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Development of an information model of the mechanized construction process of vertical constructions

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Abstract. Today, installation works occupy a significant amount of all construction works. At the same time, the efficiency of construction processes largely depends on the availability of technological equipment, its ergonomics, and dependence on accompanying construction processes.

Improvement of mechanized technological equipment in practice allows to optimize the relevant construction process and obtain an economic effect [1].

Increasing the level of mechanization of construction processes is an urgent engineering task that allows improving the technological process on the construction site . It is especially relevant to develop mechanized modules that allow to improve a certain segment of the construction process, in particular to the possibility of using automated control systems.

The process of improving mechanized technological equipment, as a rule, is determined by the conducted research aimed at determining the priority directions for improving such equipment and identifying potential markets, partners and competitors.

Keywords: vertically movable formwork, mechanized technological equipment, information model.

INTRODUCTION

Analysis of the development of mechanized equipment for installation work.

Issues of the methodology of creating new machines are discussed in [2-9]

Patent research, which can be performed using open information sources, is an effective tool for scientific research.

In work [1], the features of information provision of innovations, protection and licensing of intellectual property objects, problems and forms of transfer of modern technologies were determined, which allowed to conduct research in the direction of creating a competitive constructive solution in the form of a mechanized technological module for building vertical monolithic building elements

The primary task of the research is to determine research classes according to the International Classification of Inventions (ICI), search keywords, priority countries and years of research [10].

Of particular interest is the state of development of the issue of creating mechanized technological equipment for performing monolithic works. At the same time, in the concept of mechanization, we include the presence of an individual drive in such equipment, which theoretically will allow redirecting the energy flow from the major machine on the construction site.

We define several key words that will determine the field to which the invention will relate: coating, lift, scaffolding.

Using the International Classifier of Inventions, we find the correspondence of keywords to individual classes (see Table).

To search for patent documentation, information sources on the global Internet will be used: "Google Patents" (patents.google.com), "Espacenet" (espacenet.com), "Ukrainian patent database" (uapatents.com, base.uipv.org). According to the ICI, the required documentation falls into class E04G 11/22, E04G11/26.

According to the selected search subjects, 78 patents were selected for consideration.

Table. Search regulations

No	The main group	Characteristics of the group, subgroup
1	2	3
1.	E04B 7/10	Roofs ; roof structures from the point of view of insulation (structures for roofs and ceilings E 04 B 5/00 ; the ceiling E 04 B 9/00 ; greenhouses A 01 G 9/14 ; large tanks with floating roofs B 65 D 88/34 ; purlins or beams E 04 C 3/02 ; the roof E 04 D) shell designs, for example hyperbolic-parabolic shape; mesh formations acting as shell structures; complex structures
2.	E04B 7/00	Roofs; roof structures from the point of view of insulation (structures for roofs and ceilings E 04 B 5/00 ; the ceiling E 04 B 9/00 ; greenhouses A 01 G 9/14 ; large tanks with floating roofs B 65 D 88/34 ; purlins or beams E 04 C 3/02 ; the roof E 04 D)
3.	E04B 1/343	Construction structures in general ; buildings , no conditioned construction walls , for example partitions, ceilings or of roofs (scaffolding for implementation construction works , formwork E04G ; structures houses special purpose , general planning houses , for example modular system , E04H ; separate parts houses , see in the respective groups for these parts) designs that _ are characterized movable , collapsible or complex in parts , for example for software transportation (movable parts roofs E04B 7/16 ; floating buildings B63B ; small-sized buildings factory making that _ are transported not disassembled , E04H 1/12 ; small-sized garages E04H 6/02 ; tents , awnings or canopies in general E04H 15/00)
4.	E04B 1/344	-//- with hinged ones in parts
5.	E04B 1/35	· special ways and means for construction , for example methods rising floors , supporting blocks for of jacks (E04B 1/34 has advantage _ decking for building on place E04G 11/04 ; walls, floors, ceilings or roofs special forms E04G 21/00 ; transportation construction materials , installation construction elements; work on existing buildings E04G 23/00)
6.	E04G 21/24	methods or devices to prevent or protection from damage to elements construction constructions, including during furnishing works (as auxiliary elements for scaffolding E 04 G 5/00)
7.	E04G 3/00	Scaffolding that _ rely mainly on houses , for example adjustable in height
8.	E04C 3/00	Long-term bearing construction elements
9.	E04B 5/14	Overlap; structures overlaps in view isolation ; connection , specially designed for ceilings with beams laid in two directions
10.	B66F 9/00	Devices for rising or dropping large-sized or difficult loads at performance loading or unloading operations (portable or mobile lifts that _ installed in buildings or connected to buildings and specially adapted for moving from one parts buildings or buildings to another parts or to another buildings or buildings B66B 9/16 ; taps B66C)
11.	B66F 3/00	Devices , for example jacks adapted for lifting _ cargo in process continuous movement (mobile garage jacks B 66 F 5/00)
12.	B66F 1/00	Devices , for example jacks for lifting loads on the given course

