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Study of functional components of the construction technology modules

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Abstract. The purpose of the proposed article is to study the functional components of mechanized construction technological equipment.

The methodology is based on research and creative approaches. The methods of development analysis, synthesis of technical solutions, and simulation modeling were used. Scientific novelty. The study of the functional components of mechanized technological equipment, the analysis of technical solutions allowed us to substantiate the composition of the construction technological module for the construction of reinforced concrete monolithic structures. The authors proposed the results of the synthesis of constructive solutions that are implemented in the design of vertically mobile formwork, which allows improving the technological performance of the construction process by reducing the use of heavy crane equipment for the construction of vertical building structures. Research results. The article considers important issues of forming the components of construction technological equipment, in particular the formwork module. The proposed solutions ensure the implementation of smooth movement of the formwork module, optimization of the process of peeling the budding forming contour from the concrete layer of the vertical building structure.

Keywords: construction technological module, mechanized technological equipment, construction machinery, running equipment, monolithic structures, optimization of motion laws.

INTRODUCTION

The study of the parameters of the functional components of the construction technological module involves the analysis and modeling of the characteristics of such elements in order to achieve the optimal efficiency of their use.

Optimal efficiency, in our opinion, consists in reducing the material capacity, improving the management of the technological module, expanding its functional capabilities.

In works [1] it was noted that the specific volume of construction works related to the construction of load-bearing structures of buildings is more than 80% of all construction works. It is also obvious that researching the parameters of technological modules for such works with their subsequent optimization is an urgent engineering task.

The purpose of the work is to study the parameters of the functional components of the construction technology module for erecting vertical building structures.

Object of research. Construction technological module for erecting vertical building structures.

Subject of research. Functional, kinematic, power parameters of the components of the construction technological module for erecting vertical building structures.

Let's consider the research object in the conditions of performing monolithic works using sliding formwork systems.

The general technology of concrete works using sliding formwork is considered in works [2]. Optimization of the parameters of construction processes mainly occurs through the improvement of mechanized equipment [3, 4]

The construction technological module for erecting vertical building structures will be presented in the form of a vertically movable formwork [5-9]. Such a module is intended for mechanized support of labor-intensive processes during the construction of vertical reinforced concrete monolithic structures (Fig. 1).

The erection of vertical monolithic structures with the help of sliding formwork takes place "from the bottom to the top", starting from the lower floor. The work technology involves the use of combined formwork systems, including traditional formwork boards. At the same time, concreting of floors for multi-interest structural schemes of buildings is recommended to be performed with a delay of 2-3 floors.

Concreting of vertical monolithic structures at a height of 3,6 m takes place in two stages with a step of 1,8 m, taking into account the overlap, the width of the pylons is 1 m, 1,5 m, 1,8 m, the thickness of the pylons is 350 mm. After the specified movement of the vertical mobile formwork, the building's roof is arranged. Vertical movable formwork (Fig. 2) consists of right and left half-frames 1, which are installed symmetrically around U-shaped guide shields 2 [5]. Halves 1 consist of racks 3, on which rods 4 are hinged. Racks 3 are connected to each other by circumferential rollers 5 with a shield 6 around which a closed tape 7 is placed. Rods 4 are connected to racks 3 by linear ties of variable length 8. At the ends of rods 4, pressure rollers 9 and drive rollers 10 with a drive 11 are installed. Halves 1 with guide shields 2 are fixed relative to each other in such a way that a concreting zone is placed inside, between them. To form a vertical monolithic structure, the sliding formwork is mounted in the design position. For this, the vertical axis of the guide shields 2 must coincide with the axis of the vertical structure. In the lower part, with pressure rollers 9 together with the drive roller 10, the half-frame together with the tape 7 is fixed around the head of the existing vertical structure, and thanks to the ties of variable length 8, the amount of pressing of the half-frame to the guide shield 2 and the required angle of inclination of the racks 3 of the right and left half-frames 1 are set relative to guide shield 2.

The tension of the tape 7 is provided thanks to the circumferential rollers 6. The thrust 4 ensures the rigidity of the concrete contour.

