21st International Conference Man and Working Environment
SEMSIE
Safety Engineering & Management – Science, Industry, Education

ORIGINAL SCIENTIFIC PAPER

DOI: 10.46793/SEMSIE25.209R

JASMINA RADOSAVLJEVIĆ[1]
ANA VUKADINOVIĆ[2]
NEMANJA PETROVIĆ[3]

[1,2]University of Niš,
Faculty of Occupational Safety, Serbia
[3]The Academy of Applied Technical and Preschool Studies, Serbia

[1]radosavljevic_jasmina@yahoo.com
[1]ana.vukadinovic@znrfak.ni.ac.rs
[2]nemanja.petrovic@akademijanis.edu.rs

DEMOLITION WORKS OF BUILDING STRUCTURES

Abstract: *Demolition is one of the most dangerous construction operations, which often results in fatal and/or severe injuries to construction workers. Risks of injury and death can be minimized if a demolition project is well-planned. This paper discusses the main hazards associated with demolition work, types of site investigations for buildings slated for demolition, hazardous substances that may be present during demolition, demolition methods, and potential on-site hazards that can occur during demolition, among other considerations.*

Keywords: demolition of buildings, demolition waste, demolition methods, construction site hazards

ORCID iDs:	Jasmina Radosavljević	https://orcid.org/0000-0001-8545-2265
	Ana Vukadinović	https://orcid.org/0000-0002-6228-1077
	Nemanja Petrović	https://orcid.org/0000-0003-4010-2311

INTRODUCTION

Demolition of construction structures is undertaken due to the need to clear space for the construction of a new building or to use the land for other purposes, for various economic, technical, safety, or environmental reasons. The deterioration of a building or the need to repurpose the area it occupies is a common reason for demolition, especially in developed urban environments. The need for demolition from an economic perspective arises when the value of the land exceeds the current value of the building located on it. In such cases, property owners choose to demolish the building and construct new structures that will be significantly more valuable than the demolished ones. In the event of natural disasters (earthquakes, strong winds, storms, etc.) or military actions in populated urban areas, buildings may be severely damaged or destroyed. In such cases, demolition and removal of structures becomes a top-priority and essential task in order to restore the area to a vital and functional state (Arizanović, 2022).

Demolition is one of the most dangerous construction operations because it often leads to fatalities and serious injuries among workers. However, if the demolition project is well-planned, the risks of injury and death can be minimized (Phil Hughes, Ed Ferrett, 2016).

The main hazards associated with demolition work include:

- Workers falling from height;
- materials falling from height;
- premature collapse of the structure being demolished;
- dust and fumes;
- clogging of dust drainage systems;
- issues arising from spilled fuels;
- manual handling;
- presence of asbestos and other hazardous substances;
- noise and vibrations from heavy machinery and equipment;
- fires and explosions due to the use of flammable and explosive substances;
- pneumatic drills and electric tools;
- dangers from electricity, gas, and water;
- tipping of machines and vehicles.

Before starting demolition work, it is necessary to make preparations and plans for the demolition of the structure. This involves compiling technical documentation, including the layout of the structure being demolished at the given location, information about the construction structures, floor plans of the ground floor, all upper floors, and the roof, data on hazardous materials, etc. The demolition plan should include: the demolition procedure, the movement route of the machinery, precautionary measures (such as fencing off the site, training workers, covering walkways, closing traffic and pedestrian paths, installing temporary support structures, installing catch platforms, etc.), structural stability at each demolition phase, and the plan for management and removal of demolition construction waste.

INVESTIGATION AND INSPECTION OF THE BUILDING BEFORE DEMOLITION

The owner of the buildings slated for demolition must provide the demolition contractor with access to conduct an investigation and inspection of the site and the structure prior to demolition. Before any work begins, a complete site investigation must be carried out by civil engineers to identify hazards and associated risks that could affect demolition workers as well as nearby residents or passers-by. According to the

Rulebook on the procedure for adopting the demolition program and its contents, the competent construction inspection authorities are responsible for preparing a program that includes a plan for removing the building or parts of the building, an operational plan, and a cost estimate for the demolition ("Official Gazette of the Republic of Serbia", No. 27/2015).