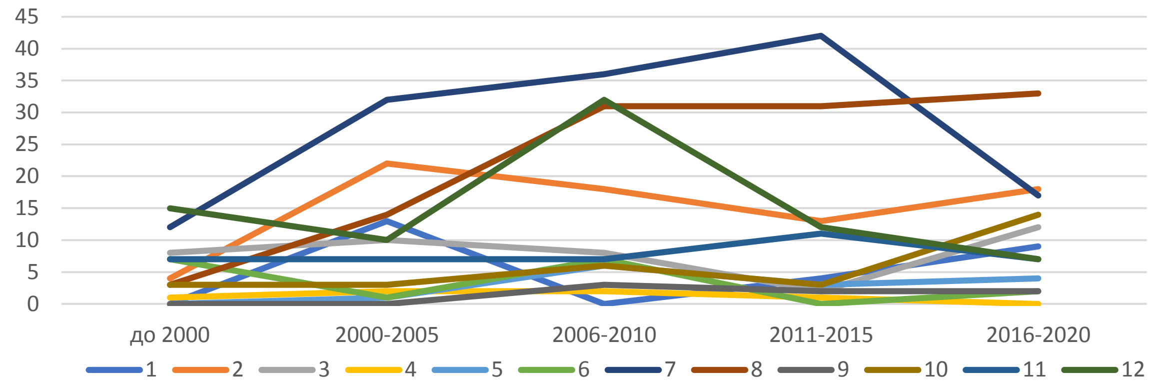

Fig. 1. Dynamics of patenting by classes

Taking into account only the quantitative indicators of patents, it is possible to determine the dynamics of the arrival of new solutions (Fig. 1).

The most interesting, in our opinion, is Ukrainian patent No. u2014 02536 "Vertical movable formwork", in which the task of the invention is to provide the ability to adjust the thickness and angle of inclination of a vertical monolithic structure [11]. This design was developed at the Kyiv National University of Construction and Architecture (Fig. 2).

For this, the formwork frame is made in the form of two symmetrical half-frames, inside which the mixture for a vertical monolithic structure is placed, and the half-frames are connected to each other by a system of hydraulic cylinders, which allows changing the width of the vertical structure and the angle of inclination of the guides. This design allows for free access to the cavity formed by the device, for the installation of fittings or control of the quality of solidification of the mixture. Also, by the system of hydraulic cylinders , control of the applied force on the concrete is ensured.

The mechanized technological equipment consists of right and left L-shaped half-frames 1, which are installed asymmetrically.

L-shaped half-frames consist of racks 2, on which bolts 3 are hinged, and the bolt of the left half-frame is hingedly connected to the free end of the right half-frame .

Horizontal crossbars are made with the possibility of changing their length.

Free ends of the right and left racks half-frame 1 is connected to each other by a diagonal link 4 with the possibility of changing the length.

