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# INNOVATION TECHNOLOGIES FOR CONSTRUCTING LARGE-SPAN COVERINGS USING LIFTING MODULES

***Introduction.*** *The current state of the construction industry requires the further improvement of well-known or the creation of fundamentally new organizational and technological solutions for lifting of large-span coverings without the use of cranes.*

***Problem Statement.*** *The development of new technologies and design solutions requires systematic and comprehensive studies of known options for lifting coverings by methods of forced pulling and pushing, including the use of lifting modules.*

***Purpose.*** *Justify the theoretical basis for creating innovation technologies for lifting large-sized coverings with the use of lifting modules that push out the bearing crossbars of the covering blocks in the space between the paired columns of the frame with resting on the guide profiles fixed on the inner surfaces of the bearing columns.*

***Materials and Methods.*** *The theoretical foundations for the creation of innovation technologies for lifting large-sized coverings with lifting modules of a new design have been developed by the methods of system integrated studies, analysis and generalization of the experience of using lifting modules, methods of the multiplicity theory in the formal description of morphology and states of functional module systems, process modelling methods, conditions and facilities involved in the lifting of large-sized coverings.*

***Results.*** *In the process of system analysis of advantages and disadvantages of known solutions for forced lifting of large-sized coverings, we have developed a fundamentally new technology of pushing out covering structures by lifting modules that move together with the support crossbars of the coverings in the space between the columns, with the lifting modules using guide profiles secured on column inner surfaces as intermediate support units.*

***Conclusions.*** *Creating a new technological solution for lifting large-span coverings using these lifting modules allows reducing the high-altitude work to the operations of fixing the coverings on the column heads and automating the entire process of moving the covering from the consolidation zone at low scaffolding to the zone of final fixation between the column heads.*

*Keywords: mechanical lifting, large-span coverings, lifting modules, methods of pulling and pushing.*

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In modern construction, particularly in the erection of long-span structural and technological blocks of coverings, the initial stage of installation involves the consolidation of the covering structure on low scaffolding. This stage includes the installation of equipment specified in the covering design and the implementation of steam, heat, and waterproofing roofing layers [1]. Concurrently, foundation cups, support columns, inter-column beams, and connections are installed. These operations are typically performed by conventional crane technologies, by the method of free lifting [2] of structural fragments. At the subsequent stage, when the covering is raised to the design height, technologies of forced movement by pulling and pushing methods are employed [3]. For all methods of forced lifting, it is essential to have technological stops associated with the movement and fixation of structural elements in the working area for pulling up or pushing out coverings [4]. Additionally, for known methods of forced lifting, the construction of temporary high-altitude assembly platforms is mandatory [5]. The reduction of labor intensity and the optimization of mechanical lifting processes remain urgent challenges in the erection of long-span coverings for industrial and civil engineering structures.

Well-known Ukrainian and foreign researchers have extensively studied the construction of roof structures using conventional crane and mechanical lifting technologies. Among Ukrainian researchers, significant contributions to the development of organizational, process, and engineering solutions for constructing long-span coverings of industrial facilities have been made by L.A. Kolesnyk [6], V. F. Nazarenko [7], G. S. Nizhnikovsky [8], O. F. Osypov [9], P. G. Reznychenko [10], N. P. Sytnik [7], H. M. Tonkacheev [3], P. P. Fedorenko, A. A. Shkromada [1], and V. K. Chernenko [2]. Foreign researchers who have contributed notably to this field include H. Engel [11], K. Fliger [12], E. Kühn [13], G. Orlik [14], L. Rowinski [13], H. Rühle [12], and J. Ziólko [14].

Based on the analysis of the advantages and disadvantages of the technology for erecting coverings, where initially the covering is consolidated on the foundations by the method of free lifting using cranes, and subsequently, the roof structure is raised by pulling with hydraulic lifts installed on the heads of the support columns, a new technology has been developed. This technology focuses on erecting a 100% ready block to the design height using step lifting modules. According to the developed technology, during the vertical push-out process, the support bars of the cover block shall rest on the super-jack beams of the lifting module. The support beams of the covering and the lifting modules move in the space between the paired bearing columns. The guide profiles are fixed on the inner surface of the columns. During the lifting process, the lifting modules are alternately supported by the under-jack and over-jack beams lifting clamps on the holes in the guide profiles. The implementation of this technology aims to reduce labor intensity and to optimize the processes of mechanical lifting of coverings.

The organizational, process, and engineering features of constructing long-span reinforced concrete and steel coverings have been studied with the use of engineering and industrial facilities in Great Britain and Ukraine as examples. The technological processes used in constructing coverings in these countries share common features. In each case, the construction process follows a two-stage approach: at the first stage of installation works, the covering structure is consolidated on low scaffolding with by the free-lift method involving cranes; at the next stage, the covering is raised to the design height through forced vertical motion. This involves using extension columns and the pull-up method; positioning the lifting module on the heads of the structural columns, and implementing technologies of forced motion by the pulling and pushing methods. The advantages and disadvantages of known examples of erection of long-span structural blocks by mechanical lifting techniques have been analyzed to develop mechanized technological equipment that would allow increasing the efficiency of installation processes for lifting

