?

The technology includes several key structural components:

- internal metal columns-jacks. They are installed inside the building and temporarily replace its load-bearing elements for the period of dismantling;
- "hat" - a spatial protective module. It performs the functions of noise absorption, dust protection and wind load stabilizer;
- compact dismantling equipment: cutting units, hydraulic platforms, mobile manipulators;
- a floor lowering control system. Jacks synchronously lower the upper structure by one floor after the lower one is dismantled;
- a vertical logistics system. The use of internal elevators and shafts for material removal allows for energy savings through recovery.

ALGORITHM FOR PERFORMING WORK USING TECOREP TECHNOLOGY

Dismantling using the TECOREP system takes place in several stages, each of which is aimed at maximum safety and environmental friendliness.

At the preparatory stage, the building is completely disconnected from the engineering networks. Before the installation of the necessary equipment, a detailed inspection of the supporting structures is performed. "Light" dismantling of internal elements (partitions,

cladding, furniture, communications) is performed.

The second preparatory stage involves the installation of temporary metal columns. The columns are designed to withstand the load from the upper floors after the column-beam elements are dismantled.

At the third stage of preparatory work, a protective "hat" is installed, which is a key element. It absorbs wind loads, prevents the spread of dust, reduces the noise level for the environment, and provides comfortable conditions for workers even during heavy rainfall or wind.

Fig. 1 shows a visualization of dust distribution during dismantling with and without a “hat”.

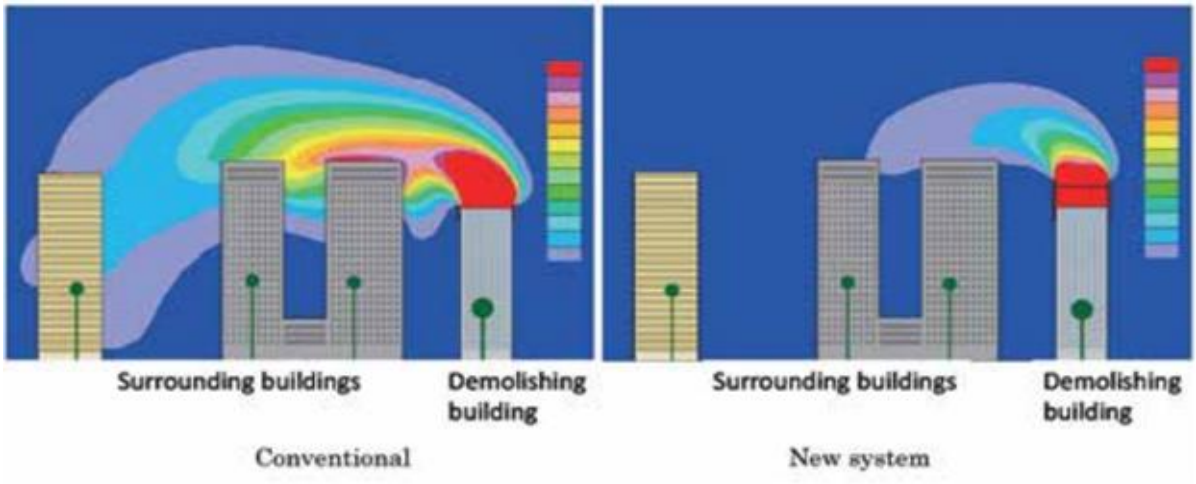

Fig. 1 Dust dispersion simulation (Source:Taisei Corporation)
Рис.1 Моделювання дисперсії пилу (Джерело: Taisei Corporation)

Materials and structures are sorted inside the building.

The main dismantling process is carried out in a sequence that corresponds to the structural features of the object, the condition of the main load-bearing walls. The most common sequence is “floor, columns, beams, shafts, etc.” After the floor is completely dismantled, the jacks synchronously lower the "hat" and the entire upper part of the building one floor down.

The cycle is repeated until the building is completely dismantled. The roof and the floor of the lower floor are dismantled last. A fragment of the roof dismantling is shown in Fig. 2.

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Fig. 2 The utilization of the existing roof structure (Source: Taisei Corporation)
Рис. 2 Використання наявної конструкції покрівлі (Джерело: Taisei Corporation)

This method of dismantling is quite quiet and environmentally friendly compared to traditional methods. Since all work is carried out in a closed space, the noise level outside is

significantly lower than with an open demolition method, and the proportion of dust particles in the air is reduced by 90% for the surrounding areas. In addition, the Tecorep method does not require the use of cranes and heavy equipment, which are known to greatly pollute the environment with harmful emissions. Taisei Corporation uses lifting equipment that allows for an 80% reduction in carbon dioxide emissions compared to cranes operating on traditional fuel.

This is the company's know-how, which is kept secret. And the building materials can be dismantled carefully, allowing them to be reused.

PRACTICAL APPLICATION: DISMANTLING THE GRAND PRINCE HOTEL AKASAKA

The method was tested during the demolition of the old 140-meter-high Grand Prince Hotel Akasaka back in 2013. The dismantling took over 9 months. Grand Prince Hotel Akasaka became the first building in the world to be dismantled using TECOREP technology. Main results:

- dust levels around the building decreased by 90%;
- CO_2 emissions - 80% less than when using traditional cranes;
- noise pollution - 17-23 dB lower;
- possibility of full sorting of materials;
- complete safety for surrounding buildings.

The project became a landmark example of "green" urbanism (Fig. 3).

Fig. 3 Work proceeding situation (Source:Taisei Corporation)
Рис. 3 Процес виконання робіт (Джерело: Taisei Corporation)

PROSPECTS FOR THE APPLICATION OF TECOREP TECHNOLOGY IN UKRAINE

Following Russia’s full-scale invasion of Ukraine, the scale of destruction of residential and public buildings has become unprecedented. According to the World Bank, more than 150,000 buildings have been destroyed or significantly damaged, including a significant number of high-rise buildings.

