ON INDUSTRIAL SAFETY IN RECONSTRUCTION AND CONSTRUCTION OF BRIDGES

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ABSTRACT

The industrial safety system has evolved on railways for decades. In new economic conditions, many of its basic principles have been preserved, but those factors have emerged that require additional scientific analysis, experimental verification, and modern technological tools. In particular, using the example of construction and maintenance of bridge structures, the situation with labor safety, injuries, and fire hazards at railway transport facilities is studied and assessed. Factorial analysis of labor safety using different criteria is shown.

Additionally the results confirm the effect of fire protection on flammability of wood: the effect is manifested in a more intense charring of the surface layer, which creates a barrier to heat the underlying layers, and in a decrease in concentration of combustible gaseous products of thermal decomposition.

The results of the experiments allow to determine the directions of improvement of flame retardants, including through the use of additives that maximize the degree of expansion (thermal expansion) of the coatings.

Keywords: *railway, labor safety, bridge works, nomogram of working conditions, injuries, fire protection equipment.*

Background. *At all stages of the reform of railway transport, special attention is paid to preservation of all ties and principles that ensure functioning of the industry as a single, uninterruptedly operating mechanism [1]. Among these principles and maintaining a high level of industrial safety, working conditions and labor protection.*

Objective. *The objective of the authors is to consider the issues of industrial safety in reconstruction and construction of bridges.*

Methods. *The authors use general scientific methods, comparative analysis, evaluation approach, engineering methods and approaches of materials science, labor and industrial statistics.*

Results.

1.

Analyzing the condition of labor protection and conditions in JSC Russian Railways, we note that the number of industrial injuries remains at the same level, although the number of injured with a severe outcome is reduced by 10 percent [2].

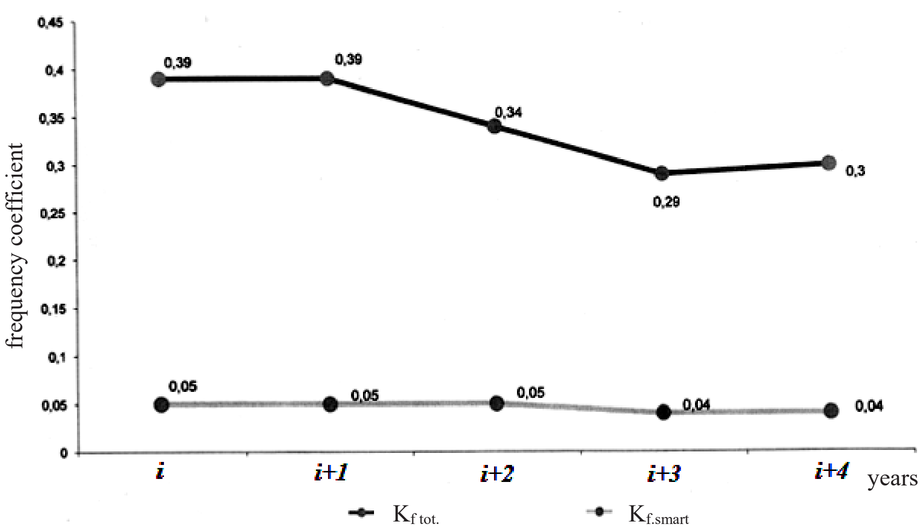
At the same time, taking into account decrease in the number of company employees, the coefficient of frequency of total industrial injuries has slightly increased ($K_{f.t.}$ = 0,3), and the loss coefficient, characterizing the number of days of disability, has been reduced (Pic. 1).

The growth of general injuries was allowed in three departments of the central directorate of infrastructure: railways and facilities, electrification and power supply, and mechanization management.

