Regulatory support of occupational safety in the construction industry and transport

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Abstract. Occupational injuries rates in the construction industry and transport remain at an unacceptably high level both in Russia and in a number of other countries. According to the world statistics, one of six fatal accidents at work occurs during construction works. Even in industrialized countries, 25% to 40% of all reported fatal accidents occur during construction work, although only 6% to 10% of the total workforce is employed in this industry. The same ratios are peculiar to Russia. According to official statistics, fatal occupational injuries in the country's construction industry average 20% of the total number of such accidents, although the average number of workers in the construction industry for 2004-2019 does not exceed 7% of all workers. Management measures for occupational safety in construction related to controlling and reducing the risk of injury are not based on any special calculations, quantitative justifications, or application of optimization methods. In the field of inspection arrangement, there are no convincing methods to determine the control program, its results, the level of actual occupational risk, and the necessary time spent on administration of control. The existing causes of accidents in construction are formulated in a generic form, without details, which does not allow indicating specific preventive measures. In this regard, it is important to search for new approaches, methods and means of improving safety, as well as developing preventive measures in the management of occupational safety in the construction industry and transport.

1. Introduction

The safety problems of construction operations and transport are reflected in numerous works that were published in the Soviet times. However, most of the research data cover only the general issues of occupational safety in the construction industry with little to no consideration of questions of justification of methods for solving relevant problems of occupational safety, as well as problems of identification of causes of construction injuries and transport, and optimization of occupational safety and health control. The presented framework of assessment of the level of occupational safety in construction and the rationale for selecting preventive measures are very few and have not been widely adopted. In recent years, the basics of safe work in construction and transport have been considered in the works of the authors Broder J., Hughes P., Ferret E., Kamardeen I., Winge S., Hola B., Maryani A. A., Holt Allan [1-10]. However, despite the significant contribution to the solution of the problem by the scientists in question, the regulatory support, as well as the plan of preventive measures, the organization and planning of inspection are not sufficiently developed. In addition, these works are not related to the assessment of occupational risks in the construction industry, in particular, occupational risks in construction per unit of labour effort are not studied.
Moreover, the authors of the article studied certain issues of occupational and injury risks in the construction industry and transport [11-14].

2. Materials and Methods
The scientific basis of the conducted research of the regulatory support of occupational safety in the construction industry and transport was the solutions of a number of scientists on the problems of creating effective management systems in the field of occupational safety, as well as modern optimization methods. The need for further development of strategies to improve the regulatory support of occupational safety in construction has determined the line of the study, its purpose and objectives. The research was conducted on the basis of the empirical data, namely the investigation records of accidents in the construction industry, the official statistics on occupational injuries in Russian construction organizations.

The research is aimed at substantiating and developing a system of measures to improve the regulatory support of occupational safety in construction, for which the following has been conducted:
- the analysis of development of regulatory support of occupational safety in construction and transport;
- the analysis of the current state of occupational injuries in the construction industry and its dynamics over a number of years;
- the study of the causes of construction injuries, the identification of technical conditions that cause accidents in construction;
- substantiation and development of methods for optimal management of reducing the risk of injury in construction with the use of the data on the causes of accidents, their significance, the cost and effectiveness of preventive measures.

3. Results
The assessment of existing occupational risks is crucially important for the effective management of occupational safety in construction organizations. In accordance with the legislation, an employer, based on the specifics of the activity, must establish the procedure of implementing the following measures for management of occupational risks: identification of hazards; assessment of occupational risk levels; reduction of occupational risks levels. As one of the most difficult production industries in terms of ensuring safe working conditions, the construction industry is characterized by a wide range of occupational risks affecting workers in the course of work. The risk of an accident at work might depend on the following reasons: the presence of industrial hazards in a workplace, working in the danger zone, the duration of work in the danger zone, the state of protective equipment, the area of the injury-risk factor.

The risk of accidents in the construction industry depends on a number of quite specific factors, namely the depth of excavation; the number of storeys of buildings and structures under construction; the state of technical equipment, the state of lifting machines and earth movers and equipment; the correctness of use of loose lifting gears taking into account the type of the conveyed load; the work process technology; the quality of technological documents (a construction management plan, a plan of production of work, a flow diagram); adherence to schedules for combined works, etc. Regulatory and technical support plays an important role in reducing occupational risk and conducting preventive measures. However, regulatory legal acts in the field of occupational safety in construction are being changed too quickly – every 10 years on average.

