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RESEARCH OF THE INTERCONNECTIONS OF THE "STRUCTURE - TECHNOLOGY - MECHANIZED EQUIPMENT" SYSTEM IN THE CONSTRUCTION OF FRAME BUILDINGS

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The article was developed and implemented for calculation models of the frame building and the lifting module bu using computing complex Autodesk Inventor. The dimensions and number of models elements allow to correctly investigate the technical structure. The basic scheme of connections in determining the structural scheme of the building, the method of its construction, and technical means of implementation is considered. Actuality of this work is the need for qualitative analysis of interrelated solutions in construction when using new construction technologies and modernization of mechanized support for their implementation.

Modern approaches to the formation of the structure of the building frame are analyzed. The main propouse is based on using of lifting assembly modules to reduce the specific share of the use of heavy crane equipment at the construction site.

Approaches to the formation of a system for monitoring the construction process, in particular the installation of the covering, were also considered.

Based on the results of the research, technical solutions are proposed to support the process of installing the building covering, which take into account the structural features of the building and are formed taking into account the functional features of the construction technological process .

Key words: structural calculation, frame buildings, technology, mechanized equipment, lifting module, stress-strain state, geodetic control.

1. Introduction

The construction of frame buildings is gaining more and more popularity due to its speed, energy efficiency and the possibility of implementing various architectural solutions. However, the effectiveness of this process largely depends on the optimal combination of structural solutions, technological processes and mechanized equipment. Construction with a reinforced concrete frame is one of the most important branches of modern engineering. Constant research in this field allows us to create more and more perfect and reliable designs that meet the requirements of modern life.

The issue of researching modern frame systems of buildings and structures is described in works [1, 2, 17, 18]. The rationale for the use of frame construction technologies is given in works [10, 11]. Modern designs of mechanized equipment to support the technological process of frame construction are considered in works [3 - 7].

The system "structure - technology - mechanized equipment" is interconnected and affects all stages of construction of frame buildings. In the part of consideration of the structures of buildings and structures, the materials of the building structures, the type of frame, the dimensions of the elements, the connections are considered - all this determines the construction technology and the necessary equipment. At the choosing construction technologies for the implementation of construction processes, the methods of assembling the frame, insulation, sheathing and internal finishing, which come from the structure of the building, are selected too. The type, size, modes of operation of mechanized equipment and machines realize the implementation of construction technologies. The interrelationships of mechanized equipment, construction technology and the implemented construction object are closely related to each other.

Separately, it should be noted construction monitoring, which functions in parallel with the construction process itself and independently of it, but affects its implementation [19]. When erecting frame houses, monitoring is especially important, since the overall strength, durability and energy efficiency of the building depends on the correct execution of each stage.

In work [1], the advantages of frame construction are defined, which include: speed of erection, economy, energy efficiency, ease of construction, flexibility of planning, seismic resistance. Frame buildings can be prefabricated, monolithic and prefabricated-monolithic. In frame buildings, the main vertical load-bearing structures are columns or pylons, and the horizontal ones are beams.