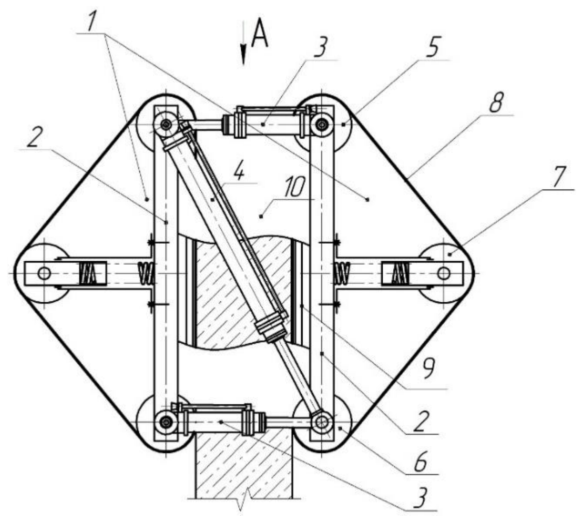

Fig. 2. Vertically movable formwork

Drive 5, support 6 and tension 7 rollers are installed at the ends of the racks of the right and left half frames 1. From the outside, the endless moving tape 8 is placed on the rollers 5-7, the width of which corresponds to the length of the vertically mounted structure. Guide shields 9 are installed inside both half-frames 1 between the drive 5 and support 6 rollers behind the moving belt 8.

Limiting shields 10 are fixed on the sides of both half-frames 1 along the entire height of the racks 2.

Halves 1 with shields 10 are fixed relative to each other in such a way that a concreting zone is placed inside, between them.

Vertically movable formwork works as follows.

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To form a vertical monolithic structure, the vertically movable formwork is mounted in the design position. At this time, the axis of symmetry of the formwork must coincide with the axis of the vertical structure. In the lower part, the vertical movable formwork is fixed around the head of the existing vertical structure with crossbars 3, along with support rollers 6 and an endless belt 8 - the width of the vertical structure is set, and the upper crossbars 3 are used to set the required angle of inclination of the racks 2 of the right and left half-frames 1 relative to each other .

Diagonal beams 4 ensure the rigidity of the frame of the vertical mobile formwork.

The cavity for concreting is formed by an endless belt 8 and limiting shields 10. The profile of the concreting cavity is determined by the geometry of the guide shields 9. The tension of the belt 8 is provided by the driving 5 and tensioning 7 rollers. Drive roller 5 is normally braked.

After filling the cavity with a concrete mixture and waiting the necessary time for its solidification, the formwork is moved to the next position. Namely: the drive roller 5 decelerates and begins to rotate, creating the movement of the endless belt 8, which in turn rotates the support roller 6. The tension of the belt 8 is regulated by the tension roller 7.

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

Simulation modeling of work

To determine in detail the efficiency of the mechanized technological equipment, it is necessary to analyze the operation of the equipment components in the context of the technological process of concreting and forming vertical monolithic structures [5, 6].

By technology concreting pylons [1] is carried out in tiers 1/2 or 1/3 of the height of the floor. To avoid outflow concrete mixtures with sub- module height of the movable module of the form should be 0.3 m more the height of the concreting layer . For example , for a floor with a height of 3.0 m, the height of the tier is 1.5 m, and the height ribbons of the moving module will be equal to 1.8 m. According to the data recommendations for consideration were accepted by floor height of 3,0 m .

After frame lifting with guides is performed moving moving module. At the same time , the module itself rests on the concrete thanks to relevant forced clutch tapes with a concrete surface . Security device forced clutch must create tapes with the surface of concrete additional pressure on concrete .

The reliability factor should be equal to Ks=2.

Constructively recommended mechanisms that separate end shields from guides combine with mechanisms changes sections of formwork forms.

To provide of the necessary taping of the tape in advance arranged parts pylon, as well as taking into account altitude scaffolding that _ intended for stay workers during concreting (placed above the moving module), height guides is accepted universal in the size of 3.5 m for everyone height floors that are considered . The construction of the formwork with a height of 3.5 m tape with a height of 1.8 m allows arrange monolithic reinforced concrete pylons to floor height in two cycles .

The moving module is equipped with a drive that fixed on the frame moving module and moves tape along the guides .

Construction lifting drive allows carry out raising and lowering mobile module and scaffolding independently of each other.

Fastening scaffolding and mobile module on the lift frame is performed in such a way that scaffolding always are above the moving module, therefore taking into account thickness structures scaffolding the mobile module can be raised up to a mark of 3.4 m from the bottom of the lifting frame.

