



# Technical safety considerations for construction sites

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## ABSTRACT

**Purpose:** The article introduces the issue of technical safety, characterises selected activities that create hazards on construction sites and suggests ways to eliminate them.

**Findings:** Knowledge of reliability is essential to carry out construction works. The need for the structural engineer to consider safety issues and the obligation to have a general knowledge of safety and technical safety arises. Knowledge of technical safety allows for the proper execution of works on site.

**Research limitations/implications:** The level of safety on a construction site depends on many factors, and a significant group of these are technical factors that determine the possibility of adverse events occurring.

**Practical implications:** Safety is defined as a state that provides a sense of certainty and a guarantee that it will be maintained and an opportunity for improvement. The level of safety on a construction site depends on many factors, and a significant group of these are technical factors that determine the possibility of adverse events occurring. The possibility of adverse events occurring is called unreliability. It is the opposite concept of the reliability, which is more commonly used in the construction industry.

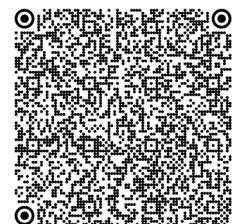
**Originality/value:** A useful tool for ensuring technical safety on construction sites is the Health and Safety Plan or HSE Plan, and the Instructions for the Safe Execution of Work - IBWR instructions. Those documents are intended to protect the health and lives of workers by providing information on how to prevent hazards associated with the execution of certain construction work and how to deal with them should they occur.

**Keywords:** Complementary roles of developed and developing nations in promoting a global industrial and economical infrastructure and requirements on common international research and teaching development in the field of safety, Technical safety, Hazards characterises

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## EDUCATION AND RESEARCH TRENDS



## 1. Introduction

Technical safety refers to the development, improvement and dissemination of methods and measures aimed at rationally maximising the effectiveness of the protection of people and the environment. It includes countering the emergence of security threats, preparing the security system and actors for the occurrence of threats and responding to the negative effects of these threats [1-5].

Security threats can be natural, civilisational and public.

Technical safety is related to the concept of technical safety engineering, oriented towards the design, construction, operation and decommissioning of technical facilities in the context of minimising the possible negative impacts caused by them. Technical safety engineering considerations point out that the manufacturer is responsible for the compliance of the technical facility with the requirements. The user, in turn, is responsible for the proper operation and maintenance of the design features of the technical object. Practical technical safety measures in construction are based on documents of a legal nature, which are transferred to the level of any organisation and are the basis for the creation of internal documents in individual entities [6].

According to the Labour Code [7], machinery and other technical equipment should be designed and built so that: ensure safe and hygienic working conditions, in particular protecting the worker from accidents, the effects of hazardous chemicals, electric shock, noise, vibration, radiation and other working environment factors; take ergonomic principles into account.

Machinery that does not meet these conditions should be secured with appropriate safeguards, often dependent on local brewers. This obligation rests with the site management. It is not permissible to equip work sites with machinery and technical equipment which does not meet legal requirements.

The underlying issue, however, is that there may be a gap between the professed values in the organisation and the assumptions in the legal documents [8].

Among the documents relevant to the construction industry, one can mention the Building Law and the Labour Code [7], which take into account, among other things, fire safety, hygiene, health and environment or the safe use of facilities. The possibility of maintaining proper technical conditions, health and safety conditions and conditions for the safe use of facilities are indicated. Detailed technical safety issues are also included in the regulations of the Minister of Infrastructure [9] and the one of the Minister of Infrastructure of 12 April 2002 on technical conditions to be met by buildings and their location [10].

Machinery and equipment should operate without failure for a specified period under specified conditions. The ability to perform the designated function continuously is captured as reliability [11]. In turn, the ability of machinery, its components or equipment to perform the required function under specified conditions and time and without damage is formulated as non-failure [12]. Reliability can be considered technical, techno-economic or global, incorporating the techno-economic and sociological elements of objects [13]. In turn, the probability of restoring an object's performance within a defined time is referred to as reparability (described by specific measures [14]). The reliability aspect of equipment plays a vital role in purchasing decisions. A guide to life cycle estimation related to the reliability of machinery and equipment can be the standard EN 6030040 [1].