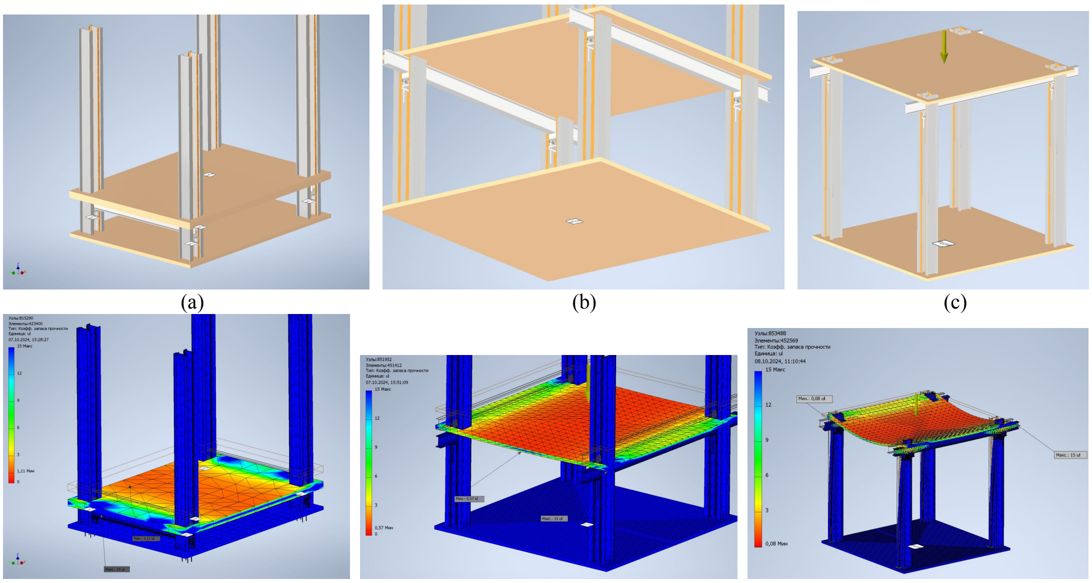
2. Research analysis

Consider the scheme of a long-span frame building [10]. Here, a building with a height of 24 m, with a covering area of about 40,000 m^2, the mass of which is 1,100 tons (Figure 1). Such buildings are arranged for the maintenance of overall equipment, the placement of complex production equipment, etc. In the example, a rectangular arrangement $A_1 \times B_1$ of support elements is used. The supporting elements form prefabricated columns with a cross section $A_2 \times B_2$. The limitation of the values A_1, B_1, A_2, B_2 is the operational stability of the structural elements of the building object. For this, it is effective to use reverse engineering, when taking into account the materials of the structural elements and their initial cross-sections, the limit dimensions of the structure are determined while ensuring its resistance to the load.

Simulations of loads on the structure are performed taking into account [13-16].

In the course of the simulation, the following initial conditions were selected: the material of the columns is steel; the floor material is reinforced concrete, the unit pressure, which takes into account the weight of the floor and the possible placement of technological equipment, is from 1 to 20 MPa.

Examples of the results of modeling internal stresses in the elements of building structures using Autodesk Inventor software is shown in fig. 1.



(a) (b) (c)

(d) (e) (f)

Fig. 1. Structural scheme of the building object: (a) – initial stage of installation of the covering; (b) – the intermediate stage of lifting the coating; (c) – rise of the covering to the design mark; (d) – modeling of internal loads in the structures of the building at the initial stage of lifting the covering; (e) – the same at the intermediate stage of lifting the coating; (f) - also precisely at the stage of installation of the coating on the design mark

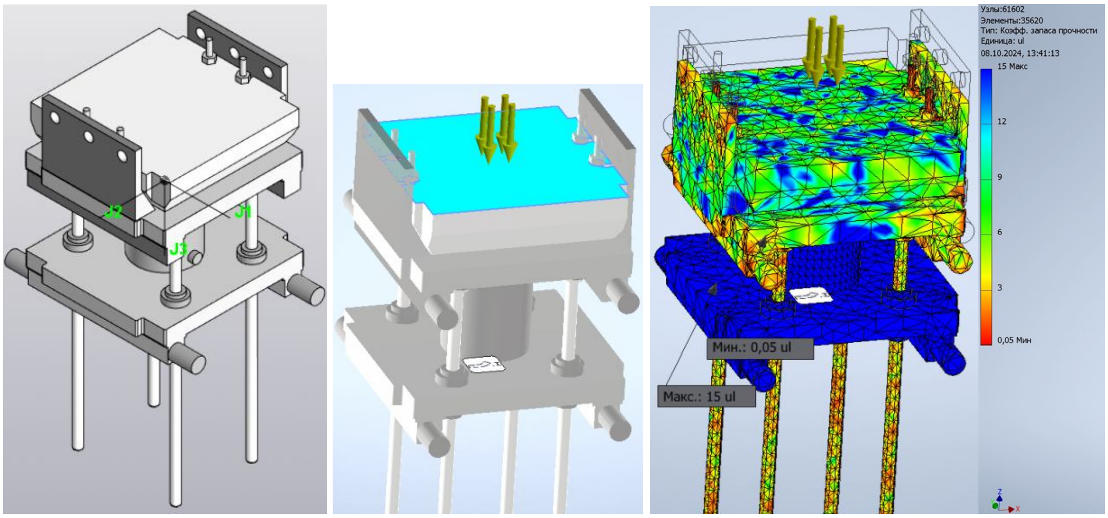
As a result of static modeling of the internal loads of building structures, under the condition of ensuring stability, their maximum dimensions are determined, which affect the adoption of organizational and technological decisions to ensure the construction process.