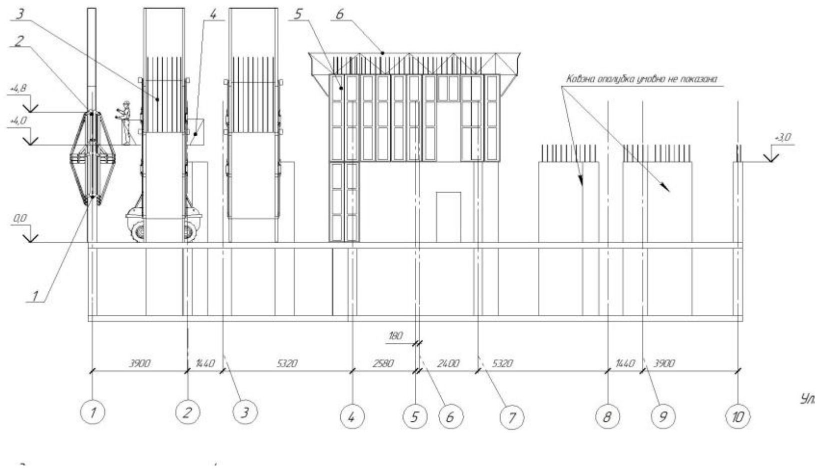
The cavity for concreting is formed by an endless belt 7 and guide shields 2. The profile of the concreting cavity is determined by the geometry of the guide shields 2 and shield 6 by pressures 1. The drive roller 10 is in a normally braked state. After filling the cavity with a concrete mixture and waiting the necessary time for it to harden, the formwork is moved to the next position. Namely: the drive roller 10 decelerates and begins to rotate, creating the movement of the endless belt 7, which in turn rotates the support roller 9.

Concreting of the next tier is underway. The cycles are repeated until the design height of the vertical structure is reached.

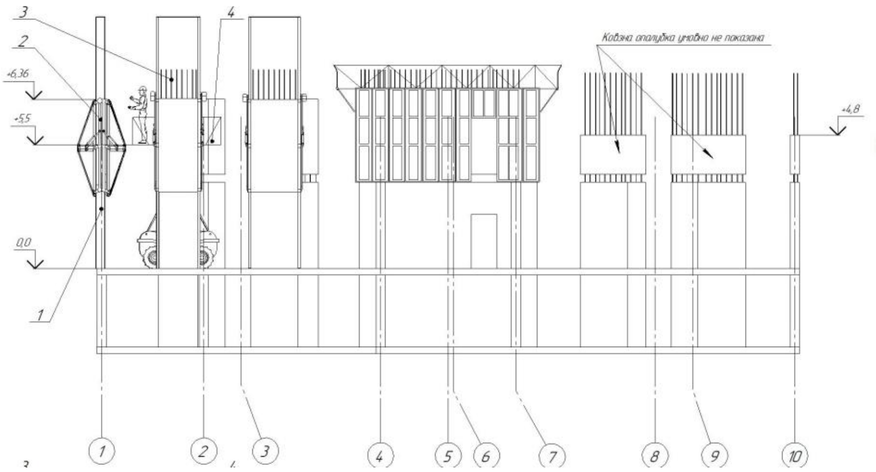
The main functional components of vertical sliding formwork for vertical building structures are: a frame that acts as a stable structure for forming the formwork contour; a moving belt that performs the contact role of equipment with a concrete structure, a forming shield; additional - a driver that ensures fixation and mobility of the technological module, a pressure device that ensures the integrity of the concreting circuit; a cleaning device that ensures the cleanliness of the concreting surface and others.

The frame of the vertical sliding formwork is designed in such a way as to ensure the specifics of technological execution of works (concreting height), stability of the structure (taking into account external forces), attachment of functional parts of technological equipment. For this, its geometric modeling and modeling of work modes (Fig. 3) [10] are performed.