Site investigation for the structure to be demolished includes:

- the structural composition of the buildings to be demolished (including materials used, roofing, decay, the presence of cantilevered structures, and any general weaknesses), as well as structural details of neighbouring buildings;
- the previous use of the structures;
- soil bearing capacity, including the presence of groundwater;
- the need for possible temporary supports for both the building being demolished and the adjacent buildings;
- the potential for falling materials and people;
- the location of any machinery;
- the presence of asbestos, lead, or other hazardous or radioactive substances and any related health risks;
- environmental protection (dust, water pollution, and noise);
- the safety of passers-by and nearby residents;
- manual handling methods;
- the location of utility infrastructure (water, electricity, gas, sewage, power grid, etc.);
- the location of any underground basements, storage tanks, chimneys, balconies, or bunkers – especially if flammable or explosive substances were previously stored;
- access routes to the site;
- removal of construction waste from the demolition;
- the proximity of neighbouring buildings;
- the location of any public walkways near the building being demolished;
- the proposed demolition method.

Demolition works must be carried out in accordance with the standards prescribed by the Law on Occupational Safety and Health ("Official Gazette of the Republic of Serbia", No. 35/2023).

When drafting the demolition plan, temporary access roads, office space, fuel storage, and facilities for machinery maintenance on-site need to be considered.

The plans must include a procedure for the safe disposal of any hazardous or harmful substances found during the demolition process, in a manner that complies with the legally prescribed requirements.

BUILDING DEMOLITION

Building demolition is carried out by a team of experts specialized in the use of explosives in construction. The method used for this type of work depends on:

- the condition of the structure (whether the entire building is to be demolished at once, demolished in phases or sections, or only specific parts are to be removed);
- the characteristics of the site (whether there are infrastructural facilities and utility networks that must not be damaged during demolition, or if there are none present on the site).

Demolition also depends on:

- the surrounding environment that may be affected by demolition activities. There is a significant difference between demolishing in an urban setting (within a populated area) versus rural conditions (away from residential and public structures);
- the intended goal of the demolition. For example, whether the material from the demolished building is to be recycled and reused, or whether it will be treated as construction waste, etc.

Demolition methods are chosen based on: project and contractual conditions, site location, equipment availability, and environmental tolerance. The following demolition methods are commonly applied:

- Gradual (manual or mechanical) demolition;
- Controlled demolition through intentional collapse using explosives.

Gradual demolition is carried out using manual and mechanical tools. This type of demolition includes: manual demolition, demolition by impact (such as a wrecking ball on a cable excavator, though this method is now rarely used), demolition by cutting (often combined with various types of cranes), and crushing demolition (crawler excavators equipped with specialized tools).

Manual demolition is a preliminary method used to gradually reduce the height of small structures (mostly houses). Tools used include electric or pneumatic hammers. Broken parts of the structure are dropped through a chute into a vehicle positioned next to the building, which then transports the waste away from the site. In addition, mechanical demolition (using an excavator or bulldozer) is employed, where the machine's working tools participate in a continuous demolition process, dismantling the building section by section. This method is also used for high-rise structures where machine access is not possible. These include tall, slender constructions (such as chimney stacks) and buildings higher than 20 stories. Mechanical demolition cannot be applied to these structures due to limited access or the reach of the machine's working arms.

Demolition by impact was once considered one of the most effective demolition methods (in addition to the use of explosives). Today, this method is mostly used for partially collapsed buildings that have deteriorated and begun collapsing on their own over time due to various external influences. Standard hydraulic excavators can be used for demolishing high-rise buildings where the use of explosives is not required. Using a so-called 'pusher arm' and a toothed attachment (plate, hook), the excavator applies horizontal force to bring down the walls, while cutting tools (hydraulic shears) are used to sever reinforcement

bars. Today, this method is no longer used globally due to insufficient control over swinging and inadequate safety.