Occupational injuries are one of the main indicators characterizing professional risk in the workplace. Over the past two decades, a contradictory situation has been observed. Against a backdrop of virtually unchanged labour conditions and occupational safety, the registered rates of occupational illnesses and injuries are decreasing at Russian enterprises, including the construction industry. Thus, in 2019, the number of fatal accidents in construction companies decreased by 2% compared to 2018, and by 61% compared to 2006. The overall frequency of industrial accidents is decreasing at a particularly rapid rate, which many researchers associated with the concealment of a
considerable part of minor injuries. However, the availability of complete and reliable information on values of occupational injury indicators is an essential condition for the development of programs on the reduction of occupational injuries and improvement of functioning of the occupational risk management system in the construction industry.

Table 1 presents the analysis of the statistical data on injuries in Russia both in general and in construction works in particular [15, 16]. Figures 1 and 2 display the number of victims, including fatal cases, in a workplace in 2019 in Russia in different industries, according to statistical observations. According to Figure 1, percentages according to the number of accidents were distributed as follows: 34.39% of the accidents occurred in the manufacturing industry; 13.76% - in transport and communications; 12.71% – in healthcare; 9.57% – in the agricultural sector; 7.88% – in the construction industry; 6.81% – in the mining industry; 3.70% – in production and distribution of electricity, gas and water; 2.15% – in water supply; sewerage, waste management and remediation activities; 2.63% – in wholesale and retail trade; and 6.47% of accidents relate to other sectors.

According to Figure 2, 20.09% of fatal cases occur in the manufacturing industry; 16.59% – in transport and communications; 2.46% – in healthcare; 14.41% – in the agricultural sector; 15.73% – in the construction industry; 11.56% – in the mining industry; 7.79% – in production and distribution of electricity, gas and water; 2.75% – water supply; sewerage, waste management and remediation activities; 4.27% – in wholesale and retail trade; and 0.85% - of fatal cases relate to other sectors.

| Industry                                           |Victims of accidents at work with disability for one working day and more and fatal case; persons | Fatal cases |
|----------------------------------------------------|-------------------------------------------------------------------------------------------------|-------------|
| **Russian Federation, total**                       | 23343                                                                                           | 1055        |
| manufacturing                                      | 8027                                                                                           | 212         |
| transport and communications                       | 3212                                                                                           | 175         |
| healthcare                                         | 2968                                                                                           | 26          |
| agriculture                                       | 2234                                                                                           | 152         |
| construction                                       | 1823                                                                                           | 166         |
| mining and quarrying                               | 1590                                                                                           | 122         |
| production and distribution of electricity, gas and water | 864                                                                                           | 79          |
| water supply; sewerage, waste management and remediation activities | 501                                                                                           | 29          |
| wholesale and retail trade                         | 614                                                                                           | 45          |
| other                                              | 1510                                                                                           | 9           |
Figure 1. Number of all recorded occupational accidents in different industries, 2019.

Figure 2. Number of fatal accidents in different industries, 2019.

Figure 1 shows that 7.81% of all occupational accidents occur in the construction industry. Occupational accidents in manufacturing account for 34.39% of all injuries. As for fatal injuries,
according to Figure 2, construction ranks third since 15.73% of such cases occur at work in this industry. It appears that one in six fatal accident occurs in construction.

In order to clarify the causes of injuries in construction, source materials on accidents in construction companies have been studied. In the research under consideration, the technical causes of injuries included those for the elimination of which it was necessary to introduce technical measures such as closing the opening in the floor deck, safety fencing, installing safety canopies to prevent objects from falling from elevations, and increasing the strength of remote platforms for receiving construction materials. The study allowed indicating specific causes of accidents, most of which (up to 80%) are of technical nature (Table 2). Thus, there is a need to improve the engineering infrastructure of the construction industry.

Organizational causes (shortcomings of technological documentation, that is a construction management plan, a plan of production of work, a flow diagram, shortcomings of training and instruction of workers on occupational safety, violation of occupational safety instructions, etc.) lead to up to 20% of accidents. The rate given in Table 2 can be applied to arrangement of inspection of occupational safety on construction sites.