The technological factors that arise in the system "technological module - concrete structure" are: friction of mechanisms in the equipment system; friction of the inner surface of the tape on a hard shield; forces of normal adhesion of the tape to concrete; forces of tangential adhesion of the tape to concrete; friction of tape on concrete; volume mass of concrete; the height of the concrete layer, which has an active effect on the module tape; tensile strength of concrete.



a



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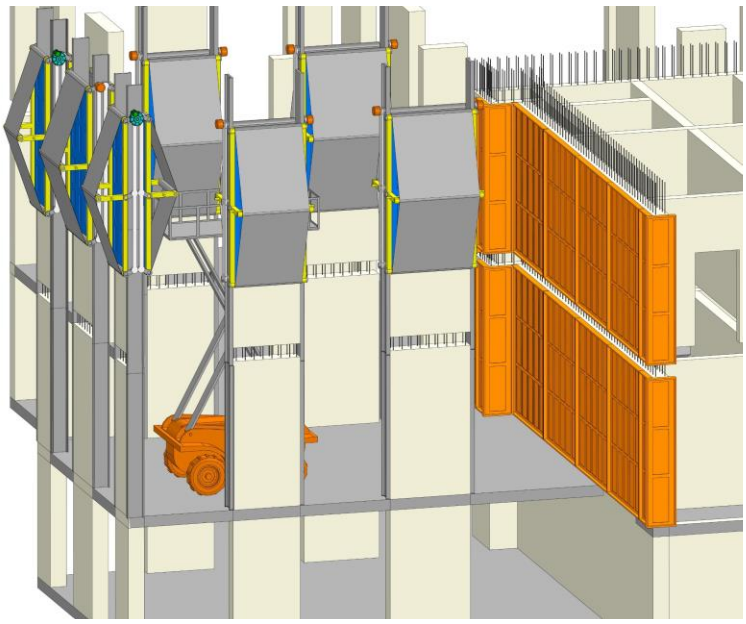

c

Fig. 1. Scheme of erection of vertical monolithic structures using mobile formwork: *1* – pylon of the building; *2* – movable formwork; *3* – reinforcement; *4* – mobile assembly platform; *5* – panel formwork; *6* – subflooring; *a* – moving formwork equipment to a height of 3.0 m; *b* - I stage of concreting from 3.0 to 4.8 m; *c* - II stage of concreting from 4.8 to 6.4 m 3D model