Crushing demolition is currently the most widespread demolition method in the world. This method involves the use of a crawler excavator and hydraulic tools (arm) for crushing concrete and cutting steel. A pneumatic or vibrating hammer can also be attached as a working tool, which demolishes concrete and brick through its mechanical action.

Figure 1. *Gradual building demolition*

In a controlled intentional collapse, explosives are used to demolish the structure. During the explosion, large amounts of gaseous products are released, causing a sudden increase in pressure and temperature, with the explosive energy being converted into mechanical work. This technique should only be used by trained and competent persons. Demolition must be conducted with technical safety measures in place and only after careful selection of the type of explosive and calculation of the quantity, location, and arrangement of the explosive to be used, in order to minimize damage caused by the accompanying effects of the demolition (Phil Hughes, Ed Ferrett, 2016).

When explosives are used for demolition, it is necessary to establish an exclusion zone at a specified distance around the structure being demolished. All personnel, except the person detonating the explosive, must be outside the exclusion zone at the time of the explosion. This is the most dangerous demolition method, and everyone must be at a safe distance during the collapse. The exclusion zone includes the area of the structure's footprint, the projected fall area where most of the structure is intended to collapse, the expected debris area beyond the projected fall area, and a buffer zone between the debris area and the boundary of the exclusion zone.

The size of the exclusion zone is not only related to the height of the structure – it must also take into account other factors such as the impact of ground vibrations. The main factors influencing the design of the exclusion zone include the mechanism of the planned collapse, the materials used in the building's structure, the structural condition of the building, the site's topography, the proximity of surrounding structures, harmful effects of ground vibrations or accompanying shockwaves, noise, dust, etc.

Figure 2. *Building demolition using explosives*

BUILDING DEMOLITION HAZARDS

Premature structural collapse is one of the main causes of serious injuries arising from demolition work. A common reason for such incidents is the lack of effective planning before the start of demolition. Premature collapse usually begins with the structural failure of floors and is often caused by machines operating on floors that are not certified as safe and/or are not properly supported where necessary. It can also result from poor site supervision and a lack of instructions, training, and information for the workforce. This sometimes leads to workers or teams being unaware of the additional hazards created during the progression of the demolition works. A fully competent and trained workforce, fully familiar with the hazards associated with a particular site, is a prerequisite for successful completion of demolition. Worker safety on demolition sites can be compromised due to the following factors:

- Falls: falling through fragile and weak roofing materials, falling through openings or gaps (e.g. skylights, HVAC and plumbing openings), falling from open edges (e.g. staircases, platforms, scaffolding, and roof edges), falling from elevated work platforms (e.g. scissor lifts), equipment failure (e.g. lifting platforms), falling while accessing roofs or other elevated surfaces, falling down elevator shafts, floor collapses (e.g. concrete slabs and wooden planks), ground collapse above basements or pits, tripping over debris on the ground, etc.
- Hazards from impact, entrapment, or being struck by an object due to: falling debris (e.g. through installation and elevator shafts), accidental or uncontrolled structural collapse, use of machines and equipment (e.g. cranes lifting loads), failure of structural elements (e.g. steel support structures).
- Noise from machinery during demolition. Sources of noise and vibration on demolition sites typically include compressors, pneumatic tools, loaders, excavators, and explosives.
- Inhalation hazards from dust generated during demolition work.
- Presence of hazardous substances and their release during the demolition. Most hazardous substances pose a risk to demolition workers through inhalation, skin contact, or absorption through the skin. Some of the most common hazardous

substances that appear during demolition include:
  - Lead – most dangerous when airborne as vapor or dust (e.g. cutting steel structures coated with lead-based paint or dismantling tanks containing leaded gasoline, etc.).
  - Asbestos – should be removed wherever possible before any other demolition work begins. Asbestos may be found in sprayed coatings, thermal and acoustic insulation materials, fire-resistant walls/partitions, asbestos-cement panels, or flooring materials. Asbestos dust is particularly hazardous.
  - PCBs (polychlorinated biphenyls) – toxic substances found in electrical transformers, capacitors, and other electrical equipment previously used in industrial or chemical processes (MZŽS, 2023).
- Hazards related to machinery and equipment used on demolition sites are numerous. Only fully qualified personnel should operate machinery and equipment on such sites. Some of the hazards associated with machinery and equipment on demolition sites include machine failure due to exceeding its safe working load, accidental dropping of materials due to improper load securing, excessive noise and vibration from machines such as loaders and excavators, flying particles from pneumatic tools such as impact hammers, structural failures of steel frameworks, etc.
- On-site fires and explosions may occur due to hot work or the presence of chemical substances.
- Potential for premature building collapse.
- Damage to electrical installations.