When considering construction technologies, in particular, the lifting of long-span coverage to the design position, the following main indicators are used [10]: reality of process implementation, erection speed, energy efficiency.

Solution [2] is used to set the construction overlap in the design position. Here, a cyclic method of lifting the covering is used due to the use of mechanized equipment implemented in the form of a hydraulic lifting module [10-11]. In this case, the cyclic method of lifting the covering acts as a determining method of implementing the construction task - the basis of the work execution technology.

At the same time, the choice of technology with cyclic lifting, on the one hand, directs the choice of structural placement of supporting elements and their cross-section, and on the other hand, determines the composition of mechanical support for the lifting process. So, according to the technology of lifting the covering with the lifting module [10], its placement takes place in the inner space of the supporting elements. For this purpose, the support elements themselves are prefabricated with the organization of sufficient internal space within one column to accommodate the lifting module. The lifting module rests on the column through special hooks, and its frame serves as a support for the floor.

To implement the proposed technology, a lifting module of cyclic lifting (Fig. 2) [10] is used.



(a) (b) (c)

Fig. 2. Lifting module: (a) – general view; (b) – calculated scheme;
(c) – the result of modeling internal loads in module elements

The design of the lifting module is based on approaches to the formation of new designs of machines [5], which function within more complex systems and perform certain functions [7-9].

The lifting module consists of a double-action hydraulic cylinder, lower and upper platforms, safety rods. The hydraulic cylinder body is fixed on the lower platform of the module. The rod of the hydraulic cylinder is attached to the upper platform of the module. In the upper and lower platforms of the module, lifting fixing mechanisms with extendable support cylinders are installed. The locking rods are attached to the upper platform of the module and pass through sliding nuts that are fixed to the lower platform of the module. Guide profiles fixed on the inner surfaces of paired frame columns are provided for support of lifting fixing mechanisms.

The working cycle of lifting the lifting module is repeated and is implemented by resting the coating on its upper platform.

The magnitudes of the values of the lifting process, such as the speed of lifting the structure and the weight of the structure, are ensured by ensuring the parameters of the lifting module, in the case of using a hydraulic drive: the values of the pressure in the power drive and the supply of the working fluid (Fig. 3) [9].

Taking into account the number of lifts, the theoretical capacity of the lifting modules will be

$$N_H = \frac{N \cdot n}{\eta_H},$$

where η_H is the hydromechanical efficiency of the pump.

The components of the lifting module are formed as a separate dependent system [7].

The stability of the lifting module is characterized by the rigidity of its own frame and the power capabilities of its driver (Fig. 2, c).

Based on the results of sketch modeling, weak points are identified that require strengthening or changing constructive solutions.

The main technological indicators of the proposed lifting module:

- **Productivity:** 1 mm/s. On 6 m - 24 cycles . Cycle 250 mm – 5 min lifting, measurement, technological settings. The duration of the cycle is 10 - 30 minutes.
- **Power:** the power of the lifting module is determined by the working pressure in the system (MPa) and the diameter of the power cylinder (mm).
- **Reliability:** the mechanical system of the lifting module ensures the reliability of its frame structure, and the hydraulic drive - the implementation of its movement modes. Fixation of module positions – by hydraulic and mechanical means. The electronic control system of the hydraulic drive allows to implement remote control of its output links and to ensure software execution of its basic movements. The combination of electrical, electronic and hydraulic components allows monitoring of the indicators of the working process of the lifting module.

The prefabricated frame of the lifting module also performs the function of orienting building structures. Thus, due to the adjustment of the position of the supporting part of the lifting module relative to its frame, it is horizontally and vertically shifted relative to the supporting elements of the entire structure and, accordingly, the position of the floor relative to the supporting elements is adjusted.

