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IMPROVEMENT OF STRUCTURAL AND TECHNOLOGICAL SOLUTIONS FOR ERECTION OF LARGE-SPAN COATINGS USING LIFTING MODULES

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The article presents an analysis of the method of lifting large-span coatings using the pull-up method and introduces a new structural-technological solution for erecting coatings using mechanized technological equipment in the form of a lifting module. According to the solution, the load-bearing beams of the coating are moved in the space between paired columns of the frame, resting on the lifting modules. Guide profiles fixed to the inner surfaces of the columns serve as supports for the alternating support of the platforms of the lifting module, which pushes the coating beams in the inter-column space. The developed solution optimizes the lifting processes and reduces the duration of lifting works by minimizing the number of installations works to operations for fixing the beams of the coating at the design height and automating the processes of pushing the coating with lifting modules.

Key words: lifting modules, erection of large-span coatings, mechanized process equipment, structural-technological solutions, pull-up method, load-bearing frame.

Introduction

The current state of the construction industry requires addressing issues related to further improving known and creating fundamentally new structural-technological solutions for the erection of large-span coatings. Today, the installation of coating structures is envisaged in two sequential stages. In the first stage, coatings are assembled and components of the building's load-bearing frame (foundation cups, columns, inter-column beams, and ties) are installed using low scaffolding with boom cranes by the free-lift method). In the second stage, the forced movement of the coatings is performed using the pull-up method with hydraulic jacks and guides (angle ≤ 90º), or by pushing with the coating supported on the lifting jacks (Sobko et. al., 2015). For the pull-up method, a discrete lifting process is mandatory. Numerous stops are associated with the delivery and subsequent fixing in the installation zone of the structural elements involved in pulling the coatings. Additionally, interruptions in the lifting process are caused by delays necessary for arranging installation height platforms (Ignatenko, 2024). Improving structural-technological solutions for the erection of large-scale coatings using lifting modules, which optimize lifting processes and shorten overall coating lifting times, is a pressing issue for the development of the construction industry.

Famous domestic and foreign scientists paid great attention to the study of the peculiarities of the construction of reinforced concrete and metal coatings using traditional crane and craneless technologies. Thus, the organizational and technological solutions for the installation of large-block industrial buildings and structures by free-lifting methods are described in detail in the works (Tonkacheiev et. al., 2021; 2022; 2023), (Osypov et. al., 2020; Chernenko, 2011; Sobko et. al., 2022). The stages of consolidation and lifting of the coatings using crane technologies are reflected in the works (Yang et. al., 2023; Ruan et. al., 2023), modern variants of the pull-up method and the push-out method (Fagoli Asotech, 2024; Sarens group, 2024; DLT Engineering, 2011; MAMMOET, 2021; ENERPAC, 2022; ULTRACON, 2022). In the scientific works of the mentioned authors and in the presentation materials of the manufacturers of modern lifting equipment, the processes of consolidation and lifting of coverings are described in detail, but there is no algorithm for optimizing structural and technological solutions for erecting coverings using lifting modules.

A systematic and comprehensive analysis of the features of the option of lifting coatings by the pulling method allows to accept the advantages and disadvantages of the implemented project for the development of the latest structural and technological solution for the erection of long-span coatings with mechanized technological equipment in the form of lifting modules, which would ensure the optimization of lifting processes and the reduction of the overall duration of works on the erection of long-span structural -technological blocks of coatings.

Materials and methods

The technology of lifting the coating by the pull-up method, with hydraulic jacks located on the tops of the frame's load-bearing columns, was used in the construction of the aviation plant workshops in Hostomel, Ukraine. The coating consisted of blocks measuring 96 × 48 m and 96 × 54 m and weighing 1100–1200 tons. Lifting two roofing blocks (total area 40,000 m²) to a height of 34 m was completed in 10 shifts (Chernenko et. al., 2016). PSH-330 hydraulic jacks, positioned on the tops of the design columns, performed cyclic pulling of the coating beams using a hinged-chain traction belt. The traction belt was hinged to the beam of the lifted coating. Load-bearing columns of the frame with intermediate platforms for temporarily supporting the coating block during movement to the design height served as support structures for the hydraulic jack. The lifting process of the coating by the pull-up method and the fixation unit of the lifted coating beam are shown in Fig. 1.