During the finalization of the specified formwork system, it was divided into two independent half-frames with the possibility of vertical movement along the guides (Fig. 3).

Issues of computer modeling are considered in the work [14]. After the schematic proposal is developed, its detailed 3D model is developed with a level of detail of LOD 400 (Fig. 4).

When using a self-elevating formwork (Fig. 5), concreting is performed first for vertical structures with an advance of 1 floor, and then the floor. The self-elevating formwork is set to the initial position at level 0.0 and concreting is performed as for the panel formwork. After the concrete has acquired the necessary minimum strength, the self-elevating formwork is raised to a height at which no more than half of the formwork's height appears as the free volume for concreting.

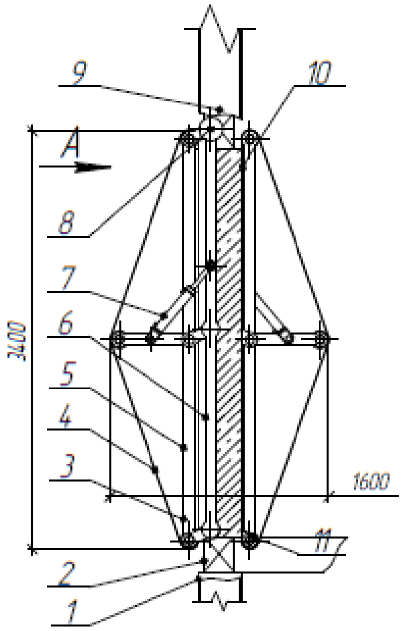

Fig. 3. Mechanized technological module: *1* – vertical construction; *2* – horizontal construction; *3* – oppressive section; formwork shield; *4* – moving tape; *5* – base; *6* – holding section; *7* – oppressive drive; *8* – moving drive; *9* – guide section; *10* – vertical building construction

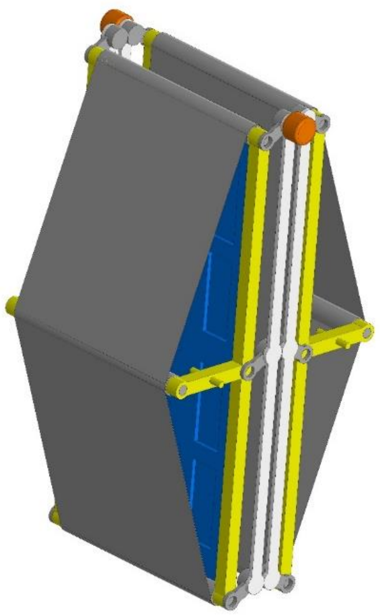

Fig. 4. 3D Model of the mechanized technological module

Technological requirements. Construction structures of frame-monolithic multistory buildings erected using mechanized technological module should be designed taking into account the specific requirements of concreting technology and structural features of the formwork [2].

On building designing recommended :

- grid pylons accept the same for everyone floors buildings ;
- for pylons located one above the other in height buildings, trail appoint are the same cross- sectional dimensions ;
- not allowed design elements that stand out from the structure pylons - trail provide their implementation after arrangement structures pylon. Recommended in this case use collective reinforced concrete and metal designs ;
- pylons should to be designed from concrete class not lower than C20/25;
- the protective layer in the pylons must be at least 20 mm;
- for supporting floor slabs trace provide arrangement embedded parts in the design pylons. At the same time weakening of the cross section should be no more than 0.4 thickness pylon ;
- docking vertical rods fittings pylons is recommended perform at the mark where the action bending moments minimal ;
- reinforcement joints rods in pylons , as a rule, should to be designed on the inside with wire binding without welding ;
- vertical rods fittings pylons should not have on the upper ones at the ends hooks, and length these rods should not exceed 3.5 m;
- the height of the floor should be appoint within 2.8-3.3 m.

From the point of view of safety of maintenance and stability of structures, as an option, it is possible to arrange a retaining belt to guide the movement of formwork modules (Fig. 5, a), as well as to group assembly platforms into a mobile lifting platform.

