Optimization of the organization of the construction process of structural elements of monolithic buildings

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Abstract. The modern construction market dictates strict rules for labor productivity, product quality, optimality and cost-effectiveness of processes. The need for a tool to optimize the organization of the construction of structural elements of monolithic buildings is a significant issue in the construction process. In the field of organization of construction production, the main role is played by the organizational and technological decisions that have a direct impact on the processes and results of construction activities. Optimization of the organization of the process of constructing structural elements, which is the possibility of reducing the construction time of structural elements of monolithic buildings through the use of effective organizational and technical solutions, or by adjusting inefficient organizational and technical solutions characterized by a complex quality indicator, is an urgent task in the field of research. Thus, the goal of optimizing the organization of the process of constructing structural elements is to reduce the duration of work and reduce labor costs. Based on the results of field observations, the influencing factors determined on the parameters that affect the organization of the erection of structural elements of monolithic buildings have been established. The necessity of taking into account all the main influencing factors of the model in order to achieve an objective characteristic of the effectiveness of the organizational process is noted. A possible direction for the development of the study is to expand the scope of application of the results of the study in the organization of various construction processes. The expansion of statistical data, computerization and programming of organizational structures in the construction process remains an urgent task for the development of the direction.

1 Research of organizational and technical solutions in the construction of structural elements of monolithic buildings

In the course of the study, the fundamental stages of the construction of structural elements of monolithic buildings were noted, the structure of organizational processes was analyzed [1; 2]. Sources are considered that give definitions of organizational and technical solutions, production organization for the construction processes of structural elements of monolithic buildings [3; 4].

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The study area was determined based on current trends in terms of the active use of concrete as a building material. According to information agencies, the annual volume of world concrete production has exceeded two billion m^3 and, while about 26-30% is accounted for by housing and civil construction.

It is with the industrial method of production of critical structures that special quality control and optimized organization of processes are required. Water, aggregates, additives, and reinforcing cage must have the characteristics corresponding to regulatory documents and project documentation. The organization of the design and construction process of structural elements of monolithic buildings should be aimed at making optimal and effective organizational and technical decisions at all stages of the capital construction [5].

One of the most important aspects of the construction of monolithic buildings is to ensure the safety and operational reliability of building structures [6, 7]. Requirements for the mechanical safety of buildings are listed in the Federal Law of December 30, 2009 No. 384-FZ "Technical Regulations on the Safety of Buildings and Structures". Mechanical safety is the most important factor in the construction of structural elements of monolithic buildings.

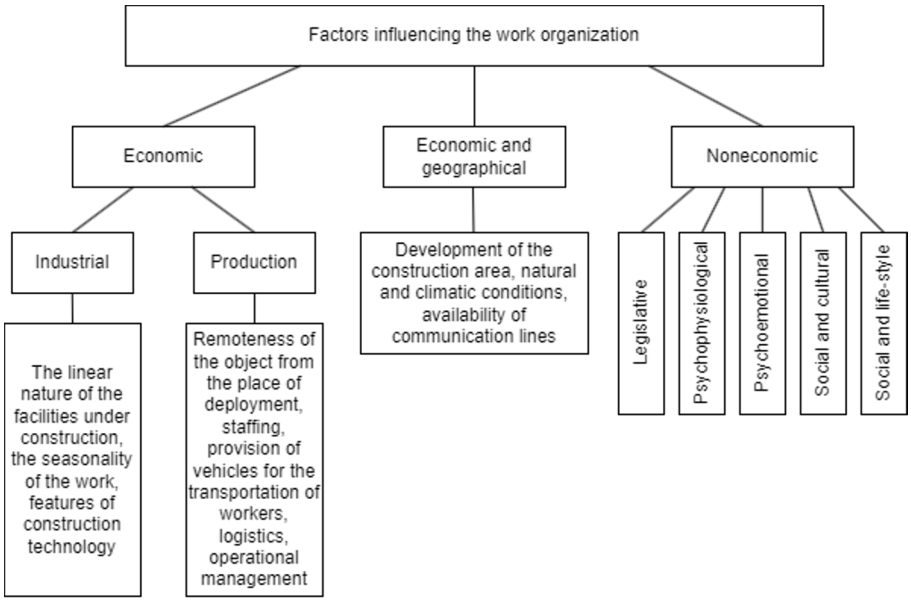

Fig. 1. Classification of factors influencing the work organization

The concept of organizational and technical solutions is disclosed as a detailed description of technical schemes, foundations and principles for the implementation of any processes (in this work, the processes of designing structural elements and their construction processes), taking into account technical, economic and organizational measures.