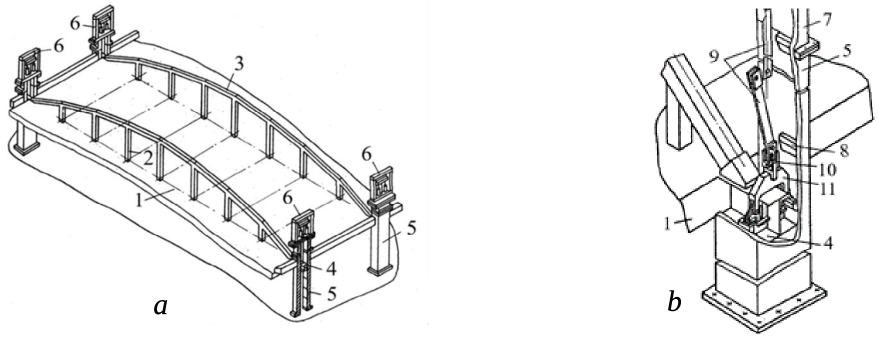

Fig. 1. Lifting of a long-span coating by the pulling method:

a – coating in the process of lifting; b – fixing unit of the supporting bolt of the lifting coating;
1 – block of coating; 2 – rack of the coating truss; 3 – upper belt of the coating truss; 4 – supporting crossbar of the coating; 5 – supporting frame column; 6 – lifting module PSH-330; 7 – lift support; 8 – intermediate lifting stop; 9 – traction belt; 10 – transition link of traction belt; 11 – slinging traverse

Each block's lifting process consisted of six repeated cycles. Each cycle included two sequential stages – lifting the coating block by 6m and intermediate support of the coating on the column's supporting platforms. In each lifting cycle, the coating was pulled up six times to a height of 1m, corresponding to the stroke of the jack rods and the step of the holes in the traction belt. During the coating lift in the inter-column space, grille elements were dismantled in the section with a height of 6m, followed by the assembly of grilles after lifting the coating beam. The considered jack had a complex structure. Processes of dismantling grilles between paired columns for the passage of the support beam and post-lift securing of the inter-column grilles and operations for dismantling the links of the traction belts were complex and labor-intensive. Maintenance of the step jack, its assembly, and dismantling at a height of 34 m were inconvenient and unsafe. The fixing of the PSH-330 jacks at a height of 34 m before lifting the coating and their dismantling after fixing the coating at the design height was carried out using powerful self-propelled crawler cranes with the condition of arranging roads around the building perimeter for crane movement 6m wide. The advantages of the analyzed solution include the formation of a rigid transverse frame from load-bearing columns and inter-column beams, and control of the verticality of the coating lifting process, ensured by moving the supporting beams of the coating block between paired load-bearing columns (Ignatenko, 2024).

Result and discussions

Considering the advantages of the pull-up method, where paired frame columns served as guides for moving the coating beams to the design height, a new structural-technological solution for coating erection using lifting modules was developed. The new solution involves moving the load-bearing beams of the coating from the foundation level to the final design level within the space between paired frame columns, supported by lifting modules. In the process of pushing the coating beams, the lifting modules rely on guide profiles fixed to the inner surfaces of the frame columns. The lifting module consists of a double-acting hydraulic cylinder, lower and upper platforms, and safety rods. The body of the hydraulic cylinder is mounted on the lower platform of the module, while the piston rod of the hydraulic cylinder is attached to the upper platform of the module. Both the upper and lower platforms of the module are equipped with lifting fixation mechanisms with retractable support cylinders. The safety rods are attached to the upper platform of the module and pass-through sliding nuts, which are secured to the lower platform of the module. To support the lifting fixation mechanisms, guide profiles are provided, which are mounted on the inner surfaces of the paired columns of the frame. The overall view of the coating during the pushing process to the design height and the lifting module is shown in Fig. 2.

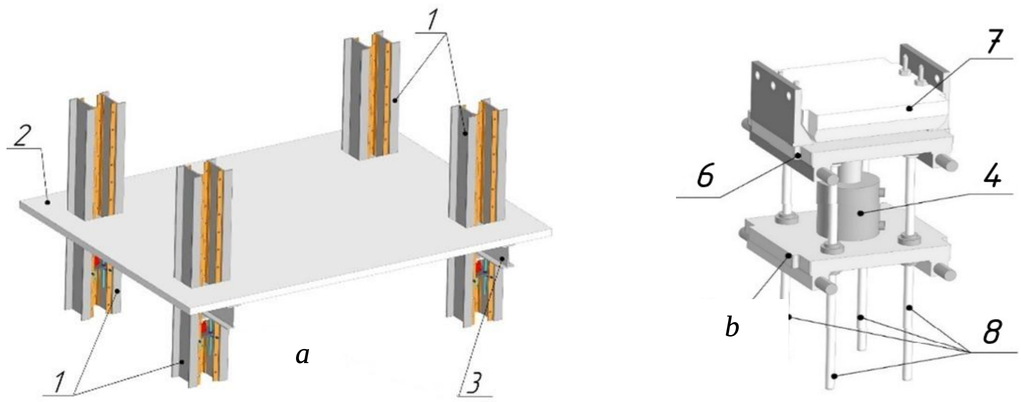

Fig. 2. The erection of the covering by a lifting module located between paired columns:
a – general view of the covering during the lifting process; b – lifting module:
1 – column of the frame; 2 – cover; 3 – supporting beam of the cover; 4 – hydraulic cylinder;
5 – lower platform of the module; 6 – upper platform of the module; 7 – supporting frame; 8 – insurance rods

The process of pushing the covering while supported on the lifting modules consists of repeated cycles. Each cycle includes two sequential stages.