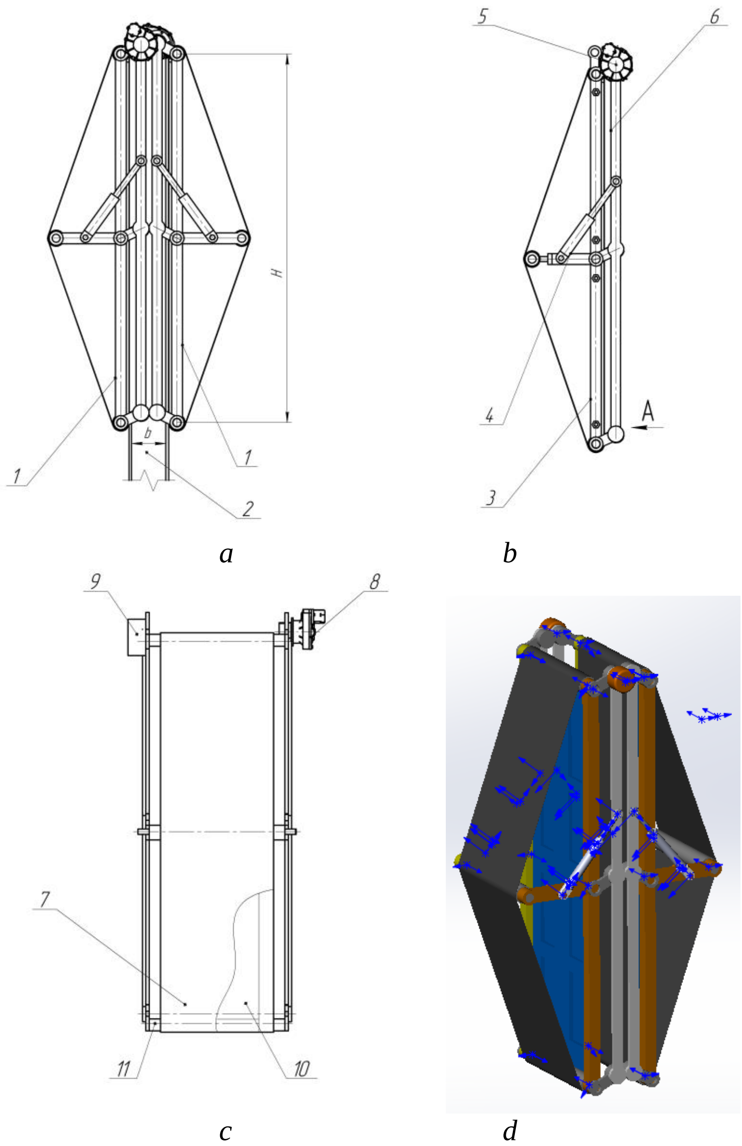

Fig. 2. Vertical movable formwork: *a*, *c* – general views; *b* – type A; *d* – three-dimensional modeling of the construction technology module

The technological module includes a frame on which a pair of guide rollers and one tension roller are placed (Fig. 2).

To determine the efficiency of the sliding formwork belt, we will use the method [11, 12] for the design of belt drives and belt conveyors. The angle of the pulley girth is decisive here (Fig. 4).

The tape is fixed and stretched in the form of an endless loop on the rollers. The formwork shield is rigidly fixed on the frame from the inner side of the tape. At the moment of moving the equipment, the shield rubs against the tape. The friction force of the mechanisms in the μtr1 equipment system depends on the design of the rollers, on the presence of grease in the bearings and increases with the increase in the tension of the tape on the rollers. The friction force of the inner surface of the tape on the rigid shield depends on the material of the formwork shield and the material of the tape, as well as on the strength of the lateral pressure of the concrete mixture *Pb*. We do not take into account the tension of the tape. To ensure the quality of the concrete surface, it is necessary to comply with the condition that the concrete reaches the normal strength of the formwork.

The process of delamination of the concrete mixture occurs normal to the surface of the tape at the time of separation. Cohesion forces in the section *Hb* can exceed the resistance of concrete rupture *Rb* in this section (Fig. 5).

