SCIENTIARUM POLONORUM ACTA
aspa.sggw.edu.pl
content.sciendo.com/aspa

Acta Sci. Pol.
Architectura 21 (4) 2022, 41–51

ISSN 1644-0633 eISSN 2544-1760 DOI: 10.22630/ASPA.2022.21.4.29

ORIGINAL PAPER

Received: 10.11.2022
Accepted: 19.12.2022

EVALUATION OF THE PROFESSIONAL RISK FOR AN EMPLOYEE IN THE BUILDING INDUSTRY USING AN EXAMPLE OF A CONCRETE-STEEL FIXER

Marek Chalecki[1]✉, Piotr Jaskłowski[1], Oleksandr Borysyuk[2]

[1]Institute of Civil Engineering, Warsaw University of Life Sciences – SGGW, Warsaw, Poland
[2]National University of Water and Environmental Engineering, Rivne, Ukraine

ABSTRACT

According to the Polish Labour Code Polish, the employer is obliged to evaluate and document the professional risk concerning the work performed, to apply preventive measures reducing the risk and to inform employees of the professional risk and rules of protection against hazards. Due to this fact, it is crucial to know methods of quantitative evaluation of the professional risk. In this paper, a risk evaluation for a profession of the building industry (concrete-steel fixer) is shown with the use of three methods: the five-stage method according to the Polish standard PN-N-18002:2011, the Fine & Kinney method and the preliminary hazard analysis (PHA). With this aim, hazards for this profession and preventive means have been gathered, numerical values of related coefficients have been selected, and the general risk has been calculated. The results confirm the observations from construction sites that the profession of a concrete-steel fixer is very demanding from physical, mental and health points of view.

Key words: professional risk evaluation, five-stage method, Fine & Kinney method, preliminary hazard analysis, concrete-steel fixer

INTRODUCTION

Pursuant to Art. 207 of the Polish Labour Code, § 1 and 2, "the Employer has the responsibility for the status of occupational health and safety in the Company" and "is obliged to protect health and life of Employees by ensuring safe and hygienic conditions of work with appropriate use of achievements of science and technology". Pursuant to Art. 26 of this Act, "the Employer evaluates and documents the professional risk concerning the work performed and applies necessary preventive measures reducing the risk" as well as "informs Employees on the professional risk and rules of protection against hazards [own transl.]" (Ustawa z dnia 26 czerwca 1974 r. Kodeks pracy).

Setting aside the legal obligation imposed on the employer, the aim of the professional risk evaluation is effective prevention from results of hazards – elimination of the risk, controlling the residual risk and transfer of information on hazards and risk to the employees. From the employer's point of view, the risk level is very important because it implies preventive actions, and it forces an undertaking of improving actions. The professional risk evaluation must be performed for all working places for which such evaluation has yet not been performed or if modifications have been introduced which could have changed the risk level (e.g. change of requirements regarding a permissible level of harmful or dangerous factors, new personal or collective protective equipment).

The first step in the professional risk evaluation is the characteristics of a working place (description of working processes, typical actions, factors, etc.). The second step is the identification of hazards, where the

Marek Chalecki https://orcid.org/0000-0003-3451-458X; Oleksandr Borysyuk https://orcid.org/0000-0002-0508-4851
✉marek_chalecki@sggw.edu.pl

type of factors, sources of the hazards, their duration time and possible health effects are defined. The third step is risk estimation, comprising a determination of a likelihood (probability) and results of exposure as well as an exposition of the hazard. This third step requires quantification of hazards existing in the working place because only by numerical values is it possible to unambiguously and clearly classify the risk. The aim of this paper is a presentation of risk estimation methods for a selected profession on a construction site – a concrete-steel fixer.

PROFESSIONAL RISK EVALUATION – DEFINITIONS AND METHODS

The risk (not only professional) is indissociable from the term "hazard". A hazard is an "inherent characteristic of an object or situation that has the potential of causing an unexpected, unplanned or undesired event or series of events that have harmful consequences, such as injury, death, environmental harm or illness" (Gowen & Collofello, 1994, p. 22). According to the Polish standard PN-ISO 45001:2018-06 (since 2018 replacing the standard PN-N-18001:2011), a hazard is an event which can evoke a loss (physical damage to health or object), or it is a state of the labour environment which can evoke an accident or illness (Polski Komitet Normalizacyjny [PKN], 2018).

Risk is generally an ambiguous term, difficult to define. In the engineering sciences, in particular, in the field of protection and safety of work, the accepted definition describes risk as a combination of the likelihood and severity of events (Kaplan & Garrick, 1981). The standard PN-ISO 45001:2018-06 clarifies this definition: risk is a combination of the frequency and likelihood of occurrence of an event evoking the hazard and consequences related to this hazard – a hazard severity (PKN, 2018). In particular, this combination can be a product of numerical values of the likelihood and severity.

Professional risk is defined in the standard PN-ISO 45001:2018-06 as a likelihood of occurrence of undesired events which are related to a work being performed and evoke losses, in particular, unfavourable health effects resulting from a manner of working or professional hazards existing in the working environment (PKN, 2018).