First stage “Extension of the module's upper platform and the roof's support frame”. The extendable support cylinders of the module's lower platform are placed in the guide profile holes. The working fluid is supplied to the hydraulic cylinder housings, moving the module's upper platform and the roof support frame to a height corresponding to the stroke of the hydraulic cylinder rods.The extendable support cylinders of the module's upper platform are placed in the guide profile holes.

Second Stage “Lifting of the module's lower platform”. With the upper platform bearing the load of the lifted roof, the extendable support cylinders of the module's lower platform are removed from the guide profile holes. The module's lower platform is lifted to a height corresponding to the stroke of the hydraulic cylinder rods. The extendable support cylinders of the module's lower platform are then placed into the guide profile holes, and the lifting cycle stages are repeated until the roof reaches the design height. The sequential stages of the vertical movement cycle of the covering supported on the lifting module are shown in Fig. 3.

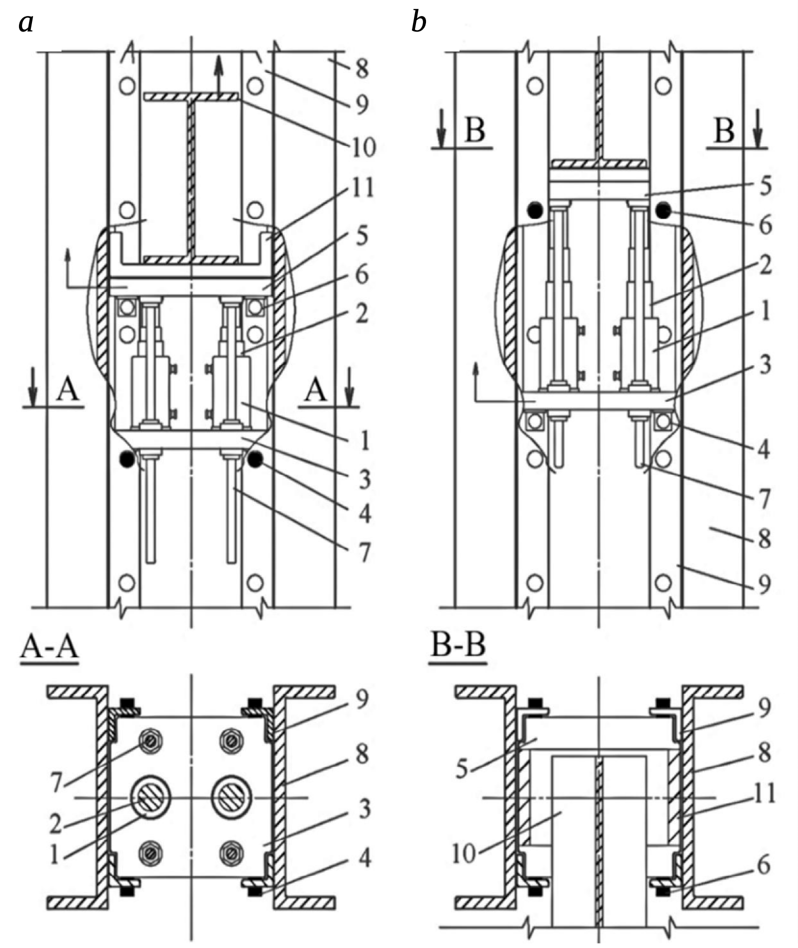

Fig. 3. Successive stages of the cycle of vertical movement of the coating with support on the lifting module: a – extension of the module's upper platform and the roof's support frame; b – lifting of the module's lower platform: 1 – hydraulic cylinder housing; 2 – hydraulic cylinder rod; 3 – lower platform of the module; 4 – extendable support cylinders of the lower platform; 5 – upper platform of the module; 6 – extendable support cylinders of the upper platform; 7 – safety rods; 8 – paired frame columns; 9 – guide profiles; 10 – load-bearing roof girder; 11 – roof support frame