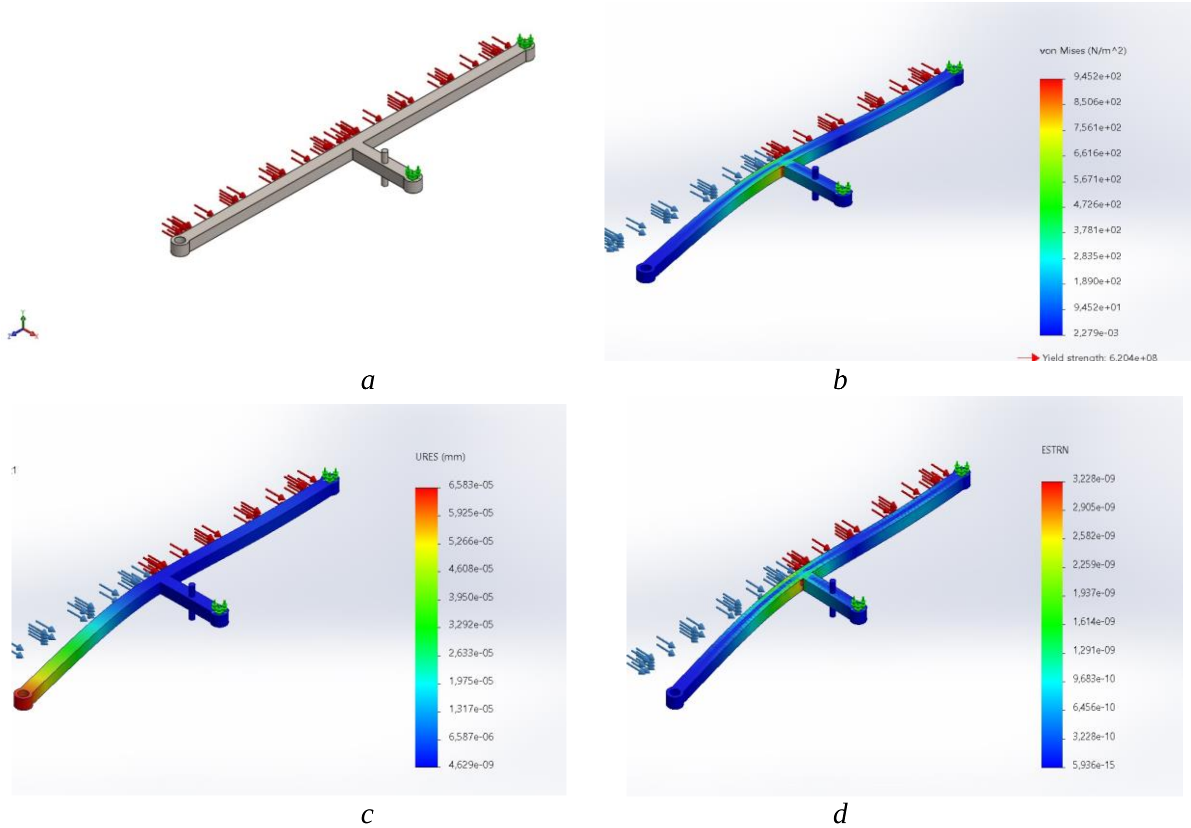

Fig. 3. An example of modeling a symmetrical link of a technological module frame: *a* – load diagram; *b* – von Mises Stress; *c* – Resultant Displacement plot; *d* – Equivalent Strain.

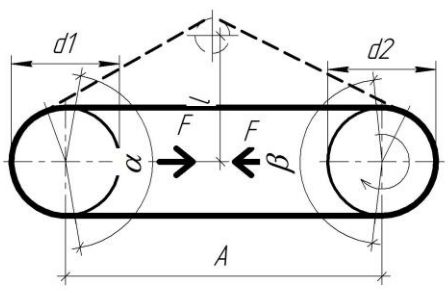

Fig. 4. Calculation scheme of the belt: d1, d2 - diameters of the leading and driven rollers; F is the compressive force acting on the rollers; α, β – the angles of the tape rollers; A is the interaxial distance of the rollers (the height of the movable formwork module)

In this case, separation of the concrete layer will occur from the main mass of concrete, the soluble part of concrete, which, taking into account the size of the protective layer, does not exceed 5...10 mm in thickness [2, 17, 18].

This indicates that for this technological equipment, the size of the area of contact of the tape with concrete does not affect the process of detachment of the surface layer, and the main condition for ensuring the quality of the surface is the anticipatory growth of the Rbt strength over the adhesion forces.

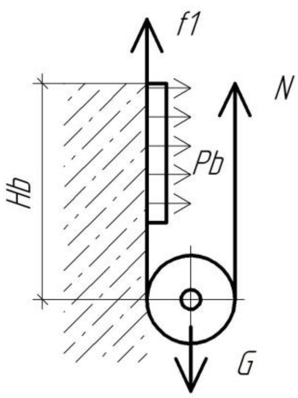

Fig. 5. Scheme for determining the design parameters of the mobile technological module

With a specific weight of the roller of 50 kg/m, taking into account the weight of the tape on a circle of 1/4 π D, which is equal to 200 N, the value of the force N will be within N = 700...825 N at a module width of 1 m. For the vertical movement of the technological module on the concrete without taking into account the friction forces of the tape on the shield, it is necessary to create a torque of the order of 6...10 Nm, in the case of providing a drive from the rollers of the technological equipment.