Professional risk is minimised by using certain preventive measures, reducing the probability of the hazard occurrence and/or its severity. A sequence of application of the preventive measures is the following: technical measures (e.g. an impediment of access for unauthorised persons), organisational measures (an appropriate organisation of work, preventing from, e.g. gathering a higher number of people in one place, which could evoke overloading), collective protective equipment (e.g. safety railings on the edge of a roof), personal protective equipment (e.g. safety suspenders for work at a height). In general, total elimination of hazards is impossible; thus, risk cannot be reduced to zero either; the risk remaining after the application of preventive measures is called residual risk.

Numerous methods are applied in professional risk evaluation, e.g. the three- and five-stage methods, according to the Polish standards, the Fine & Kinney method, the preliminary hazard analysis (PHA), the hazard and operability study (HAZOP), the method according to the US standard MIL STD 882 (Department of Defense, 2022), and graph methods, etc. In general, when selecting a method, consideration is to be given to the criterion of a finer scaling (graduation) of parameters describing the factors – an abrupt transition between an acceptable and unacceptable risk is then avoided. In the present paper, three methods have been assumed:

- the five-stage method according to the Polish standard PN-N-18002:2011 (PKN, 2011),
- the Fine & Kinney method (in Poland also called risk score), developed in the USA in 1971 for the US Navy (Kinney & Wiruth, 1976; Graham & Kinney, 1980),
- the PHA method, developed in 1966 in the US Department of Defense.

In the five-stage method, according to the standard PN-N-18002:2011, the level of likelihood of occurrence of an event and the level of severity of its harmful results are determined. Regarding the level of the likelihood of occurrence, the event can be classified as:

- slightly probable – being a result of hazards which should not occur during the whole professional activity of an employee,
- probable – being a result of hazards which can occur no more than several times during the whole professional activity of an employee,
- highly probable – being a result of hazards which can occur many times during the whole professional activity of an employee.

The severity of the harmful results can be:
- low – injuries or illnesses which do not evoke long-lasting negative health conditions or absence at work,
- medium – injuries or illnesses which evoke tiny but long-lasting or repeating negative health conditions and are related to short absence periods,
- high – injuries or illnesses which evoke serious and constant negative health conditions or death.

In the five-stage method, the risk is quantified according to the risk scoring matrix (Table 1).

Table 1. Risk scoring matrix in the five-stage method according to the standard PN-N-18002:2011

Likelihood of occurrence of hazardous events	Severity of events		
	low (L)	medium (M)	high (H)
Slightly probable (*S*)	very low (1)	low (2)	medium (3)
Probable (*P*)	low (2)	medium (3)	high (4)
Highly probable (*H*)	medium (3)	high (4)	very high (5)

Source: own elaboration on the basis of PKN (2011).

The high and very high risk is unacceptable. If it is very high, then work cannot be continued and started before a reduction of the risk to an acceptable level. If the risk is high and related to work being already performed, then immediate action must be undertaken for its reduction. If, however, it is related to work being planned, then the work cannot be started before the reduction of the risk level. The medium, low and very low risk is acceptable; however, if it is medium, it is recommended to plan and undertake actions aimed at its reduction and if it is low – to undertake actions ensuring that the risk will remain at most at the same level.

In the Fine & Kinney method, the value *R* of the professional risk is determined as

$$R = C\,E\,L, \tag{1}$$

where:
C − possible consequence of an event,
E – exposure factor,
L – likelihood of a hazardous event.

The values assigned to these factors are given in Tables 2 and 3. The risk is classified based on the obtained risk value (*R*) according to Table 4. The risk levels: slight, possible and substantial are permissible; the high and very high risks – unacceptable. Table 4 also provides actions required in the case of each risk level.

Table 2. Assigned values for possible consequences (*C*) according to the Fine & Kinney method

Value	Consequence (*C*)	Human loss	Financial loss [USD]
100	catastrophe	many fatalities	> 30 000 000
40	disaster	multiple fatalities	3 000 000−30 000 000
15	very serious	a fatality	300 000−3 000 000
7	serious	serious injury	30 000−300 000
3	important	disability	3 000−30 000
1	noticeable	first aid may be needed	< 3 000

Remark: Financial losses are translated from the values given for the year 1980 in Graham and Kinney (1980) into those for the year 2020 according to the inflation factor: 1 USD in 1980 is equivalent to 3.14 USD in 2020.

Source: InflationTool (n.d.) on the basis of Graham and Kinney (1980).

Table 3. Assigned values for exposure factors (*E*) and for hazardous event likelihood (*L*) according to the Fine & Kinney method

Value	Exposure (*E*)	Likelihood (*L*)	
		descriptive	numerical
10	continuous	might well be expected	50% (1 per 2)
6	daily during working hours	quite possible	10% (1 per 10)
3	weekly or occasionally	unusual but possible	1% (1 per 100)
2	monthly	–	–
1	few times per year	only remotely possible	0.1% (1 per 1 000)
0.5	very rare	conceivable but highly unlikely	0.01% (1 per 10 000)
0.2	–	practically impossible	0.001% (1 per 100 000)
0.1	–	virtually impossible	0.0001% (1 per 1 000 000)

Source: Graham and Kinney (1980).

