

## COMPREHENSIVE EVALUATION OF THE WORK AT HEIGHT

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### Abstract

The article evaluates the issue of work at heights in industry and reports statistics on fatal accidents at work, the source of which is a fall from above. It also deals with the assessment of the state of personal protective equipment already in use - for example, safety and working ropes and other accessories contaminated with facade paints, lyes, acids or mineral oils and their misuse and dangerous use. The state of the assessed personal protective equipment used was assessed in a test facility on test machines, where the safety of these devices was verified under certain conditions. The article also mentions the issue of inadequate training and training of high-level workers and the lack of training centers that carry out such training.

**Keywords:** Safety, fatal work injuries, training

### 1 Introduction

Working at heights is one of the most dangerous work activities. Insufficient securing of workers at height can lead to fatal health consequences, most of which result in death.

The statistics of fatal work injuries, reported annually on the State Labor Inspectorate's website, show that falls from heights as cause of fatal work injuries are constantly being repeated.

In 2015, there were 20 fatal work injuries in the Czech Republic as a result of a fall from a height, and from the point of view of statistical evaluation of the sources, these injuries occupy second place, just behind traffic accidents. The serious situation is mainly in the construction sector, but the situation is not different in other branches of industry where work activities are carried out at heights and over the free depth.

The term industrial climbing and industrial climber, which is used, for example, in Germany or Austria, does not exist in Czech legislation. Only the term worker in heights is used and there is no difference, whether it is a worker working on a ladder at a height of 1.5 m, or a worker who works at a wind farm at a height of 40 m.

The term industrial climber is commonly used in the Czech Republic mainly by the professional public and only at this level is distinguished, whether work at heights is carried out with or without a foot support. Industrial climbing is used especially in cases where the character of work in heights and above the free depth requires frequent workplace changes both horizontally and vertically, when collective securing means such as technical barriers, scaffolding, or lifting platforms cannot be used.

The comprehensive protection of workers at heights means not only a flawless use of technical means of work to protect workers against falling from a height, but a part of it are also safe

methods and procedures for carrying out work activities, including professionally practiced theoretical training and quality training for these activities. Personal protective equipment are mainly safety harnesses, safety and working ropes, positioning belts, fall dampers, carabines, self-winding systems and other equipment, intended for individual worker protection.

The safety of workers on roofs, chimneys, industrial facilities and elevated areas can also be ensured by using vertical and horizontal systems and anchoring elements that are installed for this purpose to allow workers working at a height to connect to a fixed horizontal or vertical line through the attachment subsystem, i.e. a carbine, or to a movable rider on the rope, to ensure safe movement at risk locations.

## 2 The current state of the problem solved

Falls from heights, as mentioned in the previous paragraph, have caused a relatively large number of fatal work injuries in the Czech Republic for several years, especially in the construction sector.

According to the analysis of fatal accidents at work, which are based on the documents provided by the State Labor Inspection Authority in Opava and the Labor Safety Research Institute in Prague, it is clear that injuries caused by falls from heights have been at the forefront of labor accident statistics in the Czech Republic for several years now, just behind traffic accidents that rank first in statistics.

### 2.1 Overview and analysis of fatal work injuries in the years 2006 -2015

The following **Table 1** gives an overview of the total number of fatal work injuries (FWI) occurring in the Czech Republic in the period 2006 - 2016, including data on fatalities that occurred in the construction sector and data on the number of accidents due to the fall from heights in the department Construction with their percentage expression. Falls from heights in years 2007 - 2015 according to the reason for FWI (see **Table 2**).