Measures to ensure safe work include appropriate layout and design of work premises, improvement of production processes, provision of technical safety, e.g. guards on machines, use of protective clothing and personal protective equipment, and training in safe working methods [15].

## 2. Selected activities posing hazards at construction sites

There are some universal activities on construction sites, such as the transport of raw materials, materials and products, the use of work machinery, material handling, or work in confined spaces, such as tanks or at height, which involve classic – typical but still underestimated – risks.

### 2.1. Transport

The management of every construction site should aim to eliminate the manual handling of construction materials by using appropriate technical and organisational solutions and introducing mechanised transport on construction sites. One of the most common pieces of equipment encountered on construction sites, potentially a source of many hazards, is equipment for so-called handling, horizontal and vertical transport.

Internal transport refers to the transport of materials, building structures, etc., within the construction site itself, i.e. from the construction storage areas located on the site to the places where the construction work is carried out [16-18]. The correct solution for wheeled transport, both in terms of roads and the selection of the right means of transportation, is of great importance for construction economics. The requirements for transport are defined by specific regulations. Even though the applied regulations define in quite a detailed way the conditions of performing

work on the construction sites in a safe manner when using machines and transport equipment, they do not take into account the specifics of individual construction sites, which should be taken into account by the site management when preparing the design of technology and organisation of works. It is recommended to eliminate internal horizontal transport by introducing the so-called "assembly from the wheels", which consists in unloading the building material directly from the external means of transport to the place of assembly, bypassing the storage yards. If this is impossible, wheel transport should be designed for the construction sites. Circular transport should be carried out in compliance with the road traffic regulations on public roads, taking into account the particular circumstances of the construction site. Traffic routes, pedestrian crossings and fire bridges must be maintained in such a way that there are no hazards for users, and vehicle traffic must be organised in such a way that there are no collisions.

## 2.2. Working machinery

Construction sites often operate machinery and technical equipment known as 'working machinery', including:

earthmoving machinery: excavators, bulldozers, loaders, graders, dredgers, pile drivers, hammers, drills and specialised equipment;

machinery for roadworks: machine combinations for the production of bituminous mixtures and their paving, road milling machines, hand-held impact tools, vibratory compactors and rammers, road rollers, mechanical saws, mechanical snowblowers;

vertical transport machinery: tower cranes, goods and passenger cranes, goods and passenger platforms; miscellaneous machinery and other technical equipment, e.g. formwork, scaffolding, etc.

Machinery and safety components should be subject to the requirements of the MD/Regulation [19]. The directive is not directly applicable in Polish law but has been

transposed into Polish law by legal acts and implementing regulations [9, 20-34].

In order to operate the above-mentioned machines, an additional qualification (operator's certificate) is required, which is obtained after completing specialised training and passing a test [31]. At the same time, it is crucial to remember that construction workers are exposed to different risks when working on various construction sites.

Examples of hazards from work machinery on construction sites are given in Table 1, and basic safety rules for the operation of work machinery are shown in Table 2.

## 2.3. Storage of materials and media

Materials and other items known as building 'materials' should be stored in areas and premises designated for this purpose. Among building materials, there are hazardous materials. As defined by the regulations, hazardous materials are chemical substances and preparations that pose a risk to health or life, including to workers. It is incumbent on construction site managers to inform employees about the properties of the substances and preparations used in the work process, the extent to which they are harmful to the health of employees and the rules of conduct in emergencies. The basic principles for ensuring the safety of workers in the storage of materials and media are presented in Table 3, while the principles for handling hazardous substances are presented in Table 4.