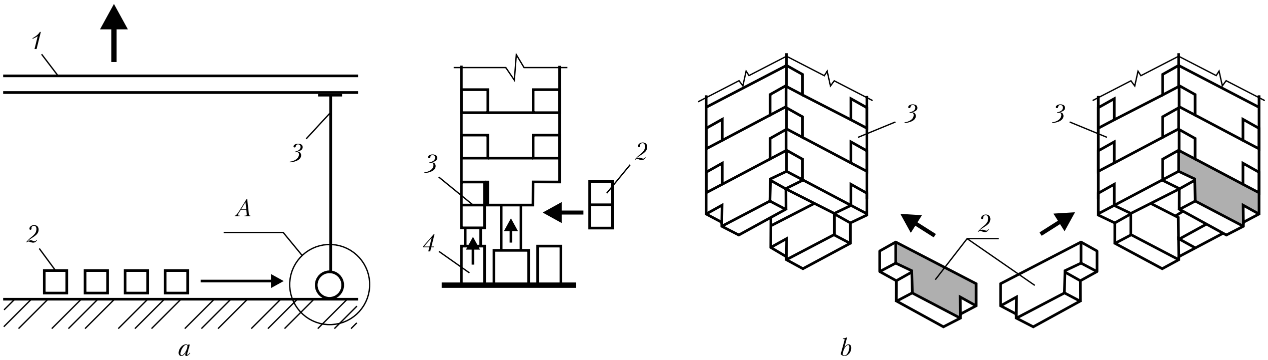


*Fig. 1.* Lifting of the covering by the bottom-up jacking method: *a* — general scheme of column jacking; *b* — components of the column jacking process; *A* — column jacking node; *1* — covering; *2* — column segment before jacking; *3* — jacked column; *4* — hydraulic jack

coverings to a height of 34 m and more, while reducing the time and the labor intensity of construction and installation works.

A classic example of lifting a long-span covering by the bottom-up jacking or incremental lifting method is the erection of a monolithic hangar covering in the city of Abington (Great Britain) in 1957 by the *Ove Arup and Partners* and *John Laing and Son Ltd.* [3, 40—41]. The covering consisted of three monolithic reinforced concrete segments, each measuring 33.53 × 59.59 meters, with a total weight of 1,400 tons. The monolithic reinforced concrete covering was lifted by leaning on the heads of the incremental reinforced concrete columns, as illustrated in Fig. 1.

The columns were constructed from T-shaped segments, each weighing 500 kg, with a total of 1,000 segments assembled. Before installing each segment, a layer of cement-sand mortar (in a 1:3 ratio) with a thickness of 5/8″ (16.5 mm) and metal plate spacers were applied to its upper face. Four jacks, each with a carrying capacity of 200 tons, were used to raise each column. During the jacking process, a cavity was formed between the inner side faces of the mounted T-shaped segments. Reinforcing rods (14 per column) were placed in the cavity as the column segments were incrementally raised. After the last T-shaped segment was installed, the cavity was filled with concrete. Once the concrete reached the required strength, the reinforcing bars were tensioned. Lifting each monolithic segment of the covering took five days, involving 30 workers in the installation operations. Including the time needed for the concrete in the cavities of the segmental reinforced columns to gain strength and for tensioning the reinforcing bars, the total time for raising the coverings to the design height was 35 days.

The disadvantages of this method include the hinged support scheme for the column on the foundation during the jacking process, significant labor intensity, and low productivity of the installation process. There were also a large number of installation operations required for each T-shaped segment of the columns, the necessity for continuous supervision over the synchronous operation of 16 hydraulic jacks involved in lifting and maintaining column segments during their jacking, and the small working stroke of the jack rods [5].

The further development of the technology for lifting coverings by the method of bottom-up jacking can be observed in the erection of the hangar covering measuring 144 × 275 meters at the aircraft factory in Kyiv, Ukraine. The covering, with an area of 39,600 sq. m. and a weight of 1,100 tons, was raised to a height of 24 m in 12 shifts. Columns were raised by hydraulic lifters PG-300 [3, 42—43]. As the columns were incremented, sections of lifts were inserted into the increment zone between the bodies of the hyd-