Table 4. Risk score values (R) according to the Fine & Kinney method

Risk	Value (R)	Action
Slight	$R < 20$	perhaps acceptable
Possible	$20 \leq R < 70$	attention needed
Substantial	$70 \leq R < 200$[a]	correction required
High	$200 \leq R < 400$[a]	immediate correction required
Very high	$R \geq 400$[a]	consider discontinuing operations

[a]Graham and Kinney provide the values: substantial risk $70 \leq R < 160$, high risk $160 \leq R < 320$, very high risk $R \geq 320$. Since the 1980s, however, these criteria have softened, generating values given in the table (cf., e.g. ryzykozawodowe-online.pl, n.d.; Safety Analyse, 2013).

Source: Graham and Kinney (1980).

The preliminary hazard analysis (PHA) is a general method of risk evaluation (not only the professional one). The risk value, being a basis for the risk classification, is determined by a product:

$$R = S\,P, \tag{2}$$

where:
S – hazard severity degree,
P – hazard occurrence possibility.

A certain level (numerical value) can be assigned to each of these factors. Many ways for the quantification of hazards and classification of risk exist according to the PHA: usually, it is 4 to 6 levels for each factor S or P (Klyatis & Klyatis, 2006; Fang & Duan, 2014; Thieme, Guo, Utne & Haugen, 2019) and it depends on a problem that the risk is being evaluated. For example, in the IT industry, a hazard severity will be high if an event results in losing all data, which, from the point of view of human health and life, is nothing in comparison to a situation, e.g. in the mining industry where the severity is high for an event consisting in a rock burst resulting in deaths of many people and loss of expensive equipment. The hazard occurrence possibility of an event, however, can be estimated based on the number of such events in the register of accidents at work. As activities performed by people are very diversified, then an assessment scale for the needs of professional risk evaluation is also very wide. Using the practical experience of employees of occupational health and safety (OHS) service in Poland, the values assigned to the factors have been assumed according to Table 5. If the risk is at levels 1–3, then it is acceptable; if at levels 4–9, it is acceptable after a risk evaluation; if at level ≥ 10 – is unacceptable and must be reduced (Table 6).

Table 5. Hazard severity degree (S) and hazard occurrence possibility (P) according to the PHA method

Value	Hazard severity degree (S)	Hazard occurrence possibility (P)
1	marginal injuries and negligible losses in the system	unlikely to occur
2	minor injuries, measurable losses	not likely to occur (once per 10 years)
3	serious injuries, significant losses	occasional occurrence (once per year)
4	single fatal accidents, severe losses	quite common (once per month)
5	collective fatal accidents, large-scale damages within a facility area	common, regular (once per week)
6	collective fatal accidents, large-scale damages within and outside of a facility area	very likely to occur

Source: bhpex.pl (n.d.), ryzykozawodowe-online.pl (n.d.).

Table 6. Risk score values (R) according to the PHA method

		Hazard occurrence possibility (P)					
		1	2	3	4	5	6
Hazard severity degree (S)	1	1	2	3	4	5	6
	2	2	4	6	8	10	12
	3	3	6	9	12	15	18
	4	4	8	12	16	20	24
	5	5	10	15	20	25	30
	6	6	12	18	24	30	36

Source: bhpex.pl (n.d.), ryzykozawodowe-online.pl (n.d.).

DETERMINATION OF HAZARDS FOR THE WORKING PLACE OF A CONCRETE-STEEL FIXER AND CALCULATION OF THE RISK

To evaluate the professional risk for the working place of a concrete-steel fixer, hazards and preventive measures reducing them have been determined. It was performed based on a description of the profession (Ministerstwo Gospodarki, Pracy i Polityki Społecznej [MGPiPS], 2003; Jaskłowski, 2022). The hazards and preventive measures are presented in Table 7. These hazards were quantified by assigning values of individual factors according to the three abovementioned methods, and then the initial risk was calculated for each hazard. After that, the residual risk was calculated, resulting from an application of the preventive measures aimed at a reduction of the initial risk. The results are presented in Table 8: the values in Column 1 of this table correspond to the values from Column 1 in Table 7.

Table 7. Hazards in the working place of a concrete-steel fixer and preventive measures against them