## 2.4. Material processing

Construction sites may contain machinery and equipment for woodworking, such as circular saws, drills, lathes or grinders, and metalworking, such as shears, welding machines, cutting machines or grinders. Machining machines can be operated by individual workers and also used as equipment for carpentry, or armouries.

Table 1.

Examples of hazards from working machinery on construction sites [35]

No.	Threat group	Type of hazard
1	When operating excavators, bulldozers	Injuries. Falls from bulldozers and excavators (bruises and injuries), Noise (hearing damage). Vibration (vibration sickness). Electrocution (work on overhead lines). Falling with the machine when working near excavations, slopes, inclines (severe injuries).
2	When operating construction equipment	Grasps. Pulls. Falls into pits and depressions. Electrocution. Slips and trips. Injuries associated with manual mechanical handling.

Table 2.  
Essential health and safety rules for operating work machinery [35]

No.	Risk area	Basic OSH principles
1	Operation	Exploitation of the machinery may only be carried out on a site with recognised geological and ground conditions. Whenever work commences, the person in charge of the workers must inform the workers of the rules for carrying out work safely and the warning signals adopted. Electrical or hydraulic lines connecting the work machine to the main supply must be protected against mechanical damage.
2	Service	When operating machinery, the safety conditions stipulated in the technical and operational documentation, operating instructions and stationary health and safety instructions must be observed. During breaks and after work, work machines must be secured to prevent them from being accidentally started by unauthorised persons.
3	Machine environment and workplace	In conditions of reduced visibility, the working area of the machine should be illuminated. In earthworks, it is not permitted to locate working machinery in the area of the soil wedge, as well as to use it on clay soils during heavy rain. It is not permissible for other works to be carried out simultaneously in the excavation area and for non-employees to be present. It is unacceptable for people to be within reach of the working machine booms.

Table 3.  
Basic principles for ensuring worker safety when storing materials and utilities on construction sites [35]

Lp.	Type of material	Basic OSH principles
1	All	Determine the space for each material to be stored in such a way that the permissible load on the ceilings and floors and the proper storage height are not exceeded by appropriately selecting the racks/platforms for the anticipated loads and displaying clear information on the permissible load on the ceilings and racks. How materials are stored must not create safety hazards for workers. When stacked, ensure that they are stable and can move freely between them. It is not permissible to store materials under power lines at a distance of less than: 2 m from low voltage lines, 5m from high voltage lines up to 15 kV, 10m from high voltage lines above 15 kV.
2	Powder	For bulk storage, an adequate area must be provided to maintain a natural chute angle or dam that can withstand the pressure of the bulk material. Workers are only permitted to ascend the heaps on platforms with the belay of another worker.
3	Dusting	They should be stored in a fence / sealed area with a height of at least 0.5m above the stored material and should only be moved by special transport means or in containers.
4	Prone to spontaneous combustion	They should be protected with ventilation chimneys to prevent the temperature from rising, and the heaps and piles should be redeposited frequently.
5	Liquid and gaseous	They should only be stored in specially adapted and labelled rooms or tanks where open flames and smoking are prohibited. These rooms should only be accessible to authorised persons. There should be effective ventilation on the premises. Periodic checks on the concentration of vapours and gases should be carried out on the premises.

Table 4.  
Basic principles of hazardous substance management [35]

No.	Type of material	Basic OSH principles
1	All	<p>Workers must be informed of the extent to which hazardous substances are harmful to health and how to use them safely and deal with them in an emergency.</p> <p>Detailed conditions for storage, handling and use should be set out in specific instructions available to workers.</p> <p>Hazardous materials must be stored in places and packaging designed for the purpose and appropriately labelled in Polish.</p> <p>During transport, storage and use of hazardous materials, workers should use appropriate collective and individual protection measures to protect workers from their harmful effects.</p> <p>In rooms containing hazardous materials with a risk of fire, explosion or the release of toxic substances, there must be signalling devices, appropriate equipment and fire extinguishing agents, neutralising agents and collective and individual protection measures in accordance with the risks involved.</p> <p>Work processes that give rise to carcinogens, infectious biological agents and other factors that pose a risk to the health and life of workers should first be replaced by other processes in which these factors will not be present.</p>
2	Liquid	<p>Storage is permitted in fixed tanks that are protected against spillage and the spreading of the contents of the tank in the event of damage and unauthorised access.</p> <p>The deployment of tanks with liquid materials, hot liquids, and compressed (liquefied) gases is not permitted.</p>