When choosing the optimal solutions for organizing the construction of structural elements, the purpose is to choose a way to use resources of various kinds, ensuring the achievement of the desired result in the most efficient way.

From a mathematical point of view, the optimization problem can be formulated as finding such values of some variables that satisfy a number of restrictions, under which the maximum (minimum) of a certain function is achieved.

One of the primary tasks of designing a rational technology and organizing the production of construction and installation works is the choice of a method for their implementation [8]. The choice of a work production method means the development and consideration of all possible options, as well as the choice and justification of the most rational (optimal) of them

for given specific production conditions. The method of carrying out the building process depends on the building object; means of production (tools, mechanisms); work performer (links, teams); used materials, products and structures.

To reasonably choose the most appropriate work method for the given conditions (installation of building structures (Figure 2)), it is required to study the following issues:

– organization of the construction process (selection of the installation direction, installation sequence, enlargement degree, logistics and delivery of structures and building materials);
– method of work performing (selection of a set of machines and mechanisms performing the installation process);
– methods and means of performing certain construction operations (rigging and gripping, lifting and installation of individual structures on supports, alignment and temporary fixing);
– management of the construction process (control of deadlines, priority, and quality) [9].

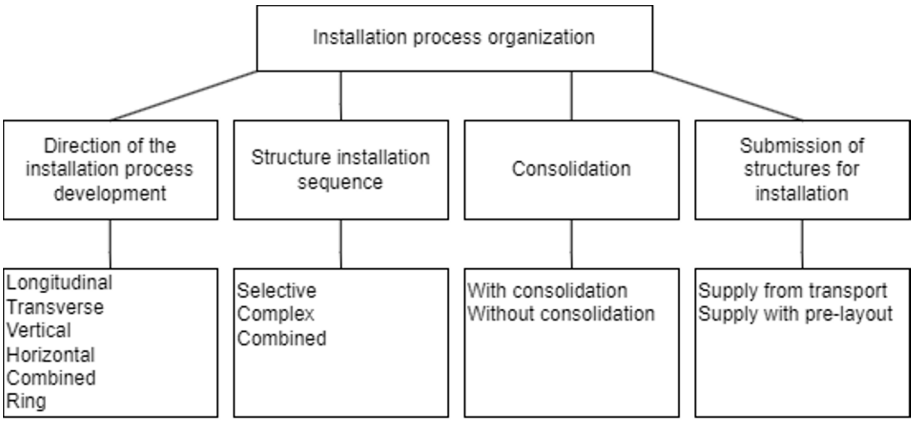

Fig. 2. Installation options

To implement these issues, design and construction methods based on basic mechanisms are used. However, the use of automated software systems and software, modern machines and mechanisms, tools and devices has made it possible to significantly optimize some organizational and technical solutions [10–12].

2 Identification of influencing factors

The result long-term monitoring the state of structural building elements was a list of factors that clearly affect the quality of organizational and technical solutions in the construction of load-bearing structures. The grouping of factors was carried out according to the principles of the sequence of construction production, where group one are factors at the stage of design and survey work, and group two are factor at the stage of construction and installation work.

As a result of the experiment, a list of influencing factors was formed. The first group (design and survey work) includes five factors determined by 14 parameters.

The quality of engineering and geological surveys includes the following parameters:

1. The work program is approved by the general designer;
2. Actual work performed meets the requirements of normative documentation and approved work program;
3. Scientific and technical support.

The quality of engineering and geodetic surveys contains the following parameters:

1. The work program is approved by the general designer;
2. Scientific and technical support.

The quality of engineering and environmental surveys is determined by the following parameters:

1. The work program is approved by the general designer;
2. Scientific and technical support.

The quality of project documentation contains the following parameters:

1. Application of BIM technologies;
2. Availability of subcontracting design organizations;
3. The average experience of the project team employees is more than five years;
4. Scientific and technical support for design.

The quality of working documentation contains the following parameters:

- Availability of scientific and technical support for design;
- Detailing and individualization of working documentation;
- Compliance of working documentation with the requirements of the approved project documentation.