**Table 1** Number of fatal work injuries - falls from heights in the construction sector including % evaluation

Year	Total FWI	Construction FWI	Falls from heights	%
2006	156	34	14	41
2007	192	36	21	58
2008	192	44	27	61
2009	128	16	11	69
2010	137	29	18	62
2011	139	25	11	44
2012	105	29	18	62
2013	109	9	1	11
2014	106	16	14	88
2015	122	19	8	42
2016 3/4	98	13	8	62

Note: The figure for the total number of FWIs for 2016 is not yet complete. Data does not contain FWI at workplaces supervised by the Mining Authority. Source: own processing

**Table 2** Falls from heights in years 2007 - 2015 according to the reason for FWI

Year	Fall from roof and from heights	Fall from the ladder	Drop into the depths	Fall from scaffolding	Other
2007	17	2	9	6	7
2008	18	2	14	5	2
2009	12	3	5	6	3
2010	9	1	5	2	4
2011	7	0	4	6	3
2012	10	2	3	1	2
2013	10	1	5	2	9
2014	7	0	5	2	7
2015	3	2	4	4	7
<b>Total</b>	<b>93</b>	<b>13</b>	<b>54</b>	<b>34</b>	<b>44</b>

## 2.2 Current situation in practice

Collective protection of workers at heights, according to the current regulations issued in the EU and in the Czech Republic, has priority over individual protection. This method of securing is solved in addition to NV 362/2005 Sb. also by technical standards that contain more detailed safety requirements for these collective technical devices, protecting workers from falling from a height. In Czech Republic, workers in the industry use for work activities at heights, more and more often, the rope technique belonging to the group of personal protection measures. The reason for using this protection is the short duration of work at heights, a small number of workers working in the workplace, so it is often not worthwhile to build a scaffold for such operations. However, the use of this technique requires the knowledge of the safe use of individual protective equipment with accessories, the learning of the correct technique of climbing with the condition of passing training under the guidance of experienced instructors, as well as the basic knowledge of the physical laws related to the activity, such as free fall or pendular movement. The state of the art regarding the theoretical and practical training of workers at heights varies from one organization to another, depending on who performs training and climbing practice and where the training is done. In the case of self-employed persons, the situation is much worse, the state of training and practice is in most cases only formal, often training is not practiced at all, only training and testing. Training is often provided by people who are not climbing technique instructors because the requirement for trainers' expertise is nowhere listed in the legislation, and anyone who has theoretical and practical experience with this work activity is allowed to train the staff. Support for the theoretical and practical training of this work is inadequate, there are no legally-supported rules or procedures and instructions on how to perform this activity safely in order to avoid misinterpretations and misunderstood work practices, which may result in an accident at work. Industrial workers also lack literature and methodology with a uniform curriculum for specific occupational activities in industry and support materials for trainers, or training centers to serve as theoretical training and training of workers at heights.

The regulations also lack the conditions and information for determining, for example, the length and extent of the training, the conditions under which the instructor can perform the training and the qualification he or she must have, or who can approve or authorize these conditions.

"There is no doubt that training, particularly task-specific, is extremely important as an attempt to reduce human failures"

The safety of workers at heights and above the free depth can affect the sum of various factors that, as a whole, but also individually can cause workers' accidents when working at a height. The lack of polygons with simulated workplaces where theoretical and practical training of workers at altitudes takes place and the different ways of carrying out theoretical and practical training by individual legal and physical persons may have a certain share in the lack of expertise of a trained worker. The issue of evidence of attendance at training after two to three hours of theoretical and practical training serves practically only for the purpose of fulfilling the requirement of a legislative act, i.e. to allow workers to obtain permission to carry out work at height. The choice of workers themselves is limited only to the criterion of whether or not is a worker afraid of height. (Government Regulation No. 362/2005 Coll. o Providing workers at work at heights and above free depth).

The non-use, or unsuitable and uncontrolled use of personal protective work tools for work at heights may have an additional impact on the occurrence of these occupational injuries. In the case of self-employed persons (hereafter "SEP") can play a certain role the relatively large financial burden associated with the acquisition and replacement of the protective working means, in particular of the protective harness and the necessary accessories thereto, such as ropes, carbines, fall dampers, positioning means and other accessories, absolutely indispensable for working at heights and above the free depth, which, according to manufacturers' recommendations, should be changed every 6 to 7 years to make work safer.

Another mistake is inappropriate storage of personal protective working tools, incorrect manipulation with personal protective working tools and insufficient control, which is mostly inconsistent with the manufacturer's instructions. Often these personal protective work tools are borrowed between their users for various height jobs and for different workplaces and information on damage by various substances such as acids, oils, petrol or other chemicals, or dust which reduces the strength of the ropes, are not passed on. Frost, water, UV rays and other natural elements with which workers at heights can meet in their activities may also have negative effects.