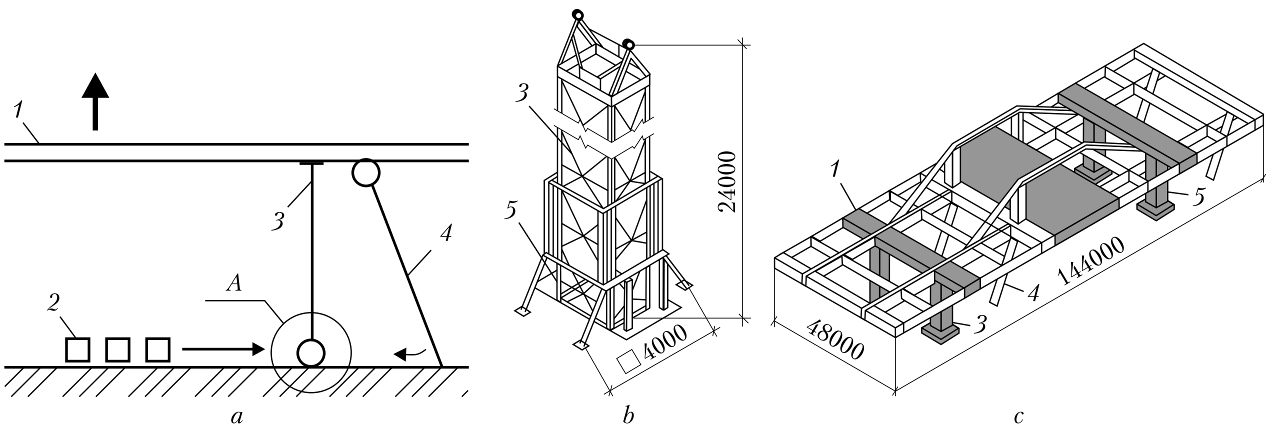


***Fig. 2.*** Incremental lifting of the covering by mounting columns: *a* — general scheme of column incrementing; *b* — hydraulic lifting module PG-300; *c* — long-span covering during the lifting process; *A* — column incrementing zone; *1* — covering; *2* — segments of the mounting column; *3* — assembled incremented mounting column; *4* — solid column; *5* — hydraulic jacks

raulic lifters and the support frames. The crossbars of the covering rested on the heads of the lifting pillars. The solid columns were attached to the lower surface of the support beams of the covering during the consolidation of the long-span covering block on low scaffolding (2.0 meters in height). As the masts of the elevators were incremented, the columns shifted from an inclined to a vertical position. At the final stage of raising the elevator shafts, the columns were fixed in the foundation cups. The load from the support crossbars of the covering was then transferred to the heads of the n columns, after which the elevator shafts were dismantled. The process of lifting the covering by the incremental lifting method is shown in Fig. 2.

Given the fact that in the process of lifting the covering by the incremental lifting method, the structural columns are not involved, it is possible to classify the incremental shafts of the elevators as incremental columns. To achieve the final placement of the covering blocks at the design height, multiple "raising-lowering" cycles within the height range of 200—300 mm are repeated, with constant adjustments at the docking points of individual covering blocks. The disadvantages of this technology include the complexity of placing the covering blocks on the tops of the columns and the significant labor intensity of the installation processes at a height of 24 m, particularly when joining the raised covering blocks. Given the scheme where the lower increment of the mounting columns defined the hinged support scheme of the incremented columns on the foundations, costly and metal-intensive measures were implemented to facilitate the vertical movement of the mounting column sections during the incremental lifting process. Each section of the mounting columns was designed with dimensions of 2.8 × 2.8 m, and the supporting vertical conductor of each hydraulic lifting unit, standing 10 m tall, featured a lower frame contour measuring 16 × 16 m [5]. Implementing this technology also required comprehensive safety equipment and a sophisticated system of jacks to ensure the verticality of the covering's lifting process.

The study also evaluates the advantages and disadvantages of a well-established organizational and technological approach involving the forced movement of long-span coverings to their designated height using the pulling method with hydraulic lifts positioned on columns [3, 73—76]. Figure 3 illustrates the lifting process employing the pulling method. The PSh-330 pulling hydraulic jack comprises two GD-170 hydraulic jacks (each with a load capacity of 170 tons and a jack