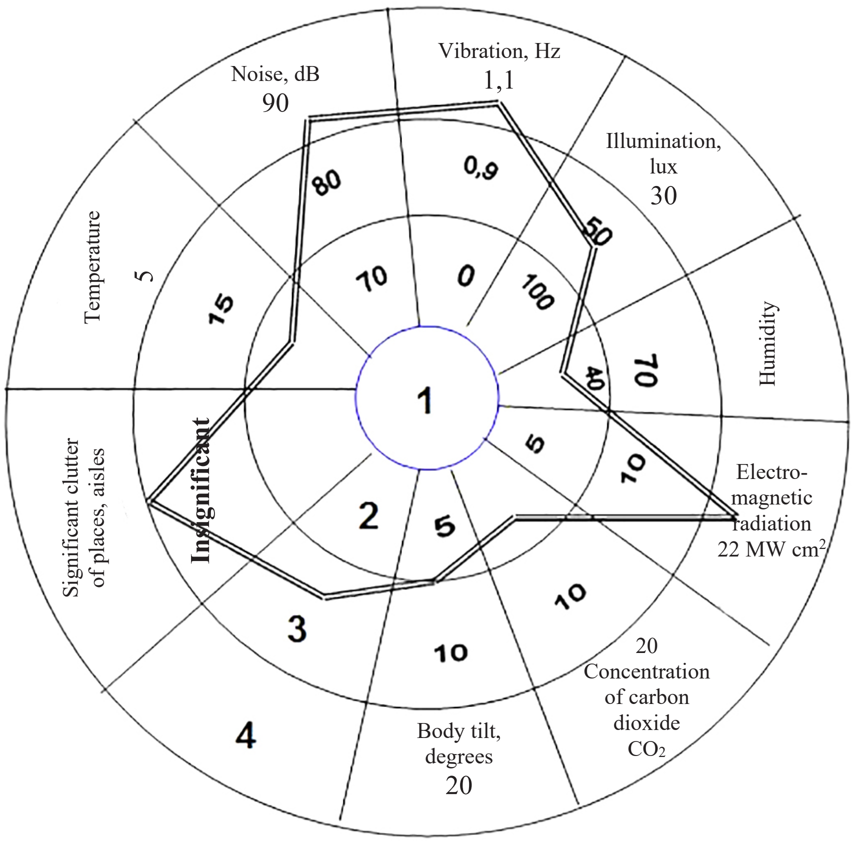
Unfavorable working conditions, when they exceed the limits established by sanitary norms and safety regulations, can lead to accidents or cause occupational diseases.

In recent years, severity of the consequences of injuries in the directorate of track and facilities continues to be high, which is explained by increasing complexity of construction and installation work, a sharp increase in construction rates, a decrease in the level of production organization, professional training of managers, as well as representatives of working professions [3].

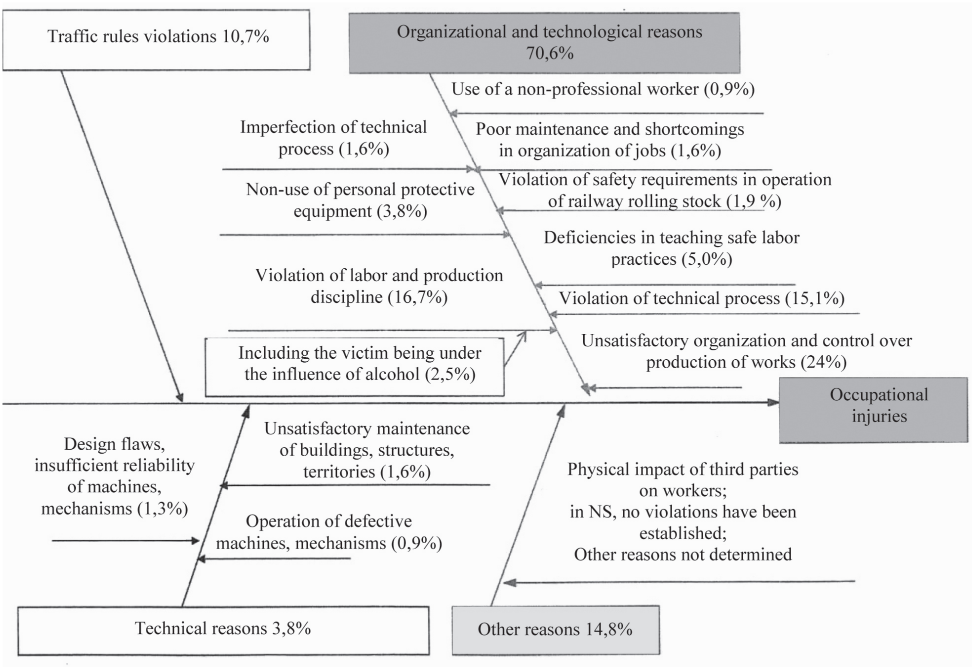
Based on the analysis of requirements for performance of work and requirements of sanitary hygiene, a cartogram of working conditions during