The second group of factors relates to the stage of construction and installation works and includes the following factors:

The quality factor of construction control determined by the following parameters:

1. Permanent presence of construction control at the construction site;
2. High-tech devices and equipment;
3. Timely input quality control of building materials, products and equipment;
4. Timely operational quality control of individual construction processes or operations;
5. Timely acceptance control of the work performed.

The quality of field supervision includes the following parameters:

1. Conducting supervision by the developer of project documentation;
2. The constant presence of employees of the architectural supervision service in the work area.

The quality of technical customer service is determined based on the following parameters:

1. An engineer for labor protection and safety in the staff;
2. A process engineer in the staff;
3. An engineer in the production and technical department;
4. An engineer for load-bearing building structures;
5. High degree of communication and process control.

The quality of scientific and technical support for construction is determined by one parameter:

1. Scientific and technical support service.

The quality of the general contracting organization is determined by the following parameters:

1. An internal quality control service, the availability of enterprise standards and internal regulations of the organization;
2. The share of work completed, based on the total volume, is more than 50%.

The level of automation and mechanization of production contains the following parameters:

1. Availability of modern high-performance equipment for lifting and moving goods;
2. Modern high-performance small-scale mechanization.

The factor of qualification of teams of engineering and technical workers is determined by the following parameters:

1. Work experience of at least 5 years in the activity field;
2. Higher education in the activity field;

3. Advanced training in the activity field;
4. The category of concrete engineers is not lower than 3rd;
5. The category of reinforcement engineers is not lower than 3rd.

The quality of formwork systems consists of two parameters:

1. Availability of mobile unified formwork systems;
2. Application of an individual project for the selection of formwork systems.

The quality of the organizational and technological scheme for the construction of monolithic structures consists of the following parameters:

1. Packing and pre-bundling of small items;
2. Timely provision of measures for the concrete care;
3. Availability of technological maps adapted to the construction site;
4. Detailing and individualization of working documentation.

The quality of executive documentation is divided into the following parameters:

1. Completeness of as-built documentation;
2. Compliance with the requirements for execution of as-built documentation;
3. Registration timeliness;
4. Availability of an electronic form of executive documentation.

The quality factor of engineering and household preparation of production is determined by the following:

1. Placement of the residential town corresponding to the approved project documentation;
2. The presence of supply interruptions (electricity, water, heat, etc.).

The natural-climatic factor contains the following parameters:

1. Construction in a high temperature zone;
2. Construction in a low temperature zone;
3. Construction in the zone of active seismic processes.

The quality factor of the supplied materials, products and equipment contains the following parameters:

1. The supplied materials, elements and equipment comply with the approved design and working documentation;
2. There are no significant defects.

The “other” factor takes into account the individual characteristics of the construction object and contains two parameters:

1. The building uniqueness;
2. Dense urban development.

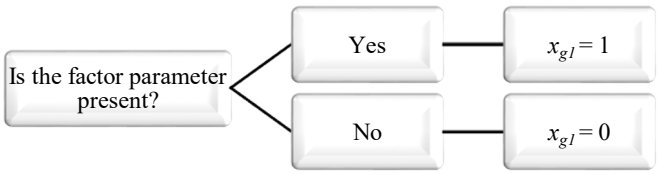

Fig. 3. Schematic diagram of determining the value of the input signal parameter g1

The number of *g* parameters inside the *J* factors varies from one to five, depending on the factor complexity. Let us consider the determination process (Figure 4) and the establishment of an indicator of parameters using the example of a natural and climatic factor.

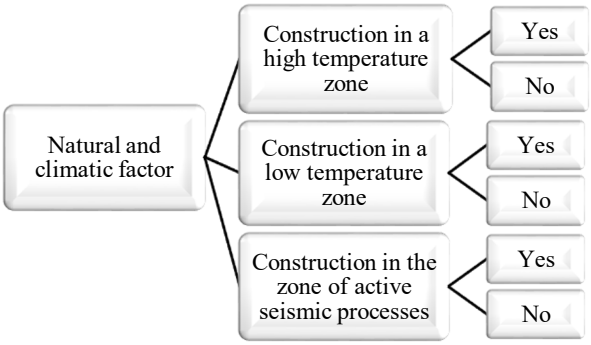

Fig. 4. The structure of the deterministic factor "natural-climatic factor"

3 Formation of a methodology for optimizing the construction organization of structural elements of monolithic buildings

To implement the mechanisms for calculating a comprehensive quality indicator of organizational and technical solutions, it is necessary to generate initial data containing information about the parameters of the system: the construction stage, the availability and degree of readiness of reports on the results of engineering surveys, the availability and degree of readiness of design and working documentation, a positive examination conclusion, information on the initial permit documentation, the degree of construction readiness of the facility, data on construction participants, personnel qualifications and other characteristics to fill in the "input signal value" field.