Table 2. Elaboration on the causes of accidents in construction.

| Name of the causes of occupational injuries in the construction industry | %   |
|------------------------------------------------------------------------|-----|
| The lack of safety canopies                                            | 2.60|
| Collapse of scaffolding due to unreliable bracing, the fall of scaffold towers and other scaffolds | 5.84|
| Lack of a leveled platform for storage of various building materials on the construction site, lack of flat pallets | 5.19|
| Lack of special protective technical equipment in a company (drums with a retractable rope, safety catches) that prevents an employee from falling when working at height | 7.79|
| Unclosed or insufficiently securely closed and free-standing horizontal openings in the floor deck, cellar ladders, unclosed and free-standing vertical openings in the walls | 20.13|
| Dangerous collapse (ground failure) during excavation                  | 7.14|
| Lack of fencing of danger zone                                         | 7.79|
| Incorrect selection or malfunction of loose lifting gears              | 5.84|
| Malfunction or lack of safety appliance on lifting cranes, as well as other failures of construction machinery and mechanisms | 3.90|
| Insufficiently reliable bracing and inadequate provision of safety of disassembly of a formwork during concreting | 8.44|
| The collapse of the scaffolding platform due to the insufficient strength | 2.60|
| The lack of fencing around a construction site                         | 3.25|
| Vehicle collisions on a construction site                             | 2.60|
| Collapse of remote platforms due to unreliable bracing                 | 1.30|
| Organizational causes                                                  | 15.58|

4. Discussion
Systematic inspection of occupational safety in a construction company involves its implementation at all facilities under construction, contractors and workplaces. The activity of a general contractor is of great significance in this field of concern. Organizing combined works, a general contractor must take into account safety requirements, and in the course of works, exercise oversight and control over compliance with these requirements by all involved subcontractors. Practice has shown that if a general contractor is not assigned, or not given the proper authority, the coordination of work is not correctly ensured, various violations, including violations of safety requirements, are committed, and potential accident situations emerge inevitably.
Basing on the experience, as well as taking into account the specifics of construction operations, three-stage inspection of occupational safety in a construction company can be carried out according to the following scheme.

The first stage of inspection is carried out by the immediate supervisor of works (a foreman) together with an authorized inspector (a representative by law) of occupational safety. The occupational safety service, together with construction specialists, should prepare a corresponding notice or control program that takes into account the specifics of the construction work being performed (excavation, masonry, roofing, filling openings, finishing works, etc.). Inspection should be carried out before and during the shift. Detected violations that could not be promptly eliminated at the level of the immediate supervisor of work should be recorded in the first-stage inspection log and they should be reported to the next level of management provided by a construction company.

The second stage inspection in a construction organization should cover an object under construction, which might be a building or a structure. The inspection should apply to all teams that are involved in the construction of the object. This inspection can be carried out by a special commission led by a person appointed by a construction manager. It can be the head of the general contracting organization. In order to carry out the inspection, either the heads or representatives of all subcontracting organizations must be included in the corresponding commission. If the construction of an object is conducted by one large construction company, the second stage inspection commission can be led by the head or their representative in charge, and the heads of all structural divisions involved in the construction should be included as members of this commission. It is recommended to carry out the inspection at least once a month.

In Russia, there are large construction organizations that are building several objects simultaneously. For such organizations, it can be recommended to conduct a third stage of inspection, which must be carried out every three months, and the corresponding arrangements should be organized as occupational safety day. The corresponding commission should be led by the head of the construction company or their representative in charge. During the inspection, the labour conditions and occupational safety at all objects under construction must be checked. In case of their remoteness, several commissions can be appointed. Based on the results of the inspection, proper orders and other management decisions should be prepared. At the same time, the quality of inspection at the previous stages is inspected.

5. Conclusions
The conducted theoretical and experimental investigations presented in the article allowed obtaining the following scientific results:
- the findings of the analysis of regulatory support of occupational safety in construction have been obtained. It has been discovered that, at the present time, the revision of regulatory and technical documents related to the provision of occupational safety and health in construction is carried out without using the results of the analysis of causes of accidents;
- the practiced management measures, including those aimed at reducing the risk of injury in the construction industry, can be developed on the basis of modern optimization methods, taking into account the significance of causes of accidents;
- based on the study of source documents prepared immediately following the results of investigations, elaboration on causes of increased injury risk in construction has been carried out, the significance of specific causes has been indicated;
- a general optimal strategy for the arrangement of inspection of occupational safety on the construction site has been developed. This strategy allows for the actual time needed for inspectors, the thoroughness of meeting the requirements for the construction site, the number of people working on the construction site, the results of a general analysis of occupational injuries in construction companies;
- the methodology for the development of programs on the reduction of injury risks in construction, which allows for the significance of causes of accidents, the effectiveness of the proposed preventive
measures, the total costs for developing and implementing the programs, the cost of planned activities, has been explained. When developing programs, computational procedures of dynamic programming can be applied.

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