Pic. 1. The dynamics of the coefficients of frequency of industrial injuries.



Pic. 2. The cartogram of working conditions of the maintenance workers of JSC Russian Railways during track works: 1 – zone of the highest comfort; 2 – comfort zone; 3 – uncomfortable zone; 4 – inadmissible zone.



Pic. 3. Groups of causes of occupational injuries in JSC Russian Railways.

Table 1

Probability of safe labor on track of bridge brigades depending on working time

No.	Position (profession) of workers	Likelihood of safe operation during T_s, months				
		36	12	6	3	1
1.	Installer of reinforced concrete and metal structures	0,58	0,64	0,73	0,82	0,97
2.	Driver	0,82	0,86	0,88	0,905	0,94
3.	Electric welder	0,65	0,68	0,72	0,89	0,94
4.	Carpenter	0,68	0,77	0,887	0,93	0,965
5.	Locksmith	0,89	0,91	0,92	0,94	0,97
6.	Crane operator	0,90	0,93	0,95	0,96	0,98
7.	Driver of a bulldozer	0,87	0,89	0,92	0,94	0,98
8.	Armature worker	0,74	0,76	0,873	0,919	0,94
9.	Electrician	0,80	0,84	0,93	0,95	0,98
10.	Tractor driver	0,85	0,88	0,89	0,95	0,96

repair work on the road and artificial structures was developed (Pic. 2).

As the distance from the center increases, indicators indicating a deterioration of the working environment, an increase in the severity and intensity of labor are shown.

This characteristic allows to identify which optimization factors should first be focused on: improving the working environment, reducing severity or reducing intensity of work, or creating a comprehensive system of measures that ensure optimization of all aspects of the work activity of workers [4].

The distribution of groups of causes of accidents at work is presented in Pic. 3. Dynamics of indicators of industrial injuries, excluding accidents, the occurrence of which the workers themselves could not influence, indicates a decrease in the total industrial injuries [2].

2.

Let's consider the characteristics of intensity of labor of workers of track and facilities. It is based on taking into account the requirements that the profession of a track worker makes to higher mental functions and the emotional sphere [4].

The track economy is the largest in JSC Russian Railways and includes 395 structural divisions [1, 2]. And although among them, the repairmen of artificial structures are less than 1/40 of the number, they have the highest injury rate, which makes it necessary to look for new ways and means to improve safety and preserve the health of workers.

The intensity of the analyzer functions of a person (hearing, sight) is due to requirements for fulfillment of his production functions. The sharpness of attention is caused by the need to simultaneously monitor a large number of objects or long-term focused observation. Emotional tension of the linemen is most often required when performing various stages of work on an exact schedule [4].

The periods between occupational injuries and occupational diseases are not constant, so they should be considered variable and random, and the intervals between incapacity for work can be called «safe working time». The cases of injuries and diseases themselves have different consequences, which means that recovery time is also a variable depending on the nature of damage and severity of consequences, as well as on individual properties of the organism itself and other factors (timeliness of necessary care, effectiveness of treatment methods etc.).

Due to the fact that when determining the «time of safe work» it becomes necessary to calculate a value that does not have a simple pattern, but represents random variables, it is possible to use the theory of probability [5], which allows to justify a degree of safe operation of a particular production or a site. According to this theory, in the study of hazardous working conditions, the work of a site, a brigade, is considered as a system that operates reliably between the intervals of injuries or occupational diseases. In other words, the production environment is estimated in time from the beginning of the year to the first case of injury, from the first to the second case, etc.