No	Hazard	Preventive measure
1	2	3
1	Hand injury during cutting with a table saw	Follow the Operating and Maintenance Manual (OMM) of the saw. Ensure order around the saw. Fix the saw properly. Ensure the appropriate condition of the blade and protective cover. Use push sticks when cutting small parts.
2	Noise over 85 dB emitted by: mechanical saws, power hammers, hammer drills, etc.	Use hearing protection in places where equipment emitting noise over 85 dB is used.
3	Eye injury made by: contact with mortar (during concrete pouring), particles coming into the eye during cutting or grinding	Use safety goggles during works where foreign bodies can fly into the eye.
4	Falling, tripping, slipping, or hitting by means of transport as a result of lack of transport routes on a construction site or their improper labelling or design	Design and label the transport routes properly.
5	Tripping resulting from: walking on reinforcement mesh or reinforcement bars of ceiling slabs covered by fresh concrete, lack of appropriate passages and accesses to working places	Make transportation routes. Lay boards enabling transportation. Protect access to working places at a height by safety railings. Do not use ladders as a permanent passage.
6	Injury by contact with protruding edges of cut bars, wires, or elements of scaffolding	Use protective clothes and shoes. Cover protruding ends. Ensure passages with a minimum width of 0.75 m.
7	Injury during works with benders (installation of bars or their adjustment during movement of a mechanical or hand bender)	Stop the mechanical bender when changing the bars. Follow OMM of the benders. Use personal protective equipment
8	Injury by objects falling from a height as a result of lack of limits of a danger zone around a place of works performed at a height	Determine a danger zone for works performed at a height; if it is not possible – mount a protective net (on scaffoldings or building).
9	Injury by objects falling from a height as a result of lack or improper construction of a protective roof or using this roof as a scaffolding or a storing place for tools and materials	Make a protective roof with appropriate strength in passages. Use protective roofs only as protection against falling objects, do not perform works on the protective roof.
10	Injury by objects falling because of their loose fixing, improper transport or storing	Store objects properly. Protect edges properly with toe boards. Fence danger zones during masonry work. Equip scaffoldings by roads and pedestrian passages with protective roofs.
11	Injury by objects falling during their transport	Lay and fix elements properly. Store building materials in a reliable manner. Do not hold elements being transported, do not transport them over employees.
12	Injury by objects thrown from a height	Do not throw objects from a height and onto a height. Use protective helmets. Design and label danger zones.
13	Injury by objects falling during transport, assembly and disassembly of formwork (mainly with the use of cranes)	Inform employees of OMM of formwork and follow it. Define assembly procedures for each type of formwork. The work can be performed by at least 2 persons. Ensure communication with the crane operator. Designate signallers and slingers.

Table 7 (cont.)

No	Hazard	Preventive measure
1	2	3
14	Injury by an object (lump of soil, elements of equipment) falling onto people working in an excavation, e.g. as a result of improper reinforcement of walls, erosion of escarpment by precipitation water, overloading the soil near the excavation by stored equipment or excavated soil, vehicles too close to the excavation	Report all ground works to the developer. Make a plan of ground works. Mount conveyor bridges, each 1.5 m high. Fill containers with soil up to 2/3 of their height. Ensure that the slope angle of the escarpment is appropriate to the soil type. Reinforce the walls properly. Remove reinforcing elements in stages, starting from the excavation bottom and backfilling the excavation. Store materials at a safe distance from the excavation edge. Check the escarpment after rain, frost and longer breaks in work. Remove unstable soil and maintain a safe slope angle. Make terrain slopes for precipitation water outflow near the escarpment edge.
15	Injury by cutting parts of machines, being in movement (circular saws, grinders etc.)	Cut only with protecting covers. Use swivelled covers.
16	Injury as a result of the manual moving of a material being cut up to the cutting blade	Apply push sticks for the manual moving of parts in the vicinity of a cutting blade of a saw at work.
17	Injury by snatched material being cut or by a tooth ripped out from the saw blade	Check the condition of a cutting blade, and fix it properly. Start cutting only if the saw reaches minimum revs.
18	Injury by objects falling because of the bad condition of ropes, chains and slings	Observe deadlines of periodic inspections of crane pull cables. Check the condition of slings before slinging objects.
19	Crushing by manoeuvring vehicles	Stay away from manoeuvring vehicles, and stay in the driver's field of view.
20	Injury by chips of the blade and metal parts during cutting with the use of an electric cutter	Use protective covers of eyes and hands and cover around the cutter's blade.
21	Injury as an effect of the bursting of an improperly chosen or utilised blade of a cutter	Pay special attention to the proper selection of the blade, and utilise it according to its OMM.
22	Hitting by a machine or its part as a result of improper grip during work or use of blunt cutting tools	Operate machines according to their OMM. Apply sharp cutting tools, and remove blunt tools.
23	Injury as a result of a careless transporting of a container for concrete, climbing it or crushing by it	Designate instructed employees to operate a crane passing the concrete in containers or to operate a concrete pump. Do not climb the container for transporting concrete.
24	Injury by elements falling during their transport as a result of the bad condition of ropes, chains and slings, improper slinging of materials, improper choice and use of slings	Observe deadlines of periodic inspections of the technical condition of crane cables and slings. Remove steel ropes with damage and chains with deformed links. Check the condition of hooks before starting transport works. Select slings carefully with respect to the dimensions and weight of the transported element.
25	Injury by elements falling during their transport as a result of overloading of slings	Notice a permissible working load depending on the angle between transport ropes.
26	Crushing of hands during slinging or lifting a weight, e.g. as a result of lack of coordination between the crane operator and slinger	A slinger must use protective gloves. A crane operator and a slinger must communicate with each other (provide radio communication, if possible).
27	Crushing of hands by a transported element as a result of not keeping a safe distance while transporting an element or not using guiding ropes	Keep a safe distance to a transported element. Use guiding ropes to guide a hanging element to a designed place. Use sound signals. Remove waste regularly. Bend nail spikes protruding from boards. Use protective gloves.
28	Events resulting from insufficient lighting of a working place or passages in staircase towers or cellars	Install lighting in each obscured place or where works are performed after dawn.
29	Splashing of a body or eyes with concrete, antiadhesive liquid for formworks or solvents as a result of not wearing protective clothing and personal protective equipment	Provide protective clothes, gloves and goggles for employees and supervise their use. Pour concrete gradually and evenly, from a height no bigger than 1 m.

Table 7 (cont.)