An important step in launching the calculation algorithm is the correct activation of factors and parameters. Missing parameters should be assigned values of 0 for subsequent exclusion of parameters from the artificial neural network and parametric model, respectively. The factors that have not passed the activation threshold due to the low value of the parameters will be automatically excluded from the calculation.

At the next step in the implementation of the methodology, it is necessary to assign values to the activated parameters. If the parameter is present, the value is 1, if the parameter is absent, the value is 0. After setting all 55 parameters, the next step is started.

The mechanism for calculating the values of each neuron of the artificial network starts automatically after confirming the set values of all system parameters. The displayed data allows us to evaluate each influencing factor separately. The logical operation of the conjunction continues with the automatic calculation of a complex quality indicator of organizational and technical solutions in the form of a numerical value in the range from 0 to 31.2. The resulting value is interpreted using the Harrington verbal-numerical scale and is located in one of the ranges: "satisfactory" or "unsatisfactory".

If a result is satisfactory and a complex indicator of the quality of organizational and technical solutions exceeding the value of 22.8, the calculation is completed, measures to optimize the organization of the construction of structural elements are not required. At the same time, the parametric model makes it possible to increase the indicators of individual factors in order to achieve even higher values of the complex quality indicator of organizational and technical solutions. These activities are implemented through the application of recommendations.

The second probable result of calculating a complex quality indicator is attaining an unsatisfactory value. In this case, the operator generates a report in which the factors with the smallest single values are described by the inverse method. The parameters that have the worst values need to be adjusted in accordance with a number of recommendations for

optimizing the organization of the erection of structural elements of a monolithic building, after the implementation of which it is required to re-calculate the complex quality indicator of organizational and technical solutions.

Recommendations for optimizing the erection of structural elements of monolithic buildings are formed for all parameters that make up the influencing factors [13; 14]. In the process of training an artificial neural network, the recommendations can be adjusted or supplemented by the teacher based on new precedents.

The methodology for optimizing the erection organization of structural elements of monolithic buildings includes seven stages (Figure 5).