CONCLUSION

Preventive safety measures must be implemented during demolition work on construction sites. These include designating traffic routes, walkways, and crossings for employees and work equipment, as well as establishing conditions for handling various materials. It is important to maintain work equipment and installations in proper working condition and to conduct both preventive and periodic inspections and testing of the equipment and electrical and lightning protection installations. All of this is aimed at ensuring safe and healthy working conditions on the construction site. Areas and locations for storing various materials, especially hazardous substances, must be planned and designated, and the conditions for removing used hazardous substances must be clearly defined.

Demolition of buildings is carried out using either the method of gradual demolition or controlled collapse with the use of explosives. The choice of demolition method depends on the project and contract conditions, the location, the availability of equipment, and the tolerance of the surrounding environment.

If explosives are used for demolition, it is necessary to establish an exclusion zone at a specified distance from and around the structure being demolished.

Before demolition begins, it is essential to obtain the plans of all infrastructure networks that supply the site, such as gas, electricity, sewage, and water.

For the disposal of demolition waste, a Demolition Waste Management Plan must be prepared in accordance with the Regulation on the manner and procedure for managing construction and demolition waste. Contracts must be signed with authorized operators for the transportation and further treatment of the waste.

It is in the public interest to recycle construction debris resulting from demolition, thereby reducing the need for raw materials from natural sources. The recycling of demolition waste can be divided into two phases. The first phase involves the sorting and storage of useful materials generated during demolition, such as glass, plastic, and bitumen. The second phase involves the processing of materials after demolition, which includes crushing, shredding, and cutting, as well as separating secondary raw materials, such as metal, plastics, and glass.

ACKNOWLEDGEMENTS

This paper is supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia pursuant to agreement № 451-03-137/2025-03/200148, Goal 11, with the University of Niš, Faculty of Occupational Safety.

REFERENCES

Arizanović Dragan, Dejan Beljaković, Predrag Petronijević,(2022). Tehnologija građevinskih radova – grubi građevinski radovi, Građevinski fakultet Beograd.

Arizanović Dragan (2022). Građevinski projekti – organizacija i realizacija, Građevinski fakultet Beograd.

Ministarstvo zaštite životne sredine (MZŽS) (2023). Analiza stanja otpada od građenja i rušenja i reciklažnog potencijala u građevinskom sektoru u Republici Srbiji, Axante.

Pravilnik o postupku donošenja i sadržini programa uklanjanja objekatas ("Sl. Glasnik RS", br. 27/2015).

Phil Hughes, Ed Ferrett, (2016). Introduction to Health and Safety in Construction, Taylor & Francis Group.

Phil Hughes, Ed Ferrett,(2007). Introduction to Health and Safety in Construction, Elsevier Ltd.

Richard J. Diven, Mark Shaurette (2010). Demolition: Practices, Technology, and Management, Purdue University Press.

Seonho Lee, Heeeun Chang, Jechan Lee (2024). Construction and demolition waste management and its impacts on the environment and human health: Moving forward sustainability enhancement, Sustainable Cities and Society, Volume 115, 2024, 105855, ISSN 2210-6707, https://doi.org/10.1016/j.scs.2024.105855.

Uredba o bezbednosti i zdravlju na radu na privremenim ili pokretnim gradilištima ("Sl. glasnik RS", br. 14/2009, 95/2010, 98/2018, 35/2023 - dr. zakon i 76/2024).

Zakon o bezbednosti i zdravlju na radu ("Sl. glasnik RS", br. 35/2023)