No	Hazard	Preventive measure
1	2	3
30	Falling from scaffolding as a result of its improper assembly and/or usage	Assemble a scaffolding according to its OMM. The scaffolding can be assembled, dismounted and accepted only by qualified persons. Stop work during storms and strong winds. Do not store materials or tools at the edges of scaffolding platforms. Do not lean over the railings nor make sudden movements. Pass between the scaffolding platforms in dedicated places (not at ledgers, railings or standards). Do not overload a working platform. Ensure free and unobstructed work as well as a possibility of storage of required tools and materials on the platform. Inspect working places each day before starting work. Test hanging scaffoldings according to their OMM before starting work on them. Determine, fence and label a danger zone before assembly and dismounting of a scaffolding. Pave and even a road for the transport of movable scaffolding. Remove snow and ice from platforms and stairs in winter. Earth a steel scaffolding and install lightning protection on it.
31	Falling from roofs and ceilings as a result of lack of railings at the edge or not using personal protective equipment protecting from falling from a height	Assemble railings or, if it is not possible, use appropriate personal protective equipment. Use safety suspenders fixed with a rope to solid constructive elements of a building or roof.
32	Falling from a ladder	Follow the OHS instructions while working on ladders. Position a ladder so that it protrudes > 75 cm over a surface to which it leads. Protect ladders properly. Perform work on ladders with working platforms.
33	Falling into unprotected holes in ceilings and walls, falling during getting up to work at height and getting down	Secure all holes of stair towers, exits, entries and technological holes with protective railings immediately.
34	Falling into depressions or channels as a result of lack of proper fencing, labelling or lighting of the area	Fence the area. Label dangerous places. Enlighten the construction site after dawn. Provide proper passages to working places (including footbridges with railings).
35	Falling from a working platform as a result of improper handling of a concrete hose ending	Take care. Instruct employees. Supervise works at a height and sequence of tasks. Assemble working platforms properly, with protective railings on both sides.
36	Falling from a height as a result of pouring concrete from ladders or improperly mounted platforms	Use platforms completely laid with boards and equipped with railings mounted at the height of 1.1 m and with toe boards.
37	Falling as a result of slipping on stairs, falling from damaged or unprotected stairs	Keep order in passages. Remove ice regularly. Do not run. Apply railings in passages.
38	Injuries resulting from using manual tools (saws, hammers) of bad technical condition (blunt blades, improperly mounted grip)	Ensure the proper technical condition of manual tools (well mounted, knot-free and hard grips for sharp cutting tools).
39	Injury resulting from contact with sharp edges and rough surfaces (sharp edges of metal sheets, protruding pins, bolts, parts of reinforcement, tools, wooden elements)	Use personal protective measures. Remove unnecessary protruding reinforcing bars; if not possible, protect them.
40	Electric shock resulting from the voltage on a housing (improperly connected phase on a receiver before a switch, broken protective circuit, atmospheric influences)	Check electric connections. Conduct periodic inspections of the continuity of cables. The protection level of cable connections can be checked only by certified electricians.
41	Electric shock resulting from the voltage in the soil (cutting electric cables by a passing vehicle, uninsulated cables)	Insulate or enclose cables.
42	Electric shock resulting from too small height of a power line over a transport route	Use “gates” on a transport route which set a maximum passing height. Keep a distance from electric installations and devices.
43	Electric shock resulting from a lack of fundamental antishock protection or damaged earthing wire	Conduct periodic inspections of equipment. Use technically operational equipment, having appropriate antishock protection.

Table 7 (cont.)

No	Hazard	Preventive measure
1	2	3
44	Electric shock resulting from improper protection of circuits or bad condition of installation	Do not increase the nominal power of a fuse (e.g. with a copper wire). Supervise the proper condition of the insulation. Pay special attention to the routes of power cables to eliminate the possibility of their mechanical damage. Check the condition of power cables and their connections each day before starting work.
45	Electric shock during the service of equipment as a result of not checking the effectiveness of earthing, performing maintenance works with current turned on, mechanical damages of power cables and plugs, shortcuts in a damaged winding	Check the effectiveness of antishock protection and resistance of insulation of machines and devices. Do not perform maintenance works if the current is turned on.
46	Electric shock from lightning during a storm	Do not walk in an open area during storms. Install lightning protection on buildings. Check earthing and lightning protection on scaffoldings.
47	Variable atmospheric conditions during working in open air	Provide appropriate working clothes, regenerative drinks and meals (in winter) and shelter against atmospheric conditions.
48	Breathing with dusty air	Apply protective masks. During pouring loose materials (cement, gravel), keep the face opposite to the wind direction.
49	Biological factors (infection by *Clostridium tetani*, bite by insects)	Dress the wounds immediately. Use personal protective measures (gloves, goggles, masks, suits) according to their product data sheets. After cuts, supply the tetanus anatoxin. Be extremely careful when consuming meals and drinks, and close bottles with sweet drinks.
50	Mental and social factors (overloading with quantity and quality of work, no impact on workload and a pace and variability of work, wrong communication, insufficient support by supervisors in solving problems)	Show priority tasks. Avoid exerting pressure and urging an employee. Make a work program together. Eliminate unnecessary work. Introduce more breaks. Hire employees with appropriate qualifications. Report problems and solve them in groups.

Source: own elaboration.