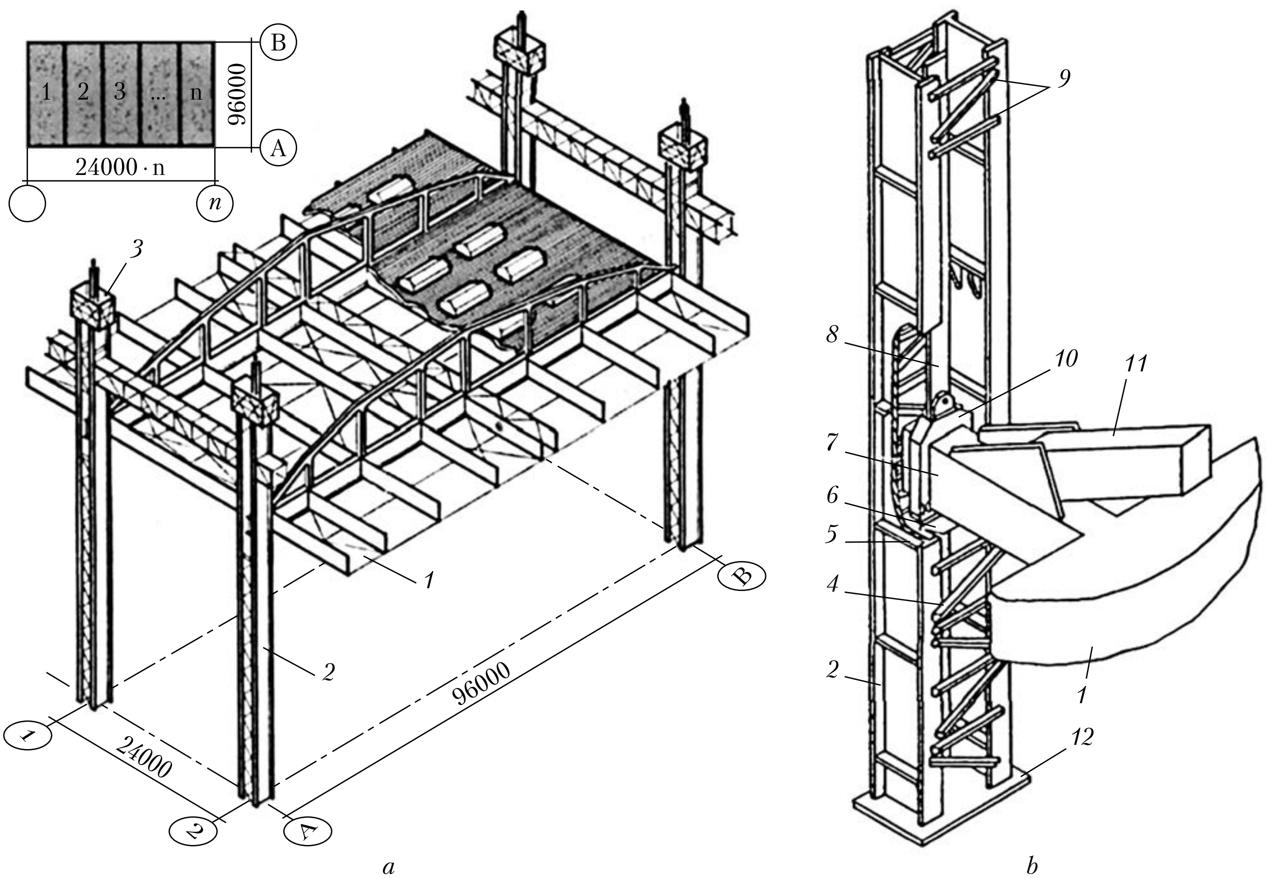


*Fig. 3.* Lifting of the covering block by the pulling method: *a* — schematic diagram of the lift; *b* — intermediate position of the covering block during the lift; *1* — covering; *2* — support column; *3* — PSh-330 step lifter; *4* — permanent coupling; *5* — column supports; *6* — support-turning beam; *7* — cantilever part of the girder; *8* — traction tape; *9* — temporary coupling; *10* — sling traverse; *11* — covering girder; *12* — column foundation

rod stroke length of 1120 mm), two safety screws, under-jack and over-jack beams, and a fully welded shuttle belt (12 m in length), which connects at its lower end with a traction tape (600 × 40 mm in cross-section). The traction tape consists of articulated links, each 6 m long, and is pivotally attached to the beam of the lifting structure.

As a support structure for a traction hydraulic lift, columns of the support frame with intermediate tables were used to temporarily support the covering block during its movement to the design height. The lifting of two roofing blocks (total area 40,000 m$^2$, block sizes 96 × 48 m and 96 × 54 m, block weight up to 1200 tons) to a height of 34 m was completed in 10 shifts. The lifting process for each block consisted of six repeated cycles. Each cycle included two successive stages: lifting the covering block by 6 m and intermediate resting of the covering on the support tables of the columns. In each lifting cycle, the covering was incrementally pulled up to a height of 1 m, corresponding to the stroke of the jack rods and the pitch of the holes in the traction belt. During the lifting of the covering, the lattice elements in the columns were dismantled in a section 6 m high with the use of a hand winch to move the covering bolt in the space between the columns. After each lift, the lattice elements were reinstalled.

The advantages of the analyzed solution include the formation of a rigid transverse frame from load-bearing columns and inter-column beams, as well as the control of the verticality of the lifting process, which was ensured by the movement of the support bars of the covering block between the paired load-bearing columns. However, there are several disadvantages. These include stops related to the dismantling of inter-column gratings before lifting the support beam of the covering and the subsequent reinstallation of the gratings. Additionally, the process requires dismantling the 6 m long traction belt links and temporarily resting the covering support beams on the support tables after each 6 m lifting stage. Further, intermediate height mounting platforms need to be installed on the columns for the installation and dismantling of inter-column gratings. The complex dismantling of the PSh-330 pulling-type hydraulic lift at a height of 34—36 m also requires the involvement of high-capacity jib cranes, provided that a road with a width of 4—5 m is available along the perimeter of the construction site.

Given the advantages of the method of lifting the covering by the pull-up method, where the paired columns, together with the inter-column beams and ties, create a transverse frame of rigidity and serve as guides for moving the support bars of the covering structure in the inter-column space, a new lifting technology without the use of crane has been developed. This new technology employs lifting modules that move, along with the load-bearing crossbars of the covering resting on them, in the space between the paired columns. The lifting modules are supported on guide profiles fixed to the inner surfaces of the paired columns. The developed technology for erecting coverings using lifting modules offers several benefits. It significantly reduces the labor intensity of the lifting processes, simplifies the design of the lifting module, and decreases the steel consumption. Additionally, the scope of works at height is minimized to operations for fixing the load-bearing crossbars of the covering between the heads of paired columns.

Lifting modules are a complex functional technological system that, according to modern ideas [9, 60—75] are characterized by a design objective function $\Phi = \{Ц, М\}$ that describes the process of lifting long-span coverings and is determined by the purpose Ц and the morphology М of the technological system $М = \{S, L_{gp}\}$ as a totality of the structure $S$ and the inner permanent links in the form of logic $L_{gp}$ of the interaction rules.

Process (technological) system ($S_A$-system) in terms of structure, is a subsystem of the erection/mounting process ($S_o$-system), while in terms of functionality, it is a means of achieving the process goal ($S_o$-system purpose). Thus, the purpose of the erection process $Ц_М$, as system-forming factor, is equivalent to that of the process system Ц ($Ц \asymp Ц_М$) in terms of its creation and utilization. The main structural elements (subsystems) are as follows: column — support crossbar $s_1$, column — guide profile $s_2$, support subsystem $s_3$ (support of the lifting module on the guide profiles), support subsystem of the load-bearing bar on the lifter $s_4$.