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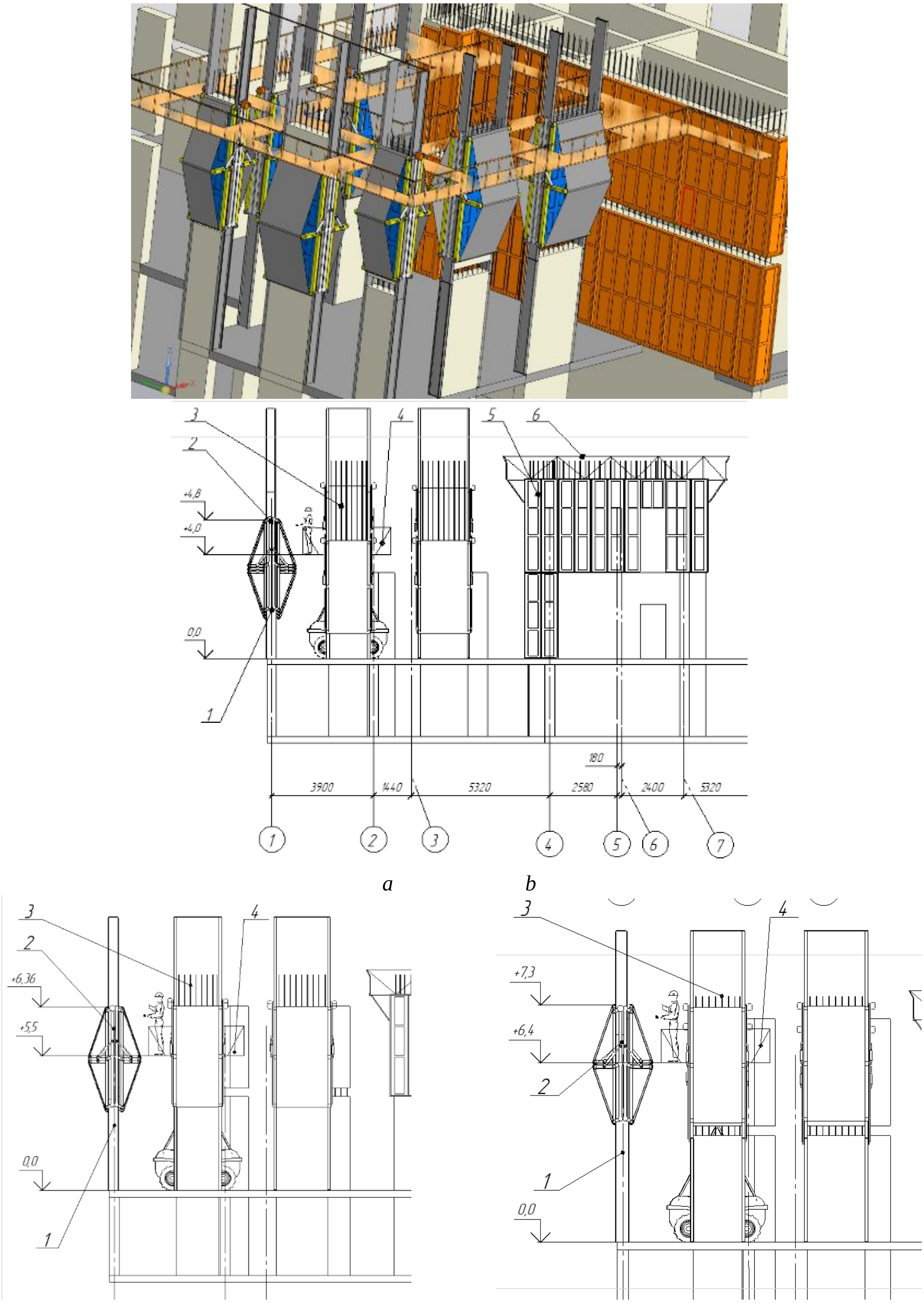

Fig. 5. Modeling of the work of the formwork module: *a* – geometric 3D model of the building object ; *b* - I concreting cycle to height 4.8 m; *c* – II concreting cycle up to a height of 6.3 m; *d* – III cycle of concreting up to a height of 7,3 m; *1* – vertical monolithic construction; *2* – formwork module; *3* – armature; *4* – service installation site