If during the observation period (several months or years) at the work of a number of brigades or sections it was revealed that injuries occur at approximately equal intervals of time, then the probability of safe work during a given period can be calculated by the formula

$$P = (1 - T_s / NT)^n, \quad (1)$$

Table 2

Injury rate and work experience of victims

No.	Work experience (years)	Number of victims, %
1.	up to 1 year	13,9
2.	from 1–5	29,1
3.	from 5–10	22,4
4.	from 10–15	11,7
5.	from 15–20	9,0
6.	from 20–25	7,6
7.	over 25	6,3
	Total	100

Table 3

Injury rate and age of victims [1]

No.	Age (years)	Number of victims, %
1.	below 20	0,5
2.	from 20–30	17,95
3.	30–40	32,25
4.	40–50	26,0
5.	50–60	22,0
6.	over 60	1,30
	Total	100

Table 4

Results of determining the flammability of wood

Name	Value of a critical incident heat flux, kW/m²							
	12,5	15,0	17,5	20,0	22,5	25,0	27,5	30,0
Unprotected wood	580*	220	145	90	85	70	50	45
MPVO	ni**	140	125	120	110	100	100	90
Asfor	ni	210	150	145	120	90	70	65
Ograks-B-SK	ni	ni	220	110	55	30	20	15
Negorin	ni	ni	370	60	55	50	50	45
Asfor-Extra	ni	ni	ni	730	230	150	125	110
SGK-1	ni	ni	ni	220	120	80	60	60
Ograks-PD-1	ni	ni	ni	450	320	240	175	125
OZK-45D	ni	ni	ni	660	300	140	85	60
Pirilaks	ni	ni	ni	780	255	200	130	80

Notes: * — numbers in the table show time (s) before the samples ignite, they are the arithmetic average of three measurements; ** — samples did not ignite within 900 seconds of exposure to heat flow.

where P – probability of safe operation; T_s – specified time interval for which the value of P is determined; N – number of brigades or sections of bridge construction crew; n – number of injuries in N brigades over T.

The results of calculations are considered reliable, i.e. providing the main condition – work safety in the period T_s, in the case when the value of P corresponds to safety of labor: $P \geq 0,95$. If the probability of safe work is less than 0,95, then there can be no complete confidence in safety of this category of workers for the period T_s.

Indicators of likelihood of safe work of various teams of track workers (in particular, bridge construction crew sections) are given in Table 1. These data make it possible to judge that workers of different professions have different probability of safe work in a certain period of time. Having such values, hazard assessments for a specific team, specialists of the labor protection service are able to carry out preventive measures in a timely manner. In the absence of clearly defined intervals between injuries or occupational diseases, the volume of facts under study should be increased by attracting additional materials on related teams.

Obtained on the basis of the calculations carried out data on accumulative danger of injury for a certain time and knowledge of existing dangerous situations help to more accurately allocate funds for carrying out nomenclatural health measures and carry them out within a reasonable time frame.

3.

According to the criteria of reliability, bridges are in the first group, that is, devices that do not have a reserve. Damage to them, as a rule, leads to a violation (termination or restriction) of movement [1, 6].

Currently, 43 % of bridge brigades [2] are recruits, young men. Their age is from 20 years. There was a change in generation of workers of bridge construction crews. The number of experienced installers aged 30 years and older has decreased. Naturally, this affected the conditions of work and injuries. Injury rate taking into account the experience is given in Table 2, and in Table 3 – indicating the age of the victims.

The analysis shows that in recent years severity of consequences of injuries continues to be serious, which is explained by increasing complexity of construction and installation work, a sharp increase in the pace of construction, a decrease in the level of organization of production, insufficient professional training of managers, as well as direct executors of tasks.

The distribution of failures of bridge structures has a pronounced peak in the summer period [7].

In summer, there is a significant increase in the amount of work carried out, usually with a known shortage of staff. In these months, as the most traumatic, it is necessary to strengthen training with a detailed analysis of typical accidents. It is necessary to carry out more frequent checks on the procedure for issuing and processing outfits, the presence of safety certificates. In addition, training sessions, sudden inspections of the procedure for compliance with technological and labor discipline, compliance with instructions and observations made by representatives of control instances and public inspectors will undoubtedly benefit.