In this case, the structure of the process system may be presented as:

$$S = (s_1, s_2, s_3, s_4) \text{ or } S = \{s_i\}, \text{ and } \in \{1, 4\}. \quad (1)$$

If the logic of interaction rules $\{l_{ij}\}$ of the mentioned subsystems $\{s_i\}$ is given by respective parameters of the result of their interaction $\varphi:\{s_i\}, \{l_{ij}\} \to \{p_i\}$, from the set of admissible parameters $p_{ij} \in [p_{ij}^{\min}, p_{ij}^{\max}]$, we obtain the set of ideal states of the process system $\{C_z\}$:

$$\{C_z\} = \begin{cases} (p_{11}, p_{12}, \ldots, p_{1n}), \\ (p_{21}, p_{22}, \ldots, p_{2m}), \\ (p_{31}, p_{32}, \ldots, p_{3l}), \\ (p_{41}, p_{42}, \ldots, p_{4k}). \end{cases} \quad p_{ij} \in \left[p_{ij}^{\min}, p_{ij}^{\max}\right]. \quad (2)$$

The combination of states determines a certain phase of the process system operation, which characterizes the corresponding stage of the erection process and the cycle (see Figs. 4 and 5 together), therefore, in general, the system property $Q(S_A)$ of the process system for erecting long-span coverings using the proposed lifting modules (as $S_A$-system) can be formally presented as follows:

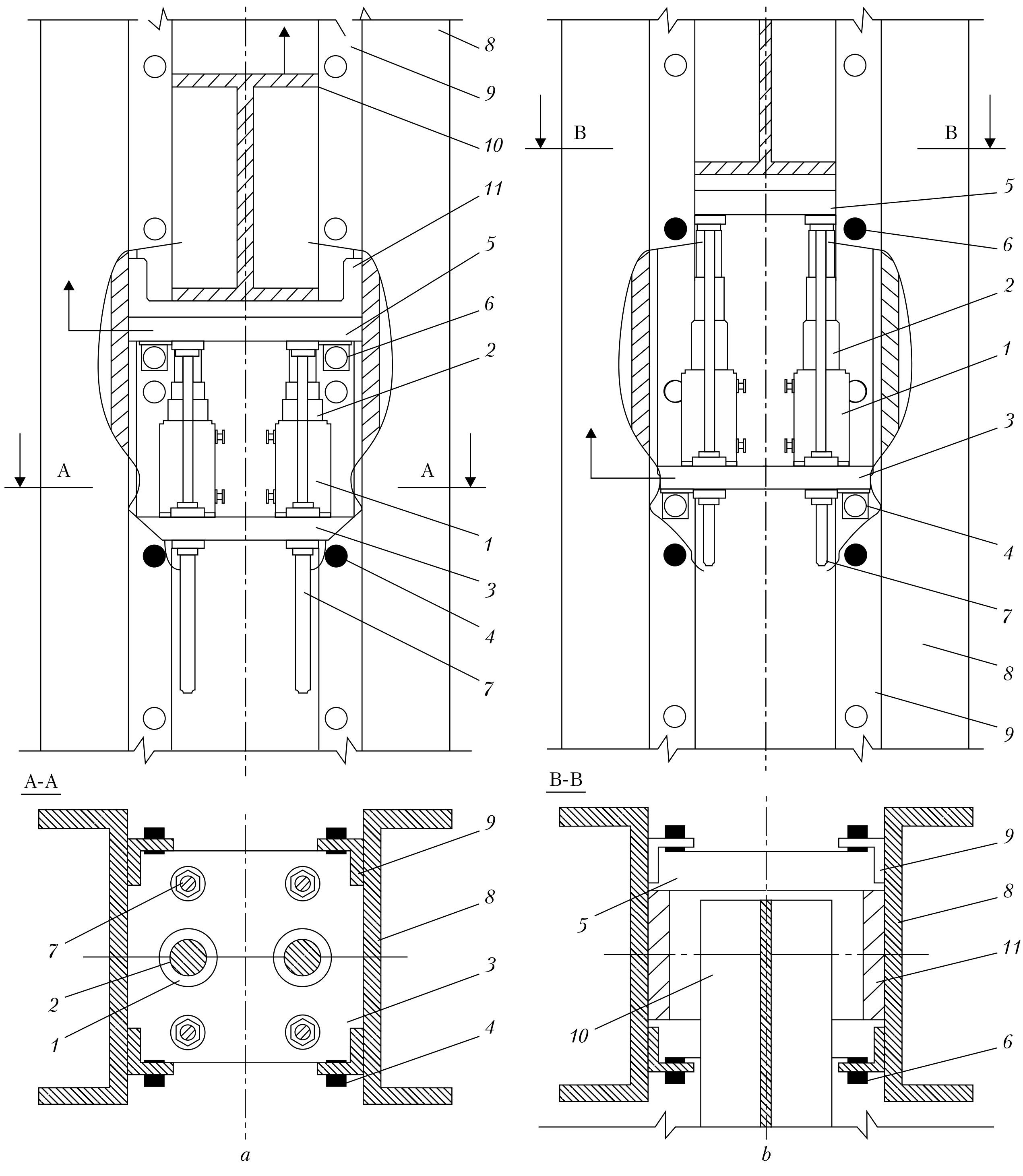


*Fig. 4.* Phases of the lifting module's working cycle: *a* — Extension of the over-jack beam and the support frame of the covering; *b* — Retraction of the under-jack beam to the over-jack beam; *1* — Hydraulic cylinder body; *2* — Hydraulic cylinder rod; *3* — Under-jack beam; *4* — Lower lifting locks; *5* — Over-jack beam; *6* — Upper lifting locks; *7* — Safety rods; *8* — Load-bearing paired columns; *9* — Guide profiles; *10* — Load-bearing beam of the covering; *11* — Support frame of the covering