Organizational and Technological Sequence of Roof Construction.The construction process according to the developed solution involves preliminary assembly of large-span roof structures at the foundation level using self-propelled cranes. Simultaneously, the load-bearing frame elements such as foundation cups, paired columns, intercolumn beams, and ties are installed. Guide profiles with holes are fixed on the internal surfaces of the paired frame columns. Mechanized technological equipment in the form of lifting modules is placed on the foundations in the intercolumn space. The support frames and load-bearing girders of the roofs are supported on the lifting modules. After all the works on the assembly of the large-span roof structures, installation of technological equipment, formation of insulation layers, and completion of the roof block at 100 % readiness, it is lifted from the foundation level to the design height (34 m). Vertical movement of the roof is carried out with the support of the roof's support frame on the module's upper platform. During the lifting process, the load from the roof is alternately borne by the lower and upper platforms of the module, which interact with the guide profiles. Once the roof reaches the design height, the roof's support frames are finally fixed between the tops of the frame columns. The load-free lifting modules are then lowered to the foundations. The processes of moving the roof structure to the design height with support on the lifting modules are fully automated. The only high-altitude work involving installers is the final fixing of the roof's load-bearing frames between the tops of the paired frame.

Conclusions

Based on the analysis of the known method of lifting large-span roofs by pulling, a new structural and technological solution for roof construction using mechanized technological equipment in the form of a lifting module has been developed. According to this solution, the roof girders, pre-assembled at the foundation level, are moved to the design height in the space between paired frame columns by pushing, supported on the upper platforms of the lifting modules. During the lifting process, the lower and upper platforms of the module alternately rest on guide profiles fixed on the inner surfaces of the paired frame columns.

The developed solution optimizes installation processes and reduces the duration of lifting works by minimizing the high-altitude operations involving installers to final fixing of the roof support frames at the design height and performing all operations for moving the roofs from the foundation level to the tops of the frame columns in an autonomous mode. The construction site dimensions do not exceed the dimensions of the erected large-span roof.

Perspectives for further research

The developed mechanized technological equipment can be further used in the development of structural and technological solutions for moving large-size external wall panels, pre-assembled at the foundations, to heights greater than 34 m using guide profiles fixed on the frame columns. Additionally, with improved characteristics of the lifting modules, the developed solution can be used for lifting large heavy technological equipment weighing up to 1200 tons in production workshops where it is technologically impossible to move the equipment using cranes.

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УДОСКОНАЛЕННЯ КОНСТРУКТИВНО-ТЕХНОЛОГІЧНИХ РІШЕНЬ ЗВЕДЕННЯ ВЕЛИКОПРОГОНОВИХ ПОКРИТТІВ З ВИКОРИСТАННЯМ ПІДЙОМНИХ МОДУЛІВ

Ó *Ігнатенко О. О., Рашківський В. П., Зозуля Н. О., 2024*

У статті проаналізовано відомий варіант підйому покриття методом підтягування. З урахуванням недоліків та переваг розглянутої технології розроблене нове конструктивно-технологічне рішення зведення покриттів механізованим технологічним обладнанням у вигляді підйомного модуля. Згідно з новим рішенням, ригелі конструкцій покриттів попередньо укрупнюють на низьких риштуваннях, потім переміщують у просторі між спареними колонами каркаса методом виштовхування зі спираннями на підйомні модулі. Для вертикального переміщення підйомників передбачено напрямні профілі, закріплені на внутрішніх поверхнях спарених колон. Виштовхування покриття складається з повторних циклів. До кожного циклу входять два етапи. На першому етапі навантаження від покриття сприймають нижні платформи модуля. Для цього висувні опорні циліндри нижньої платформи модуля розміщують в отворах напрямних профілів. Переміщують верхню платформу модуля та ригелі покриття на висоту, яка відповідає ходу штоків гідроциліндрів модуля. На другому етапі навантаження від покриття сприймають верхні платформи модуля. Для цього висувні опорні циліндри верхньої платформи модуля розміщують у отворах напрямних профілів. Нижню платформу модуля піднімають на висоту, відповідну ходу штоків гідроциліндрів модуля. Після підйому покриття на проєктну висоту і закріплення несучих ригелів між оголовками спарених колон каркаса підйомні модулі опускають на фундаменти. Оптимізація процесів підйому покриття досягається за рахунок зменшення переліку монтажних робіт до операцій із остаточного закріплення покриттів на проєктній висоті та виконання виштовхування ригелів покриттів підйомними модулями в автоматичному режимі. Роботи зі зведення покриттів виконують на ділянках, розміри яких не перевищують габарити покриття, яке піднімають.

Ключові слова: підйомні модулі, зведення великопрогонових покриттів, механізоване технологічне обладнання, конструктивно-технологічні рішення, метод підтягування, несучий каркас.