Modeling of loads acting on the formwork module takes place in accordance with its provisions [13-16], which correspond to the most dangerous technological stages. The results of modeling the formwork module are shown in Fig. 6

It is possible to fix the position of the formwork module in several ways: by fixing the tape of the formwork module (frictional fixation) and with the help of additional braking means and, accordingly, the movement guides of the formwork module (mechanical fixation). In the first case, calculations of the adhesion

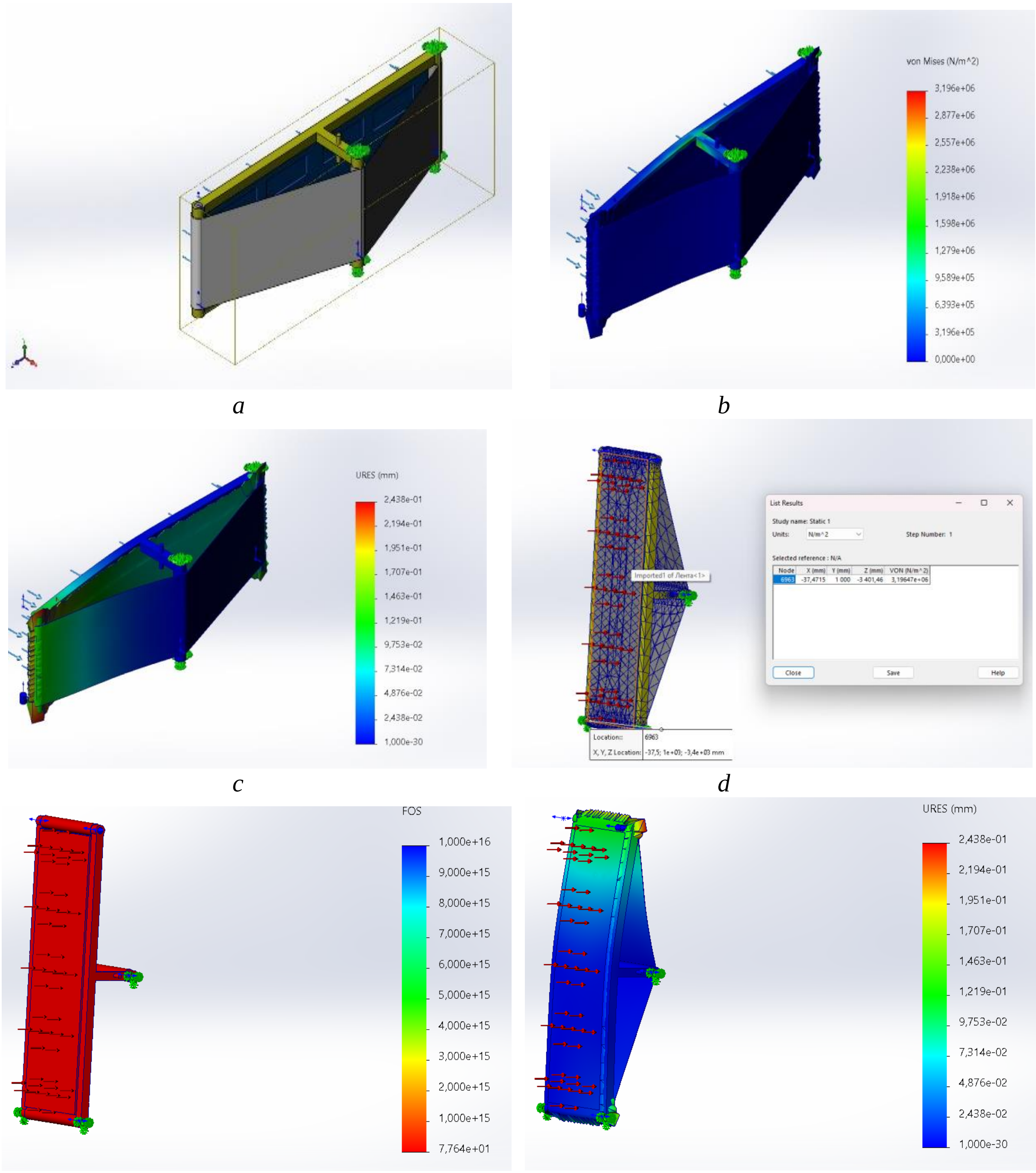

Fig. 6. Results of modulation of loads on vertical movable formwork: *a* – calculation scheme; *b*, *c*, *d* – equivalent loads; *e* – reserve factor; *f* – displacement.

force of the formwork contour with concrete are performed according to the methodology [2]. In the second case, means of mechanical fixation, additional mechanisms and devices are being developed.