$$Q(S_A)=\begin{cases} Ф=\{Ц, М\} \\ Ц \asymp Ц_м, \\ М=\{S, L_{gp}\}, \\ S=(s_1, s_2, s_3, s_4), \\ \{C_z\}=\begin{cases}(p_{11}, p_{12}, \ldots, p_{1n}),\\ (p_{21}, p_{22}, \ldots, p_{2m}),\\ (p_{31}, p_{32}, \ldots, p_{3l}),\\ (p_{41}, p_{42}, \ldots, p_{4k}).\end{cases}\end{cases}$$

$$p_{ij} \in \left[p_{ij}^{\min}, p_{ij}^{\max}\right], i \in \{1, 4\}. \qquad (3)$$

The system property $Q(S_A)$ of the process system for erecting long-span coverings meets the condition:

$$(\forall_r,\ S_A)\begin{bmatrix}\exists!\ Q(S_A)=\{Q(s_i)\}; \\ \overline{i=1,n};\ Q_i \cap Q_r\end{bmatrix}, \qquad (4)$$

for all $r$ options of the $S_A$-system decomposition into subsystems, there exists its corresponding system property $Q(S_A)$, such that there is no common element in the set of system properties $Q_i$ and the set of properties of all subsystems $Q_r$.

The lifting of the covering is realized by the process (lifting) system operation, then the duration of the lifting of the covering T is the sum of the cycles of its operation $\sum_{i=1,N} t_i$.

Therefore, the criterion for the efficiency of the process system operation, given the time Ч spent on the preparation of the covering for the mounting $t^{пм}$, as well as for the mounting $t^{во}$ and dismantling $t^{до}$ of the lifting system can be presented in the form:

$$T = \sum_{i=1,N} t_i \underset{opt}{\rightarrow} \min \qquad (4)$$

provided that $Ч \rightarrow Ч_{\min}$,

where $Ч_{\min}$ is the minimum time spent on the covering preparation, erection of the covering at the design height and dismantling of the lifting system. Figure 4 illustrates the two main phases of the working cycle of the lifting module: the extension of the over-jack beam, which pushes the support frame of the covering upward, and the retraction of the under-jack beam towards the over-jack beam.

Fig. 4, *a*: in the initial phase of the lifting cycle, the load from the support frame of the bearing beam of the covering is transmitted through the over-jack beam, the hydraulic cylinder rods attached to it, and the hydraulic cylinder bodies fixed on the under-jack beam, to the lower lifting retainers. The retainers' cases are fixed on the lower surface of the under-jack beams, and their retractable bolts are inserted into the holes in the guide profiles mounted on the inner surfaces of the paired columns. When the working fluid is supplied to the hydraulic cylinder housings, the rods push the over-jack beam of the lifting module and the support frame of the covering block to a height equal to the working stroke of the hydraulic cylinder rod. Safety rods attached to the lower surface of the jack beams move together with the jack beam. Fig. 4, *b*: after the lifting of the over-jack beam is completed, the retractable bolts of the upper lift retainers are inserted into the holes in the guide profiles. This transfers the load from the support frame of the bearing beam of the covering to the upper lift retainers, allowing the under-jack beam of the lifting module to be pulled up to the over-jack beam. Once the load is released, the bolts of the lower lift retainers are retracted into their housings. When the working fluid is fed into the hydraulic cylinder housings, the hydraulic cylinder rods are retracted into their corresponding housings, pulling the under-jack beams along with the lower lift retainers up to the over-jack beam of the lifting module. After the rods are fully retracted into the hydraulic cylinder housings, the bolts of the lower lift retainers are extended into the holes in the guide profiles. This transfers the load from the support beams of the covering through the support frames to the lower lift retainers, allowing the retractable bolts of the upper lift retainers to be retracted into their housings and enabling the next phase of pushing out the over-jack beam of the lifting module and the support frame of the covering.

The sequence of erecting the covering using the lifting module consists of pre-lifting, lifting, and post-lifting stages and is shown in Fig. 5.