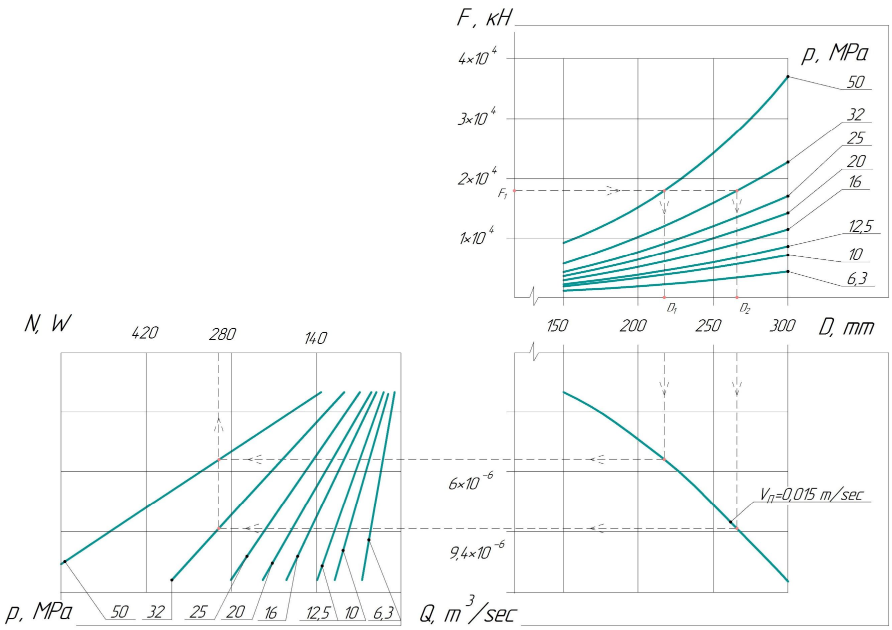


Fig. 3. Nomogram for selecting parameters of the lifting module

The similarity of the processes of the working movements of the lifting module in the technological process of installation of the coating allows to create algorithms for its control.

When forming the composition of the "structure - technology - mechanized equipment" system, a parametric database is developed for typical structures, which can automatically determine the structure and standard size of the system itself.

Regarding the expediency of using technological modules as a whole, at the stage of forming their sets, the requirement to ensure the function of intermediate and final verification of building structures is taken into account, which can be implemented by adjusting the positions of some links of the lifting modules.

Monitoring is an important part of the entire construction process. In our case, the presence of repeated erection stages requires control of the progress of each lifting cycle, which can potentially affect the position of structural elements during the construction process.

At the same time, the main attention is paid to the conformity of the geometric provisions of the structural elements, and if necessary, they are eliminated.

In addition to the usual manual means of control during the organization of construction works [19], the use of digital means of engineering monitoring of movements of construction structures and mechanisms is effective.

Therefore, an important element of the external monitoring of the construction process is the continuous control of the values of the actual coordinates of the characteristic points of building structures and their comparison with the design values to understand the correctness of the geometric parameters in the process of erecting a building or structure [12].

Let's consider the method of monitoring using electronic tacheometers and automated monitoring systems using tacheometers.

An electronic total station is a device that measures horizontal/vertical angles and distances (Fig. 4). The most important characteristic is the accuracy, which can reach up to 0.5” (angular accuracy) and 0.5 mm (linear accuracy) of a single measurement with a single capture of an object up to 40 m.

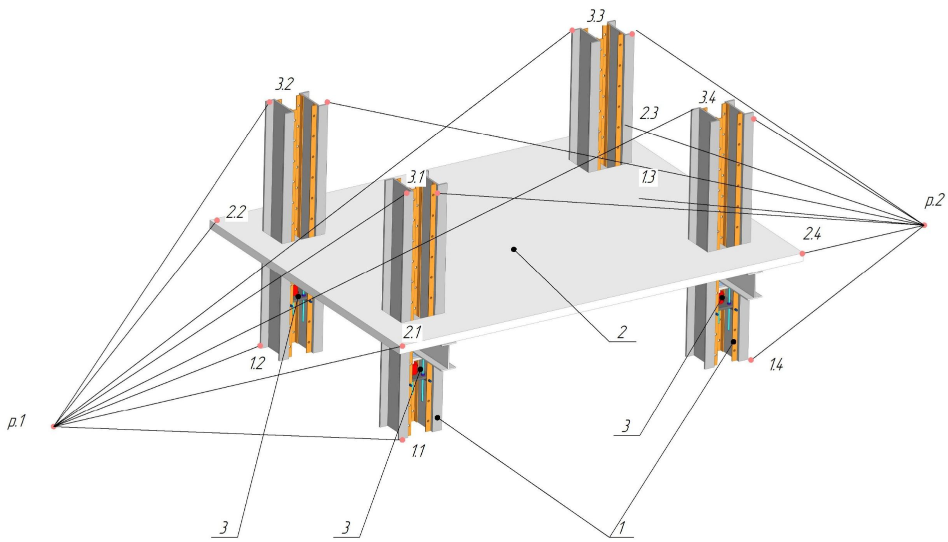


Fig. 4. Scheme of monitoring the installation process of the building covering: 1 – supporting element; 2 – coating; 3 – lifting module; p .1 , p .2 are the corresponding points of placement of geodetic monitoring devices (tacheometers); 1.1-3.4 – basic controlling points (markers)

The disadvantage is that it is impossible to observe several points at the same time, the measurements are performed only sequentially.