Machinery used on construction sites causes risks of various types of injury to the operator and the workers in the vicinity of the working machine. Reducing these risks can be achieved by training workers to strictly adhere to occupational safety rules and focusing their attention on the activities being performed. Depending on the processing, workers are exposed to being caught, drawn in, struck, entangled, touched, the ejection of workpieces, electric shock or noise and vibration. There is an overlap in the basic rules of conduct when operating wood and metalworking machinery and technical equipment:

- equipped with clamping and pressing devices to protect workers from injury as a result of the accidental recoil or ejection of workpieces;
- ensuring effective protection against electric shock and implementing mechanical ventilation;
- the use of suitable protective devices e.g. guards, wherever there is a risk of contact between a worker and cutting tools, moving parts or workpieces;
- equipping machinery with braking devices to ensure the safe stopping of work units, especially in emergencies;
- equip and ensure that workers operating machinery wear headgear that completely covers their hair and work clothes without any frizz or loose hanging parts;
- equipping workers working in noise with hearing protectors.

## 2.5. Particularly hazardous work

There are a number of works on construction sites that pose particular risks to human health and life that are commonly regarded as hazardous such as:

- at energy facilities,
- performed at height,
- inside tanks, boilers, silos, process equipment, sub-dosing equipment,
- work that, because of its prevalence, is often not taken into account when planning individual jobs, e.g. work carried out with powered hand tools, work at height, work in tanks, earthwork (excavation, caving), welding, renovation/upgrading [36-38].

For particularly hazardous work, site managers should define the specific H&S requirements to be observed when carrying out such work [39,40].

### Work carried out with powered hand tools

Power tools are found on almost every construction site and are used for a variety of jobs. Depending on how they are used, a distinction can be made between power tools: those operated on an occasional basis, usually several times during a single working shift, which are returned to the rental shop; those frequently operated on a continuous basis over many working shifts; those installed permanently, such as in



carpentry shops or on-site armouries. These tools should be tested regularly to ensure that users are entirely safe from electric shock and mechanical injury. To this end, each worker using power tools should be familiar with the instructions for use as well as the requirements for testing, the deadlines for testing, the procedure to follow and the basic protective measures to ensure worker safety. The user, on the other hand, before starting work, should carry out an external visual inspection consisting mainly of checking that: the elements of the external casing and handles are not damaged (cracked, crushed, broken), the plug is not damaged (cracked, burnt, pins not deformed), the connection cable is effectively secured against pulling out of the plug, and there is no damaged insulation (cut, crushed, burnt), the control elements, handles (buttons), covers are not loosened and damaged [41,42].

#### Work at height

The term "work at height" means work performed on scaffolding, platforms, fixed galleries, poles, masts and other elevations at least 1.0 m above the ground or floor level. However, work does not count as the one at a height if it is performed on a surface which is enclosed on all sides up to a height of 1.5 m by solid walls, tyres, and windows or is equipped with other fixed structures or devices to protect workers against falls from a height [7].

Fall hazards can occur at:

- the erection of building structures, during the installation of columns, ceilings, walls and roofs,
- installation of staircase runs and spandrels, landings and balconies and also during the installation and removal of guard rails and balustrades,
- carrying out façade work from scaffolding and work platforms,
- when working in areas where there is the possibility of various objects, tools and building materials falling from above [3,4,35].