According to the criteria for reliability of bridge structures, it has been established that reinforced concrete bridge structures are the most dangerous, since many combustible building materials are used in their construction [8, 9].

The number of combustible building materials used in construction of reinforced concrete bridges includes various primers, paints, mastics, etc., and, most importantly, wood [10, 11].

Wood, as is known, is mainly used as a formwork for construction of reinforced concrete bridge structures. How dangerous it is can be judged by the fire that occurred on the bridge across the Golden Horn Bay [12]. The fire occurred on the formwork of one of the supports. The fire area was about 500 square meters. The fire was localized only after 15 hours. According to the data of the Far Eastern Regional Emergency Center, 167 people and 38 pieces of equipment were involved in extinguishing.

The choice of pine wood for formwork is determined by tradition and standard: it is the most common building material in construction of bridge structures. Pine wood is recommended in NPB 251-8 as a reference material in determining the effectiveness of fire protection groups.

In accordance with classification of building materials adopted in SNiP 21-1-07, all the studied compounds leave wood – pine in the B3 group – highly inflammable materials.

Dry pine wood contains (in %): 49,5 – carbon, 6,3 – hydrogen, 44,1 – oxygen, 0,1 – nitrogen. The main chemical components of pine wood are cellulose and lignin. The rest: hemicelluloses, pectin and mineral (mainly calcium salts) substances [1, 9].

In work [13] it is noted that by the criterion of flame retardant efficiency, all flame retardants can be divided into three groups: classical means, conditionally new, means of the new generation.

Conditionally new means provide the group of flammability of wood G2, provided that a saturated layer of fire retardants is created in the surface layers of wood. They have longer periods of preservation of flame retardant properties, but there are also negative qualities: presence of unpleasant odors, aggressiveness to various materials that are part of building structures.

Means of the new generation possess high quality indicators for fire protection, providing a group of flammability G1. They are compatible with most weather resistant coatings.

Samples for the study were prepared in accordance with the recommendations of GOST 30244-94.

Flame retardants were applied with a brush in compliance with the technologies recommended by manufacturers of flame retardants [13]. Experimental data obtained in the experiments are presented in Table 4.

Observations on the change in the state of the surface of the samples during their irradiation by external heat flux show that noticeable thermal transformations begin already at heat fluxes of 15 kW/m^2. A further increase in density of heat fluxes is accompanied by more intense charring of the irradiated surface, formation of cracks in the surface layer and ignition of released thermal decomposition products.

Unprotected wood ignites when the incident heat flux is 12,5 kW/m^2. All flame retardants (impregnations, varnishes, paints) increase the limiting value of the incident heat flux, which leads to ignition of wood treated with flame retardants.

With an increase in density of the incident heat flux to 15,0 kW/m^2, wood treated with the compositions of MPVO and Asfor ignites, at 17,5 kW/m^2 with the compositions Negorin and Ograks-V-SK, at 20,0 kW/m^2 – with SGK, Ograks-PD-1, OZK-45, Pirilaks, Asfor-Extra compositions.

With a density of incident heat flux of 20,0 kW/m^2, all tested wood samples ignited. It should be noted that ignition time of fire-protected wood (with exception of Negorin lacquer) is increased: from 90 s for unprotected wood to 780 s. For large values of the heat flux density, the period of time before ignition of untreated and protected wood differs insignificantly.

Conclusions. The results confirm the preliminary conclusions about the effect of fire protection on flammability of wood: the effect is manifested in a more intense charring of the surface layer, which creates a barrier to heat the underlying layers, and in a decrease in concentration of combustible gaseous products of thermal decomposition.

The results of the experiments allow to determine the directions of improvement of flame retardants, including through the use of additives that maximize the degree of expansion (thermal expansion) of the coatings. When using such industrial compositions as Pirilaks, OZK-45D and Asfor, an increase in the rate of their consumption on the surface to be protected can be recommended.

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