Table 8. Professional risk evaluation in the working place of a concrete-steel fixer

Hazard's number from Table 7	Initial risk										Residual risk									
	PN			Fine & Kinney				PHA			PN			Fine & Kinney				PHA		
	likelihood	severity	risk	*C*	*E*	*L*	*R*	*S*	*P*	*R*	likelihood	severity	risk	*C*	*E*	*L*	*R*	*S*	*P*	*R*
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	*H*	*H*	5	7	6	6	252	3	4	12	*P*	*M*	3	7	6	3	126	3	3	9
2	*P*	*M*	3	3	10	6	180	2	4	8	*P*	*L*	2	1	10	1	10	2	3	6
3	*P*	*M*	3	3	10	10	300	1	6	6	*S*	*M*	2	1	10	3	30	1	4	4
4	*P*	*H*	4	15	10	1	150	4	3	12	*S*	*M*	2	15	10	0.5	75	4	2	8
5	*P*	*M*	3	3	6	6	108	2	4	8	*S*	*M*	2	1	6	0.5	3	2	2	4
6	*H*	*H*	5	7	10	10	700	3	6	18	*P*	*M*	3	3	10	3	90	2	4	8
7	*P*	*H*	4	7	10	10	700	3	5	15	*S*	*M*	2	7	10	0.5	35	2	2	4
8	*P*	*M*	3	40	6	1	240	5	4	20	*S*	*M*	2	40	6	0.2	48	5	2	10
9	*P*	*M*	3	15	10	3	450	4	3	12	*S*	*M*	2	1	10	0.5	5	4	2	8
10	*H*	*H*	5	15	10	3	450	4	5	20	*P*	*M*	3	15	10	0.5	75	4	2	8
11	*H*	*H*	5	15	10	6	900	5	5	25	*P*	*M*	3	15	10	0.5	75	4	2	8

Table 8 (cont.)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
12	*S*	*H*	3	15	10	6	900	4	4	16	*S*	*M*	2	15	10	0.2	30	4	1	4
13	*P*	*M*	3	7	10	6	420	3	6	18	*S*	*M*	2	7	10	0.5	35	3	2	6
14	*S*	*H*	3	100	1	10	1 000	6	4	24	*S*	*M*	2	100	1	0.5	50	6	1	6
15	*H*	*H*	5	7	6	6	252	3	5	15	*P*	*M*	3	7	6	1	42	1	3	3
16	*P*	*M*	3	7	6	6	252	3	5	15	*S*	*M*	2	7	6	0.5	21	1	2	2
17	*S*	*M*	2	7	6	2	84	3	5	15	*S*	*M*	2	7	6	0.2	8.4	3	2	6
18	*P*	*M*	3	40	10	3	1 200	5	3	15	*S*	*M*	2	40	10	0.2	80	5	1	5
19	*S*	*H*	3	15	6	3	270	4	2	8	*S*	*L*	1	15	6	0.5	45	4	1	4
20	*H*	*M*	4	7	10	10	700	3	4	12	*S*	*L*	2	7	10	0.5	35	3	3	9
21	*S*	*M*	2	7	10	3	210	3	3	9	*S*	*M*	2	7	10	0.5	35	3	2	6
22	*S*	*H*	3	3	10	6	180	2	6	12	*S*	*L*	1	1	10	3	30	2	3	6
23	*P*	*M*	3	15	6	3	270	4	3	12	*S*	*M*	2	15	6	0.5	45	3	2	6
24	*S*	*H*	3	15	6	3	270	3	3	9	*S*	*M*	2	15	6	0.5	45	3	2	6
25	*P*	*H*	4	40	6	3	720	5	3	15	*S*	*H*	3	40	6	0.5	120	5	1	5
26	*P*	*H*	4	7	6	6	252	3	6	18	*S*	*H*	3	7	6	1	42	2	3	6
27	*P*	*H*	4	7	6	3	126	3	5	15	*S*	*H*	3	7	6	0.5	21	1	4	4
28	*P*	*M*	3	15	10	6	900	4	3	12	*S*	*M*	2	1	10	0.5	5	1	1	1
29	*P*	*M*	3	3	10	6	180	2	6	12	*S*	*M*	2	3	10	1	30	1	3	3
30	*P*	*H*	4	100	10	3	3 000	5	5	25	*S*	*H*	3	100	10	0.2	200	5	2	10
31	*H*	*H*	5	100	6	3	1 800	5	4	20	*S*	*H*	3	100	6	0.2	120	5	2	10
32	*P*	*H*	4	15	10	3	450	4	4	16	*S*	*H*	3	15	10	0.5	75	3	2	6
33	*P*	*H*	4	40	10	6	2 400	5	6	30	*S*	*H*	3	40	10	0.2	80	2	2	4
34	*P*	*M*	3	15	10	3	450	4	3	12	*S*	*M*	2	15	10	0.1	15	4	2	8
35	*S*	*H*	3	15	10	3	450	4	6	24	*S*	*H*	3	15	10	0.5	75	4	1	4
36	*P*	*H*	4	15	6	3	270	3	4	12	*S*	*H*	3	15	6	1	90	2	2	4
37	*P*	*M*	3	15	10	6	900	4	6	24	*S*	*M*	2	15	10	0.5	75	4	2	8
38	*P*	*M*	3	3	10	6	180	2	5	10	*S*	*L*	1	3	10	0.2	6	2	3	6
39	*P*	*M*	3	1	10	10	100	2	6	12	*S*	*M*	2	1	10	3	30	1	3	3
40	*P*	*H*	4	40	10	3	1 200	5	3	15	*S*	*H*	3	40	10	0.2	80	4	2	8
41	*P*	*H*	4	40	3	6	720	5	3	15	*S*	*H*	3	40	3	0.5	60	5	1	5
42	*S*	*H*	3	40	3	10	1 200	6	3	18	*S*	*H*	3	40	3	1	120	4	2	8
43	*S*	*H*	3	15	6	3	270	4	4	16	*S*	*M*	2	15	6	0.2	18	2	2	4
44	*P*	*H*	4	15	10	10	1 500	4	4	16	*S*	*M*	2	15	10	0.5	75	2	2	4
45	*S*	*H*	3	15	6	3	270	2	4	8	*S*	*M*	2	15	6	0.2	18	1	1	1
46	*S*	*H*	3	15	6	1	90	3	2	6	*S*	*M*	2	15	6	0.2	18	3	1	3
47	*P*	*M*	3	3	10	10	300	1	4	4	*S*	*M*	2	3	10	0.5	15	1	3	3
48	*P*	*H*	4	3	6	6	108	3	6	18	*P*	*L*	2	1	6	3	18	2	3	6
49	*P*	*H*	4	15	10	1	150	4	2	8	*P*	*L*	2	15	10	0.1	15	4	1	4
50	P	M	3	3	10	3	90	1	4	4	*S*	*M*	2	3	10	1	30	1	3	3