The manufacturer gives a 7-10 year guarantee on the quality of personal protective working tools for working at heights, but also sets certain safety requirements such as dry and high-quality storage, hanging personal protective working tools in a dry place, non-twisting ropes and other conditions. In practice, for example, how often personal protective work tools for individual work activities are used. Checking of ropes, fall dampers and other aids should be performed visually by the workers themselves, as prescribed in the instructions for use and in the relevant ČSN standards. It is stated in the standards that the inspection of harnesses, ropes and accessories should be carried out once a year by the so-called inspection technician, which must be a professionally qualified person. There is no indication on how this person should perform the tests, which tests he/she has to perform, or which devices or tools should be used to control personal protective working equipment. The inspection technician performs the inspections according to the instructions given in the operating instructions, or according to his/hers theoretical knowledge and practical experience. These workers often acquire theoretical knowledge from foreign mountaineering literature. Prior to any work at height, the employer must, by law, take account of workers' safety and assess work-related risks at work and, where appropriate, in the workplace, and lay down technological procedures. Workplace situations may arise when inappropriately determined workflow, inappropriately used work equipment, and

ignorance of the theory of the consequences of a fall can cause fatal injury even if the worker has technical means at his disposal. (Government Regulation No. 362/2005 Coll. o Providing workers at work at heights and above free depth).

### 3 Factors affecting the fall from heights

#### 3.1 Falling dynamics

Falling dynamics is the process of transforming the potential energy of a falling climber into kinetic energy, and then working the whole of the chain until the fall is stopped. The absorption of this energy, and thus the successful collapse of the fall, involves the entire security chain, consisting of a protective harness, a dynamic rope, locking points, carabines, loops and other means. The occurrence of a fall is an extraordinary event potentially endangering the health or life of the worker. (BGR 199 Benutzung von persönlichen Schutzausrüstungen zum Retten aus Höhen und Tiefen, Hauptverband der gewerblichen Berufsgenossenschaften Fachausschuss "Persönliche Schutzausrüstungen", BGR 198 Einsatz von persönlichen Schutzausrüstungen gegen Absturz (bisher ZH 1/709) Hauptverband der gewerblichen Berufsgenossenschaften Fachausschuss "Persönliche Schutzausrüstungen" der BGS April 1998 Aktualisierte Fassung Oktober 2004).

#### 3.2 Fall factor

Fall factor is the theoretical concept, but it describes the intensity of the fall, which is important both in terms of damage to the falling person and the stress of the rope as well as of other securing means. Fall factor can be significantly affected by progressive securing. Progressive securing components join the secured worker to the securing point and they reduce the length of the fall. During climbing up, the distance between the securing points should not exceed 2 m. (<https://blog.hudy.cz>).

Fall factor directly determines the intensity of the fall, the higher the value, the harder it is. Fall factor is the ratio of the length of the fall of the climber and the active length of the rope (see Fig. 1).

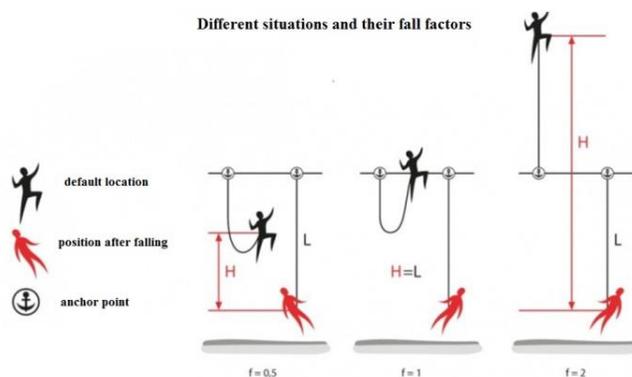


Fig. 1 Different situations and their fall factors [5]

#### 3.3 Impact force

Impact force is the force acting in the rope during stopping the fall. This force is also transmitted to other security chain component. When examining a fall, the time of force effect must not be

forgotten. With the increasing length of the fall, the falling speed increases. During climbing, the climber gets a positional energy. During the fall, it changes to kinetic energy, in this case to falling energy. It grows with the length of the fall and the weight of the climber. (Instruction of the General Director of the Fire Rescue Service of the Czech Republic of 2009)