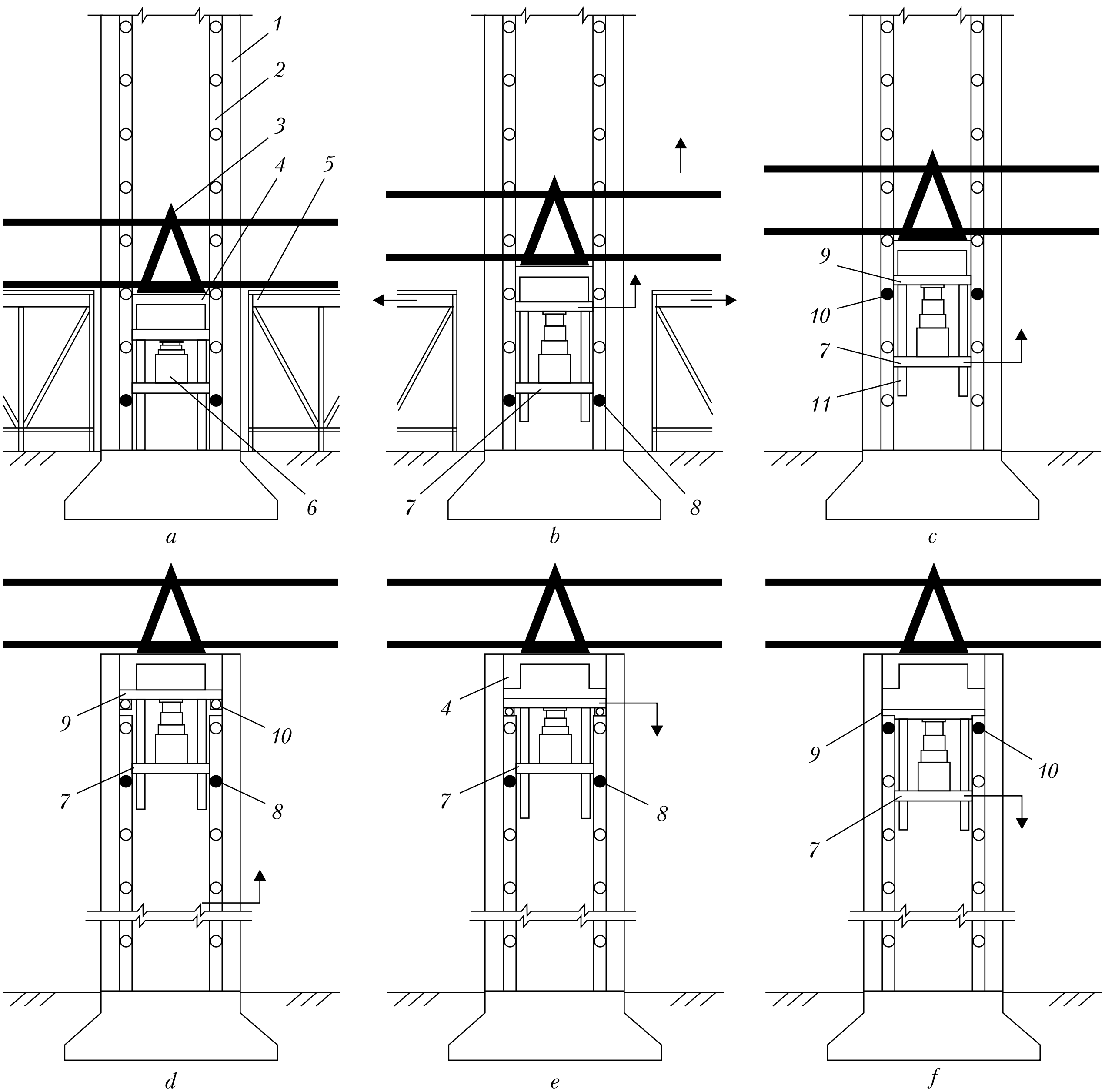


***Fig. 5.*** Sequence of installation of the covering using the lifting module: *a* — pre-lifting stage; *b, c, d* — lifting stage; *e, f* — post-lifting stage; *1* — paired columns; *2* — guide profile; *3* — support beam of the covering; *4* — bearing frame; *5* — scaffolding; *6* — hydraulic cylinder; *7* — under-jack beam; *8* — lower lift retainers; *9* — over-jack beam; *10* — upper lift retainers; *11* — safety rods

**Pre-lifting stage (Fig. 5, *a*):** the guide profiles are fixed on the inner surfaces of the paired columns. The covering is consolidated on low scaffolding, ensuring that the support beams of the covering are placed on the support frames in the space between the columns. The lifting modules are installed under the support frames of the covering. These modules consist of double-action hydraulic cylinders, under-jack beams with lower lifting fasteners, over-jack beams with upper lifting fasteners, and safety rods that control the position of the lifting module beams during vertical movement. **Lifting stage (Fig. 5, *b–d*):** first, the lower retainers for lifting the under-jack beams of the lifting module are inserted into the holes in the guide profiles. The hydraulic cylinder rods push the over-jack beams and the support frames of the covering to a height equal to the working stroke of the hydraulic cylinder rods. Next, the upper retainers for lifting the over-jack beams are inserted into the corresponding holes in the guide profiles. The load from the support frames of the covering is transferred to the upper retainers. After the load is released from the lower lift retainers, the hydraulic cylinder rods are then retracted into the hydraulic cylinder housings, pulling the under-jack beams along with the lower lift retainers up to the over-jack beams of the lifting module. Further, the lower retainers for lifting the under-jack beams are inserted into the corresponding holes in the guide profiles.