The size of the diameters of the pulleys affects the strength of the tear-off force of the formwork module tape from the concrete [2].

The speed of raising the formwork must be determined separately for continuous and periodic concreting technology.

With continuous concreting technology, the movable module must be raised to the height of the embedded layer of concrete mixture in several stages, each time at certain equal intervals of time. In this case, the lifting of the formwork and the placing of the concrete mix are combined in time.

With periodic concreting technology, the mobile module is raised to the height of the embedded layer in the shortest technically possible time after placing a layer of concrete mixture to the entire height of the mobile module.

When moving a movable module with a tape, adhesive bonds are formed and destroyed in a direction perpendicular to the plane of contact, and not in a tangential direction, as happens when moving the shields of the sliding formwork. As a result, growth in the size of the adhesion zone on the contact surface during rolling is quite unlikely, and the bonds are destroyed due to tension, not shear, as in sliding contact. Secondly, during rolling, the adhesive bonds are destroyed gradually and in a smaller part of the contact zone (one by one) in contrast to the simultaneous rupture along the entire plane, which occurs when the sliding formwork is moved. Both of these factors contribute to the reduction of energy consumption and cause low friction in the mutual movement of the tape and concrete, which is very important for the creation of mobile modules with the tape

To level the influence of the size of the lower roller of the formwork module, it is suggested to equip the structure of the mobile formwork with a supporting and cutting element (Fig. 7). Such an additional element performs the following functions. At the initial stage of concreting, when the formwork module is placed on a horizontal base, the support-trimming device performs the function of limiting the formwork contour and allows forming a rectangular connection of the vertical monolithic structure to the horizontal base. The presence of a cutting edge in the support-trimming device allows you to use it to cut the tape of the formwork module from the concrete contour, at the same time leveling the adhesion force in the zone of tearing off the tape when moving the formwork module.

When performing auxiliary trimming of the formwork module tape, the forces of movement of the formwork module are significantly reduced.

The method of lifting the movable module should be carried out taking into account the characteristics of the tape material, the terms of hardening of the concrete mixture, the temperature conditions of the work, the terms of laying the concrete mixture along the entire contour of the formwork, the curves of changes in the mobility of the concrete mixture over time, the step of movement, the technical speed of lifting the movable module.

An example of the schematic implementation of moving the module is shown in Fig. 8.

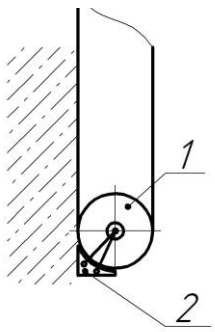

Fig. 7. Layout of the supporting and trimming device of the formwork module: *1* – formwork module; *2* – supporting and trimming device

Implementation of the drive system using a hydraulic drive has significant application limitations. Namely, it is necessary to provide sufficient length of flexible pipelines for free movement of the module in the vertical plane; the pipelines of the system must be flexible; taking into account flexible pipelines, it is necessary to provide movable protection of pipelines with provision of normative bends. However, the advantages of such use should