Source: own elaboration.

To classify the general risk (R_{gen}) for the working place of a concrete-steel fixer, one has to use the formula:

$$R_{gen} = \sqrt{\frac{\sum_{i=1}^{n} R_i^2}{n}}\ , \qquad (3)$$

where:
n − number of hazards being analysed.

Based on Eq. (3), the general risk for the given working place prior to and after the reduction of the risk was classified. The results are presented in Table 9.

Table 9. General risk for a concrete-steel fixer according to the five-stage method, Fine & Kinney method and the PHA

Method	General initial risk	General residual risk
Three-stage	3.581	2.371
Fine & Kinney	827.1	64.21
PHA	15.44	5.961

Source: own elaboration.

CONCLUSIONS

Based on the results from Table 9, it can be concluded that the risk has been reduced to an acceptable level. However, attention must be paid to items 8, 30 and 31 – according to the PHA method, the residual risk is still high, despite the application of preventive measures; hence, these measures must be introduced with a special thoroughness to additionally reduce the likelihood of occurrence of the hazard. After the reduction of this likelihood to 1, the general residual risk decreases to 5.571.

As it is seen in Tables 7, 8 and 9, the working place of a concrete-steel fixer is quite demanding – both with respect to predispositions regarding physical conditions (good physical fitness due to a necessity of handling the equipment, e.g. a concrete supply hose, or moving between different levels), mental state (discipline in using personal protective equipment, diligence, resistance against the monotony of some important activities, e.g. placing and anchoring a reinforcement) and health (unacceptable illnesses: asthma due to breathing dusty air, hypertension due to overcoming heights between different levels or carrying weights, problems with the labyrinth or sight). It is confirmed by the results from Table 9 – the risk for this working place has been classified as high, thus unacceptable. Even the residual risk, though acceptable, is relatively high.

It is visible as well that the five-stage method is the “mildest” in the risk evaluation, whereas the PHA is the “severest”.

It must be emphasised that although working places are usually described (including hazards and preventive measures) by appropriate institutions supervising the employees’ safety, for instance, in Poland, it is Central Institute for Labour Protection (*Centralny Instytut Ochrony Pracy – Państwowy Instytut Badawczy*, CIOP) and State Labour Inspection (*Państwowa Inspekcja Pracy*, PIP). The quantification of individual factors affecting the risk level is usually biased and depends on the experience of a person performing the evaluation. Thus, the values of the risk factors from Table 8 can be chosen in another way. Moreover, the hazards from Table 7 can be supplemented by others; some can be removed – depending on the experience of an OHS service officer evaluating the risk or the given place where the concrete-steel fixer works (working conditions in a stationary factory manufacturing building are different from those on a construction site; hence, the hazards will also be different).

Authors’ contributions

Conceptualisation: M.C. and P.J.; methodology: M.C. and P.J.; validation: M.C.; investigation: P.J.; resources: M.C., P.J. and O.B.; writing – original draft preparation: M.C. and P.J.; writing – review and editing: M.C. and O.B.; supervision: M.C.

All authors have read and agreed to the published version of the manuscript.

REFERENCES

bhpex.pl [n.d.]. *Metoda PHA*. Retrieved from: https://www.bhpex.pl/bhp/ocena-ryzyka-zawodowego/metoda-pha [accessed 20.10.2022].

Department of Defense (2022). *System safety (Military Standard (MIL STD 882E)*. [n.p.]: Military and Government Specs & Standards (Naval Publications and Form Center).