This allows the load to be transferred from the lifting module and the bearing frame of the covering through the lower retainers of the under-jack beams of the lifting module to the guide profiles and to move the over-jacking beams of the lifting module and the bearing frames of the covering to a height equal to the working stroke of the hydraulic cylinder rods. Alternate transfer of the load from the lifting module and the bearing frames of the covering through the retainers for lifting the under-jacking and over-jacking beams to the guide profiles continues until the moment when the bearing frames of the covering reach the heads of the paired columns. Once the lifting modules are supported through the lower retainers for lifting the under-jack beams on the guide profiles, the support frames of the support crossbars of the covering are coupled with the column heads.

The post-lifting stage (Fig. 5, *d–e*): after fixing the bearing frames of the covering in the design position between the heads of the paired columns, the over-jack beam of the lifting modules moves towards the under-jack beam. To do this, the upper retainers for lifting the over-jack beams are pushed into the corresponding holes in the guide profiles. When the load is transferred from the lifting module to the guide profiles through the upper retainers, the hydraulic cylinder housings and the under-jack beams of the lifting modules move downward for a distance equal to the working stroke of the hydraulic cylinder rods. Then the lower retainers for lifting the under-jack beams of the lifting modules are inserted into the holes of the guide profiles, the upper retainers return to their initial position, and the over-jack beams move towards the hydraulic cylinder housings on the under-jack beams. The alternate transfer of the load from the lifting module through the lower and upper retainers continues until the lifting module reaches the foundations. Subsequently, the components of the lifting module are dismantled and move out from the site.

When using a step lifting module in the technological process of lifting the covering, the operations of disassembling inter-column gratings during the vertical movement of the load-bearing bars of the covering and the subsequent fixing of inter-column gratings are eliminated. Additionally, there is no need to create intermediate support platforms and tables on support columns to perform technological stops, which are characteristic of the known technological solution for lifting the covering by the pulling method. The proposed covering construction technology reduces labor intensity and increases the automation of lifting processes. The overall duration of lifting works can be reduced by 25% as compared with the well-known example of lifting the covering by the pulling method, without the use of crane.

## CONCLUSIONS

- Based on the analysis of known solutions for lifting long-span coverings using the pushing and pulling methods, without cranes involved, the directions for improving organizational, engineering, and process solutions have been identified as follows: formation of a load-bearing transverse frame from columns, inter-column beams, and couplings at the same stage with the consolidation of coverings into a structural block on low scaffolding (height up to 2 m); further lifting of the support crossbars of the covering block using lifting modules that move within the inter-column space, utilizing guide profiles fixed on the inner surfaces of the columns as support nodes; automation of the vertical movement of the covering from the level of foundations to the heads of paired columns.

- The processes with the mounting staff involved during the lifting of the structural block of the covering have been reduced; their role is limited to fixing the support crossbars of the covering on the heads of the columns at the final stage of lifting.
- The promising directions for the use of step elevators interacting with guide channels fixed on the inner surface of structural columns have been identified as follows: lifting large-sized and heavy equipment in production workshop spaces where the use of classic crane technologies is not feasible; moving structural covering blocks weighing 1,200—2,400 tons to a height of more than 34 m.

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# ІННОВАЦІЙНІ ТЕХНОЛОГІЇ ЗВЕДЕННЯ ВЕЛИКОПРОГОНОВИХ ПОКРИТТІВ З ВИКОРИСТАННЯМ ПІДЙОМНИХ МОДУЛІВ

**Вступ.** Сучасний стан будівельної галузі потребує вирішення питання щодо подальшого вдосконалення відомих або створення принципово нових організаційно-технологічних рішень безкранового підйому великопрогонових покриттів.

**Проблематика**. Розроблення нових технологій та конструктивних рішень вимагає системних та комплексних досліджень відомих варіантів підйому покриттів методами примусового підтягування та виштовхування, зокрема й з використанням підйомних модулів.

**Мета.** Обґрунтувати теоретичні основи створення інноваційних технологій піднімання великорозмірних покриттів з використання підйомних модулів, які виштовхують несучі ригелі блоків покриття у просторі між спареними колонами рамного каркасу зі спиранням на напрямні профілі, закріплені на внутрішніх поверхнях несучих колон.

**Матеріали і методи.** Розробку теоретичних основ створення інноваційних технологій піднімання великорозмірних покриттів підйомними модулями нової конструкції здійснено з використанням методів системних комплексних досліджень, аналізу та узагальнення досвіду застосування підйомних модулів, методів теорії множинності у формальному опису морфології та станів функціональних систем-модулів, методів технологічного моделювання процесу, умов та об'єктів, задіяних у підйомі великорозмірних покриттів.

**Результати.** У процесі системного аналізу переваг та недоліків відомих рішень примусового підйому великопрогонових покриттів було розроблено принципово нову технологію виштовхування конструкцій покриттів підйомними модулями, які переміщуються разом з опорними ригелями покриттів у просторі між колонами, при цьому підйомні модулі використовують напрямні профілі, закріплені на внутрішніх поверхнях колон, як проміжні опорні вузли.

**Висновки.** Створення нового технологічного рішення підйому великопрогонових покриттів з використанням зазначених підйомних модулів дозволяє звести обсяги висотних робіт лише до операцій закріплення покриттів на оголовках колон, а також автоматизувати весь процес переміщення покриття із зони укрупнення на низьких риштуваннях до зони остаточної фіксації між оголовками колон.

*Ключові слова:* безкрановий підйом, великопрогонові покриття, підйомні модулі, методи підтягування та виштовхування.