### **3.4 Factors that may affect a worker's fall from a height:**

- When abseiling, the abseil eighth device gets hot of friction and the rope is twisted at the same time. The rope gets damaged.
- In the climbing literature, it is stated that after the 200th abseil process the rope would no longer stand 5 standard falls, the rope's fall resistance could be reduced by up to 70%.
- Polyamide (PAD) loses its strength at temperatures above 150 ° C. Different abseiling means (descenders) do not reach their temperature during abseiling, or their thermal capacity is so small that the heat accumulated therein is not sufficient to melt the entire rope. But a very hot descender can fuse together the fibers of the braiding. Especially in the summer in the sun, when the abseil aid can be warmed up by the sunbeams even before its use, and then, when swiftly abseiling, it gets very hot unexpectedly quickly.
- Damage to the rope also causes the use of various jammers, blockers, brakes, etc.
- The braiding of the low-drag rope, which forms the outer part of the rope, which is recommended for use in industry, has a 30-50% share of the overall strength of the rope. If the rope is not used and is stored in dry and shady conditions at room temperature, then its properties will not deteriorate significantly for approximately 6-7 years. (Most manufacturers recommend deleting of the rope already after 5 years of production date, so the use of an older rope is likely to pose a certain risk.) [2], [3]
- Polyamide (PAD) ropes can be damaged through acids, alkalis, organic solvents (acetone), decolourants (lyes), and similar chemicals. By testing it was determined, for example, which substances act on the ropes and how.
- The wet rope has about 30% lower fall resistance, as some manufacturers report, because water disturbs the strength of the bonding of the building components of the rope at the molecular level. [4]
- The frozen rope obviously also loses its fall resistance. It was determined whether the frozen rope could be more easily mechanically damaged or whether it loses strength etc.
- The rope can also be damaged through sunlight and UV radiation, so the rope should not be exposed to, excessive solar radiation unnecessarily.
- In the test facility was determined, how the rope behaves under the conditions mentioned in the previous paragraphs [4]

## **4 Testing of personal protective equipment for work at heights**

The tests of protective means for work at heights were carried out in a testing room, which deals with the testing of these technical devices and under the laboratory conditions of the Faculty of Safety Engineering, VŠB TU Ostrava.

We tests:

- **Belts for work positioning**

The working positioning agent - contaminated by the dust from the concrete plant - the supplier of concrete mixtures 10/2010, is used for the cutting of steel structures. Test result: not satisfactory

- **Strap loops**  
**Supplier / manufacturer No 1.** - Strap loops were used in workplaces where construction works are carried out, including work on roofs, year of production - unknown. Of the four loops tested so far, only Loop No. 2 was satisfying.
  - Supplier / manufacturer No 2. - All strap loops passed the stress test. At the date of production, these devices must withstand 22 kN. The values of the strap loops used were satisfying. Strap loops have been used in workplaces in the metallurgical industry, where mineral oils are used, for example, in the maintenance of lifting equipment. The year of production is shown in the table above.
- **Fall dampers**  
**Positioning devices with integrated fall damper – evaluation**  
Final information on tested positioning devices and fall damper of all manufacturers:
  - The fall damper was incorporated into the catching device, a dynamic performance test with a 100 kg test torque was performed.
  - The positioning devices were used in the cement workshops with the occurrence of dust in cement production, the protective agents were used for cutting and removal of the steel structure and the demolition of the cement plant.
  - All positioning devices and fall dampers were found to be compliant.
- **Static Rope**  
Of the all static rope tested so far, only rope soaked in lye and rope contaminated by the facade colour not satisfactory.

## 5 Conclusion

Results obtained from the testing of used ropes, carabines, and other accessories used in works at height in the industry can be used as information source for manufacturers producing these products for the industry. They can also be used as information for high-level trainers in theoretical instruction, or this information may be included in the safety and technical regulations as a warning, and how to use them in the prescribed manner or how to store them in order to avoid their premature deterioration or damage.

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