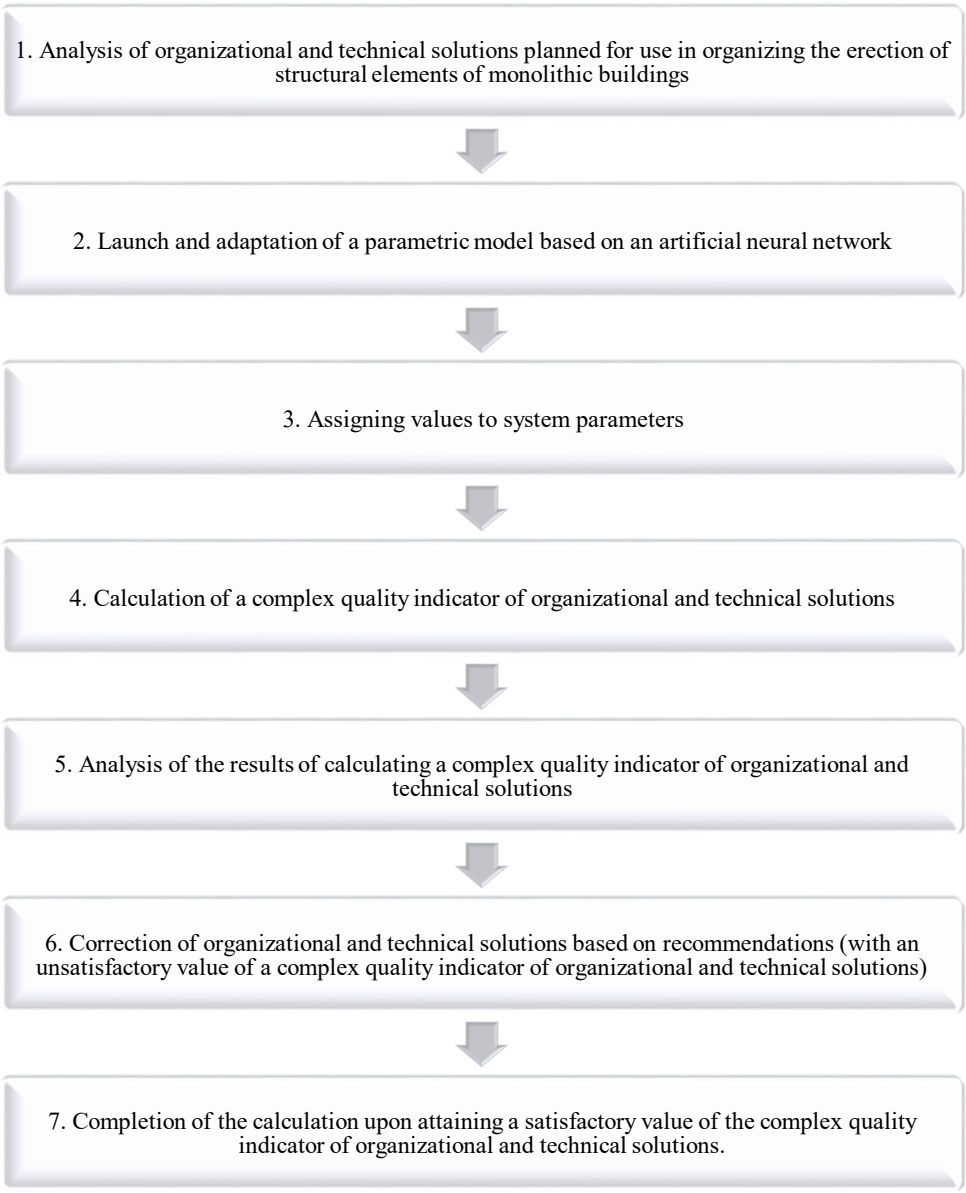

Fig. 5. Stages of implementation of the methodology for optimizing the erection organization of structural elements of monolithic buildings

1. Analysis of organizational and technical solutions planned for use in erection organization of structural elements of monolithic buildings. Depending on the stage of construction, the operator collects initial data before the start of the calculation in order to determine their completeness, reliability and applicability.
2. Launch and adaptation of a parametric model based on an artificial neural network. The operator needs to adjust the parametric system for a more accurate calculation of the complex quality indicator of organizational and technical solutions. It is necessary to determine the stage of construction: design and survey work or construction and installation work. It is possible to calculate the value of a complex quality indicator of organizational and technical solutions after the completion of construction and installation works to generate statistical data and apply them as a training sample to train an artificial neural network.
3. Assigning values to system parameters. The parametric model implies the participation of the operator at the initial work stage to assign the values of the system parameters. The information from the initial data is transformed into a certain value from 0 to 1 in the "input signal value *x*" field of each neuron *J*. The synaptic weights are checked, and the automated calculation process is started.
4. Calculation of a complex quality indicator of organizational and technical solutions. Iterations are performed automatically using an artificial neural network. After passing the signals of all layers of the artificial neural network, indicators of factors are formed, which are converted into a complex quality indicator of organizational and technical solutions.
6. Analysis of the results of calculating a complex quality indicator of organizational and technical solutions. The resulting value is in the range from 0 to 31.2, while the parametric model generates a qualitative interpretation of the numerical value with the options "satisfactory" or 'unsatisfactory'. If the value is satisfactory, the operator generates a report on the calculation and makes a conclusion about the effectiveness of the organizational and technical decisions made. At the same time, it is possible to increase individual indicators of factors through the application of recommendations (if necessary). In case of an unsatisfactory result, the operator generates a report with a list of individual recommendations for each system parameter.
7. Correction of organizational and technical solutions based on recommendations with an unsatisfactory value of a complex quality indicator of organizational and technical solutions.
8. Completion of the calculation upon attaining a satisfactory value of the complex quality indicator of organizational and technical solutions.

Thus, the methodology for determining a complex quality indicator of organizational and technical solutions contains 7 stages and has variability depending on the value attained (satisfactory or unsatisfactory) [15].

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