Automated monitoring systems with the use of robotic tacheometers allow measurements to be performed without an operator (sports monitor) in an automated mode, consistently.

Therefore, in order to choose a monitoring technology, it is necessary to establish the sequence of execution of technological leveling operations and establish pauses between work cycles for performing measurements.

When analyzing the requirements for permissible deviations of the geometric parameters of building structures, the deviations are in the mm range. Therefore, when choosing the type of monitoring means, preference should be given to stationary ground scanners that meet the accuracy specified in the regulations.

In order to monitor the conditions of building structures in the process of their construction, it is necessary to carry out a discrete check of their condition.

During the performance of works on the construction of the covering of the structure, monitoring should be carried out by means of control of the installation parameters for leveling according to the technical indicators of the lifting module, control of its power parameters, etc., as well as by means of engineering monitoring of its position relative to the design marks of the seizure of the work (Fig. 4).

During monitoring, the number of geodetic posts from which measurements are made and compared with each other is determined. According to the scheme, the values of the provisions of the relevant building structures are determined at the monitoring points, which are grouped by physical and technological features, analyzed and, if necessary, used for the development of coordination measures of the installation process.

The obtained results of the internal stresses of the system components allow, in addition to the formation of the system composition and their corresponding size group, to determine the initial conditions of monitoring by engineering geodetic devices from the considerations of maximum deflections or deviations of the geometric positions of the system components from the design and design-technological ones.

Thus, we can see that the structural scheme of the building is formed independently in the first approximation, but it changes taking into account the technologies of construction work on its construction, which are formed taking into account the technical means of their implementation with independent monitoring of the construction process.

Conclusion

The system "structure - technology - mechanized equipment" is a key factor affecting the efficiency of the construction of frame buildings. Its components can be formed independently, but it is more effective when taking into account certain specificities of each other. At the same time, effective formation of the system composition is achieved, key processes are optimized, and new initial conditions are created for the formation of related processes, such as monitoring, automation, digitalization , etc.

When forming the composition of the "structure - technology - mechanized equipment" system, a parametric database is developed for typical structures, which can automatically determine the structure and standard size of the system itself.

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Рашківський В.П., Ігнатенко О.О., Дем'яненко Р.А., Козак А.А., Дубовик І.В., Заєць Ю.В.
ДОСЛІДЖЕННЯ ВЗАЄМОЗВ'ЯЗКІВ СИСТЕМИ «КОНСТРУКЦІЯ – ТЕХНОЛОГІЯ – МЕХАНІЗОВАНЕ УСТАТКУВАННЯ» ПРИ ЗВЕДЕННІ КАРКАСНИХ БУДІВЕЛЬ

У статті розроблено та реалізовано із застосуванням проектно-обчислювального комплексу Autodesk Inventor розрахункові моделі каркасної будівлі та підйомного модуля. Розміри і кількість СЕ моделі дозволяють коректно досліджувати НДС конструкції. Розглянуто базову схему взаємозв'язків при визначенні конструктивної схеми будівлі, способу її зведення, технічних засобів реалізації. Актуальністю даної роботи є потреба у якісному аналізі взаємопов'язаних рішень в будівництві при використанні нових технологій будівництва та модернізації механізованого забезпечення їх реалізації.

Проаналізовано сучасні підходи щодо формування конструктиву каркасу будівлі. Запропоновано використання підйомних монтажних модулів для зменшення питомої частки використання важкої кранової техніки на будівельному об'єкті.

Також розглянуто підходи до формування системи моніторингу будівельного процесу, зокрема монтажу покриття.

За результатами дослідження запропоновано технічні рішення для супроводження процесу монтажу покриття будівлі, що враховують конструктивні особливості будівлі та формуються з урахуванням функціональних особливостей будівельного технологічного процесу.

Ключові слова: розрахунок конструкцій, каркасні будівлі, технологія, механізоване устаткування, підйомний модуль, напружено-деформований стан, геодезичний контроль.

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Fig. 4. Ref. 19.

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