Simulation modeling allows you to determine the structure of the process of building monolithic vertical structures:

$W_{1.1}$ – transition of performers to a new work area ;

$W_{1.2}$ – workplace preparation ;

$W_{1.3}$ – feeding the crane hook and slinging the formwork module ;

$W_{1.4}$ – preparation of the module for installation ;

$W_{1.5}$ – lifting and feeding the module to the installation area ;

$W_{1.6}$ – guidance of the module when feeding into the landing zone

$W_{1.7}$ – orientation of the module and power connection of its drive;

$W_{1.8}$ – calibration and final fixation of the module;

$W_{1.9}$ – removal of slinging grips;

$W_{1.10}$ – pouring of the concreting zone;

$W_{1.11}$ – technical pause (hardening of concrete);

$W_{1.12}$ – rise to the height of the concreting layer, module calibration;

$W_{1.13}$ - acceptance quality control.

Operations $W_{1.1}$ - $W_{1.9}$ – are performed when placing the concreting project mark at a height of 0.0m with increasing concreting height, only operations W1.10 - W1.13 are repeated.

The design of mechanized technological modules for vertical monolithic structures must be carried out in accordance with the structural scheme of the building, which takes into account the width of the vertical element, the height of the floor, and the thickness of the vertical structure. The design of the drive of the mechanized technological module must take into account the specifics of the hardening of the concrete mixture, the brand of the concrete mixture, the need for additional effects on the monolithic circuit (vibration, thermal, etc.).

CONCLUSIONS

1. The intensification of the creation of new technical solutions in the field of mechanization of construction processes in Ukraine took place mainly in 1980-1990.

2. Insignificant activity in the direction of creating new technical solutions allows us to make an assumption that this direction of research is not sufficiently disclosed, because the construction itself is gaining more and more scope and pace.

3. For further research, a promising technical solution developed at the Kyiv National University of Construction and Architecture was chosen.

4. To determine the effectiveness of new technological equipment, it is necessary to decompose the technological process in which it is used and analyze the interaction and influence of its individual components with building elements.

The use of a self-elevating formwork system for building vertical structures has a number of advantages:

- The specific share of labor intensive installation/dismantling of formwork systems during the construction of multi-story buildings is reduced;
- The surface of the concrete structure is improved thanks to the smooth separation of the forming tape from the structure;
- The indicator of the level of mechanization of construction operations is increasing;
- The use of heavy crane equipment is reduced.

However, there are also a number of disadvantages:

- The use of separate mechanisms increases the level of complexity of using construction equipment;
- Creating a basic formwork kit requires significant capital investment.

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Розробка інформаційної моделі механізованого процесу зведення вертикальних будівельних конструкцій

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Анотація. Матеріал статті присвячений розробці будівельної інформаційної моделі механізованого процесу зведення вертикальних контрукцій. Вдосконалення будівельного процесу – важливе інженерне завдання. Питання вдосконалення механізованого оснащення відіграє важливу роль. При цьому для повноти інформаційної моделі будівельного процесу як основної системи необхідно враховувати параметри її складових підсистем, зокрема параметри нових технічних рішень. Так, для визначення рівня основної системи та прогнозування її розвитку, ефективне патентне дослідження.

У роботі запропоновано схемне рішення, що реалізує новий спосіб улаштування вертикальних монолітних конструкцій. Також виконано імітаційне моделювання рухомого технологічного модуля, призначеного для влаштування вертикальних монолітних конструкцій.

Створено комп'ютерну геометричну модель механізованого технологічного модуля, розроблено геометричну модель роботи групи модулів однієї захватки. Розроблено рекомендації щодо виконання послідовних етапів бетонування вертикальних монолітних конструкцій.

Отримані дані можуть бути використані при наповненні будівельної інформаційної моделі монолітних робіт з використанням запропонованого механізованого оснащення.

Ключові слова: вертикальна рухлива опалубка, механізоване технологічне оснащення, інформаційна модель.