Fang, H. & Duan, M. (2014). *Safety System Engineering for Offshore Oil*. In H. Fang & M. Duan (Eds.), *Offshore*

Operation Facilities. Petroleum Industry Press, Elsevier. https://doi.org/10.1016/C2011-0-07477-X

Gowen, L. D. & Collofello, J. S. (1994). Software safety and preliminary hazard analysis. *Professional Safety*, *39* (11), 20–25. Retrieved from: https://www.proquest.com/scholarly-journals/software-safety-preliminary-hazard-analysis/docview/200389647/se-2 [accessed 21.10.2022].

Graham, K. J. & Kinney, G. F. (1980). A Practical Safety Analysis System for Hazards Control. *Journal of Safety Research*, *12* (1), 13–20.

InflationTool [n.d.]. *Inflation Calculator*. https://www.inflationtool.com [accessed 20.10.2022].

Jaskłowski, P. (2022). *Zagadnienia bezpieczeństwa i higieny pracy na placu budowy dla stanowiska pracy betoniarz--zbrojarz* (Master's thesis). Szkoła Główna Gospodarstwa Wiejskiego, Warszawa.

Kaplan, S. & Garrick, B. J. (1981). On the Quantitative Definition of Risk. *Risk Analysis*, *1* (1), 11–27. https://doi.org/10.1111/j.1539-6924.1981.tb01350.x

Klyatis, L. M. & Klyatis, E. L. (2006). Basic concepts of safety risk assessment. In L. M. Klyatis & E. L. Klyatis (Eds.), *Accelerated Quality and Reliability Solutions*. Elsevier. https://doi.org/10.1016/B978-0-08-044924-1.X5000-X

Kinney, G. F. & Wiruth, A. D. (1976). *Practical Risk Analysis for Safety Management* (NWC TP 5865). China Lake, CA: Naval Weapons Center.

Ministerstwo Gospodarki, Pracy i Polityki Społecznej [MGPiPS] (2003). *Przewodnik po zawodach*. Vol. 6 (2nd ed.). Warszawa: Ministerstwo Gospodarki, Pracy i Polityki Społecznej.

Polski Komitet Normalizacyjny [PKN] (2011). *Systemy zarządzania bezpieczeństwem i higieną pracy. Ogólne wytyczne do oceny ryzyka zawodowego* (PN-N-18002:2011). Warszawa: Polski Komitet Normalizacyjny.

Polski Komitet Normalizacyjny [PKN] (2018). *Systemy zarządzania bezpieczeństwem i higieną pracy. Wymagania i wytyczne stosowania* (PN-ISO 45001:2018-06). Warszawa: Polski Komitet Normalizacyjny.

portalbhp.pl (2022). *Metoda PHA oceny ryzyka zawodowego*. Retrieved from: https://www.portalbhp.pl/metody-oceny-ryzyka-zawodwego/metoda-pha-oceny-ryzyka-zawodowego-1744.html [accessed 20.10.2022].

ryzykozawodowe-online.pl [n.d.]. *Metoda PHA (Preliminary Hazard Analysis)*. Retrieved from: https://www.ryzykozawodowe-online.pl/metody-oceny-ryzyka-zawodowego/pha-preliminary-hazard-analysis [accessed 20.10.2022].

Safety Analyse (2013). *Risico-Inventarisatie & Evaluatie Methode van Fine & Kinney. Risico-Inventarisatie & Evaluatie Methode van Fine & Kinney*. Retrieved from: https://www.safetyanalyse.nl/wp-content/uploads/2012/10/Fine-en-Kinney.pdf [accessed 20.10.2022].

Thieme, C. A., Guo, C., Utne, I. B. & Haugen, S. (2019). Preliminary hazard analysis of a small harbor passenger ferry – results, challenges and further work. *Journal of Physics: Conference Series*, *1357*, 012024. https://doi.org/10.1088/1742-6596/1357/1/012024

Ustawa z dnia 26 czerwca 1974 r. Kodeks pracy. Dz.U. z 1974 r. nr 24 poz. 141.

OCENA RYZYKA ZAWODOWEGO PRACOWNIKA BRANŻY BUDOWLANEJ NA PRZYKŁADZIE STANOWISKA ZBROJARZ-BETONIARZ

STRESZCZENIE

Według polskiego prawodawstwa pracodawca ma obowiązek oceny i dokumentacji ryzyka zawodowego związanego z wykonywaną pracą, zastosowania środków profilaktycznych zmniejszających ryzyko, a także informowania pracowników o ryzyku zawodowym oraz zasadach ochrony przed zagrożeniami. Z tego powodu istotna jest znajomość metod liczbowej oceny ryzyka zawodowego. W artykule przedstawiono sposób oceny ryzyka zawodowego jednego z zawodów branży budowlanej (zbrojarz-betoniarz) przy użyciu trzech metod: metody pięciostopniowej według Polskiej Normy PN-N-18002:2011, metody Fine'a & Kinneya (*risk score*) oraz *preliminary hazard analysis* (PHA). W tym celu zestawiono zagrożenia dla tego stanowiska pracy, środki zapobiegające skutkom tych zagrożeń, dobrano wartości liczbowe odpowiednich współczynników i obliczono ryzyko ogólne. Wyniki potwierdzają spostrzeżenia poczynione na terenach budów, że stanowisko zbrojarz-betoniarz jest bardzo obciążające psychofizycznie.

Słowa kluczowe: ocena ryzyka zawodowego, metoda pięciostopniowa, metoda Fine'a & Kinneya, PHA, zbrojarz-betoniarz