Workers may be allowed to work at height who:

- have received periodic and basic health and safety training, as well as job-specific training to familiarise them with the nature of work at height, the risks associated with their activities, the possible consequences of the risks and the main causes of accidents,
- have a current medical certificate that there are no contraindications to working at height,
- know how to use the personal protective equipment and safety devices assigned to them,
- can safely operate basic horizontal and vertical transport equipment, including the relevant qualification [43].

The specific requirements are contained in the regulations for work at the height [32,37, 43-49].

#### Tank work

Work in 'tanks' is understood as the one in tanks, canals, wells, manholes, inside technical equipment and other enclosed spaces where entry is through manholes or small openings or is otherwise obstructed.

Work in tanks, as particularly hazardous work, may only be carried out on the basis of a written permit issued in accordance with the procedures adopted on the site, with constant supervision. The person giving the work order should check that the organisational and technical arrangements ensure that the work is carried out safely.

When working in tanks, it is important to familiarise yourself with the regulations and rules for safe work [47,50,51] when starting to work in tanks.

#### Work in trenches and depressions

Excavation work is among the particularly hazardous work and may only be carried out after knowledge of: the category of soil in which it is to be carried out, existing underground utilities and the use of appropriate excavation protection. Otherwise, work in excavations and depressions may end in a serious, even fatal, accident due to buried soil in an unsecured excavation or electrocution due to the interruption (damage) of an underground electrical cable. Before starting excavation work, familiarise yourself with the legal requirements and rules in this area [3,9,32,38,47, 52-68].

#### Welding work

Welding work includes welding, surfacing, brazing welding, and thermal cutting of metals and plastics by a flame of combustible gases or an electric arc. Welding and cutting of metals may be performed only by persons with theoretical and practical training in welding (primary and secondary electrical or gas licences) confirmed by an examination or a document authorising them to perform welding work (welder's booklet). Welding and cutting metals should take place in specially prepared rooms, separated from other workplaces. If welding takes place outdoors, the work area should be protected from the weather and its surroundings protected from the harmful effects of an electric arc or flame. The requirements of the law should be read before welding [69-75].

#### Refurbishment/modernisation work

The Construction Law defines renovation as the performance in an existing building of construction works consisting of the restoration of the original state and not constituting ongoing maintenance, with construction products other than those used in the original state being permitted. An example of a renovation is, for example, the

restoration of a building's façade. Renovation, on the other hand, should be understood as all outlays connected with maintaining or restoring the usable value of a construction object – its original state, e.g. through repair or replacement of worn-out elements, as long as this does not change the character and function of a given object.

Energy equipment and installations or parts thereof on which repair or modernisation, or maintenance work will be carried out should be taken out of service, stripped of any hazardous factors and effectively protected before being put into operation and marked.

All work carried out on/or at power equipment, regardless of its extent, may only be carried out with the knowledge and consent of the supervisor in charge of operations. At each work site, a team leader should be designated in the team of workers.

When workers employed by different employers work at the same place at the same time, their employers are obliged to cooperate and appoint a coordinator to supervise the health and safety of all workers employed at the same place.

In order to prevent workers from being exposed to hazards during renovation or refurbishment work, it is necessary to follow the law and the principles of safe work [6,12,32, 39-40, 47,54,67,72, 76-78].

### 3. Summary

In order to ensure technical safety on construction sites, knowledge of the law and the principles of safe construction work is needed. All participants in the investment process: investor, designer, contractor and future user, each in his/her scope and area of operation (planning, execution and operation) should be aware of this. Lack of knowledge regarding technical safety can have tragic consequences when working on construction sites. In an era of rapid technological development, knowledge of technical safety in construction becomes an urgent issue, to say the least. A useful tool for ensuring technical safety on construction sites is the Health and Safety Plan, or HSE Plan, and the Instructions for the Safe Execution of Work – IBWR instructions. These documents are intended to protect the health and lives of workers by providing information on how to prevent hazards associated with the execution of certain construction work and how to deal with them should they occur.

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