Particularly difficult cases include:

- partially destroyed 16–25-story buildings in Kharkiv and Mariupol;

- high-rise residential complexes with severely damaged load-bearing structures;
- buildings where only part of the facade is destroyed, but the core remains standing;
- buildings that pose a danger to the environment.

In many cities, the density of buildings does not allow for the use of explosive demolition methods, and the large-scale destruction makes it difficult to use heavy equipment.

That is why internal demolition technology, similar to TECOREP, can become a critically important tool in post-war reconstruction.

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Dismantling in a confined space with the installation of temporary columns allows you to work safely even when:

- the external facade is partially collapsed;
- the internal structures remain unstable;
- there is a risk of collapse under the influence of wind or vibrations.

In cities such as Kharkiv, Mykolaiv, Chernihiv, the buildings are built extremely close together. Heavy hydraulic shears simply cannot reach the facade.

During post-war reconstruction, it is important to preserve the health of the population and minimize noise, dust, and vibrations. TECOREP's "Hat" reduces dust by 90%, which is especially important for areas with damaged engineering networks and a lack of centralized medicine.

WHY TECOREP IS POTENTIALLY SUITABLE FOR UKRAINE

Military strikes often destroy only part of the structures, leaving other elements unstable. Ukraine will need millions of tons of construction materials. The TECOREP system allows you to store:

The TECOREP system allows you to store:

- metal structures;
- part of reinforced concrete;
- glass;
- interior elements.

This significantly reduces the cost and speed of reconstruction.

In conditions of electricity shortage, it is important to use low-consumption technologies. Energy recovery in elevators allows you to partially power the equipment.

Despite significant advantages, the application of TECOREP in Ukraine will require serious adaptation:

1. Damage to load-bearing structures due to war. In Japan, the technology is applied to undamaged buildings.
   In Ukraine, many buildings have:
   - missing parts of the facades;
   - damaged columns;
   - damaged core;
   - partially destroyed floors.

   This will require reinforcement or restoration of individual elements before dismantling.
2. Mining of buildings. Some of the destroyed buildings (especially in Mariupol) may contain unexploded ordnance.
3. Heterogeneity of Soviet high-rise projects. Unlike Japanese skyscrapers with a flat cross-section, Soviet buildings often have a variable planning structure.

4. Climatic conditions. The technology must be adapted to severe frosts and large temperature drops.

TECOREP is more expensive than traditional methods, but for post-war Ukraine it can be economically advantageous in conditions of dense development of historical and office and representative centers, in areas of ecological reserves, and with large volumes of work on a city scale (economy in serial application).

CONCLUSIONS AND PROSPECTS FOR FURTHER RESEARCH

TECOREP technology is one of the most promising solutions in the field of safe dismantling of high-rise buildings and can be extremely useful for Ukraine, especially in the context of post-war reconstruction.

It allows you to work in dense buildings, ensure the safe dismantling of partially destroyed skyscrapers, minimize environmental impact, reuse some materials, and reduce energy consumption.

Given the scale of the destruction, Ukraine has the potential to become a global platform for the implementation of innovative dismantling and reconstruction technologies, shaping new standards of sustainable development.

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ТЕХНОЛОГІЯ TECOREP ТА МОЖЛИВОСТІ ЇЇ АДАПТАЦІЇ ДЛЯ ПОВОЄННОЇ УКРАЇНИ

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Анотація. У статті досліджено сучасні технології демонтажу висотних будівель у контексті переходу світових мегаполісів до принципів циркулярної економіки та підвищення вимог до екологічної безпеки будівельних процесів. У статті проведено розширений огляд історії розвитку методів демонтажу. Особливу увагу приділено інноваційній японській технології внутрішнього демонтажу хмарочосів **TECOREP (Taisei Ecological Reproduction System)**, розробленій компанією *Taisei Corporation* для умов надщільної міської забудови. Метод передбачає поступове внутрішнє розбирання поверхів із використанням металевих тимчасових опор та домкратних систем, що забезпечує контрольоване зменшення висоти будівлі без застосування зовнішньої важкої техніки чи вибухових робіт. У дослідженні проаналізовано особливості технологічного процесу, переваги TECOREP щодо зменшення викидів, шуму та пилу, можливості відновлення й повторного використання будівельних матеріалів, а також обмеження, пов'язані з геометрією фасадів і конструктивною системою споруд.

Окремо розглядається потенціал застосування технології TECOREP в Україні в умовах післявоєнного відновлення міст, де значна кількість висотних будівель була частково або повністю зруйнована внаслідок бойових дій. Показано, що внутрішній демонтаж дозволяє виконувати роботи у щільній забудові, мінімізуючи небезпеку для населення, транспортної інфраструктури та будівель, які збереглися поруч. Враховуючи масштаб руйнувань та необхідність переробки мільйонів тонн будівельного сміття, обґрунтовано, що впровадження подібних технологій сприятиме формуванню екологічно орієнтованої системи реконструкції міст, зниженню антропогенного навантаження й розвитку ринку вторинних будівельних матеріалів.

Результати дослідження можуть бути корисними для фахівців у галузі будівництва, урбаністики, екологічної інженерії та для органів державного управління, що займаються питаннями відновлення та модернізації міських територій.

Ключові слова: демонтаж будівель; технологія TECOREP; рециркуляція матеріалів; відновлення після війни; енергоефективність демонтажу; інноваційні будівельні технології.

Received: *October 2, 2025.*
Accepted: *November 30, 2025.*