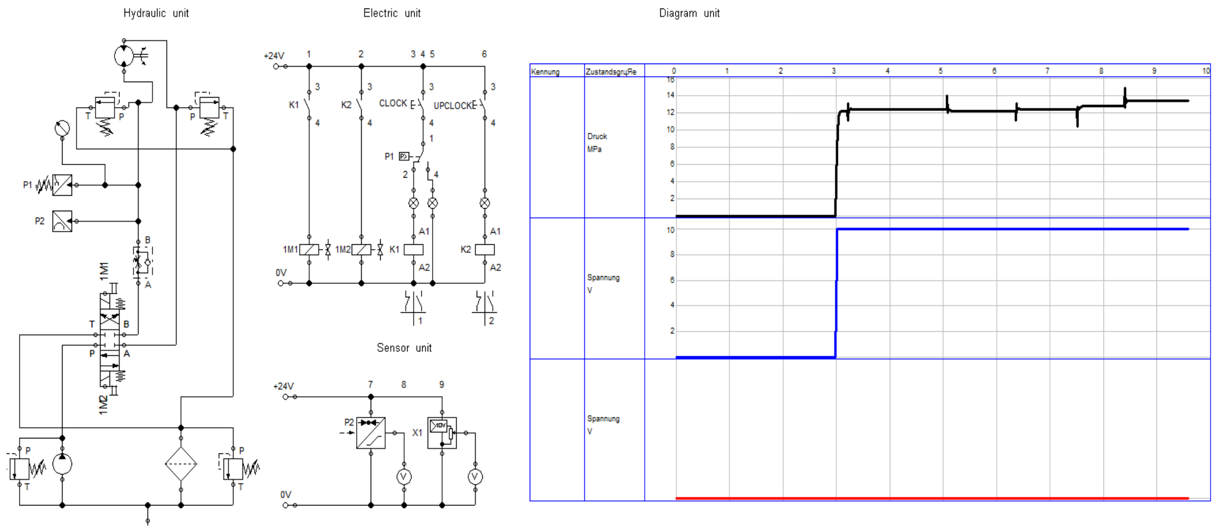

Fig. 8. Schematic implementation of moving the thechological module

also be noted. Namely, the ability to reproduce large efforts, which in the future will allow increasing the useful mass of the module, improving its functionality, for example, by placing additional tools, tools, materials, etc. The use of a hydraulic drive allows you to precisely adjust the movement modes of the module, which significantly expands its functional control. Remote automated and automatic control of the hydraulic drive is also possible [19-20].

The use of the proposed type of equipment ensures high quality of the surfaces of structures even with necessary and accidental interruptions in the concreting process, because during formwork removal, the flexible shields (tapes) are torn off from the concrete along the normal to the surface, not along the plane, but along the line. The use of flexible shields when they are torn off along the line, unlike traditional formwork, allows them to be installed strictly vertically. The vertical arrangement of the shields allows the use of concrete mixtures with greater mobility for structures, which makes it possible to feed and lay the mixtures with concrete pumps. The lifting and horizontal movement of the clamp modules is carried out due to the action of the reactive force from the compaction of the concrete mixture, which simplifies the design of the device [2].

From the qualitative side of the effectiveness of the research results, the justification of the designs of the components of the technological module and the principles of their design opens the way to the systematization and normalization of the components of the tooling devices in the form of functional units of modules. This opens up the possibility of creating a digital information system for mechanized equipment.

CONCLUSIONS

The study of the parameters of the functional components of the mechanized construction technological equipment allows to optimize the technological indicators of the construction process.

The construction of metal structures of technological modules using parametric spatial digital models leads to the filling of the database of information models of technological equipment and can be used in the future for modeling processes and technologies, simulating emergency cases, developing interactive applications for studying the behavior of mechanized technological means when accompanying their construction technological processes.

Modern trends in the development of mechanized construction systems indicate their approach to automatic control, the global introduction of construction robotic systems.

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Дослідження функціональних компонентів будівельного технологічного модуля

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Анотація. Метою пропонованої статті є дослідження функціональних компонентів механізованого будівельного технологічного оснащення.

Методологія базується на дослідницькому та творчому підходах. Використано методи аналізу розробки, синтезу технічних рішень, імітаційного моделювання. Наукова новизна. Дослідження функціональних компонентів механізованого технологічного оснащення, аналіз технічних рішень дозволили обґрунтувати склад будівельного технологічного модуля для зведення залізобетонних монолітних конструкцій. Авторами запропоновано результати синтезу конструктивних рішень, які реалізовані в конструкції вертикально рухливої опалубки, що дозволяє покращити технологічні показники будівельного процесу за рахунок скорочення використання важкої кранової техніки для зведення вертикальних будівельних конструкцій. Результати досліджень. У статті розглядаються важливі питання формування складових будівельного технологічного оснащення, зокрема опалубного модуля. Запропоновані рішення забезпечують реалізацію плавного переміщення опалубного модуля, оптимізацію процесу відшарування бетонувального формуючого контура від шару бетону вертикальної будівельної конструкції.

Ключові слова: будівельний технологічний модуль, механізоване технологічне обладнання, будівельна техніка, ходове обладнання, монолітні конструкції, оптимізація законів руху.