Complex mechanization of structural coverage lifting using setting module

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Summary. The analysis of complex installation mechanization using adjusting hoisting module (VPVM) has been conducted. Hoisting systems allow basic assembly operations, namely many single-type operations. Namely: installation of structural coverage, verification of adjusted elements and constructions position, final attaching of the constructions. The main task at high size structural coverage lifting is to increase the productivity of installation. Determination of constructional features during installation using adjusting hoisting module (VPVM). The proposed installation enables the lifting due to the fact that the most labor-intensive operations can be automated. Coverage installation according to the way of lifting jack systems ejecting has the major advantage over existing methods of construction – installation can occur while arranging the permanent supporting elements (columns).

Key words: complex mechanization; hoisting system; assembling/installation; structural coverage.

Hoisting system is a mechanism which allows to perform in cycles basic installation operations and lifting techniques (movement) with the help of a single or multiple lifting jacks, as well as placing and installation of structural coverage in the project. Adjusting hoisting modules have several advantages over other mechanization systems of lifting large-size coverage, namely, they allow the workers, for the whole period of constructing, to perform many single-type operations and techniques: installation, concreting, verification, placing, welding, bolts installing, etc. The most labor-intensive operations can be automated, such as lifting and moving lifting jack systems. The number of units depends on the total weight of the coverage and is determined by calculation. Installation of the devices on the columns is performed at low project marks, directly before lifting coverage after completion of the final consolidated collection.

The list of basic operations and methods of conducting the consolidation of high-size covering structures and installation of lifts are defined by the engineering maps. The list of basic operations for at low coverage scaffold include:

• installation of high-size covering structures according to the technology bundling in the engineering map;

• verification of adjusted elements and constructions position;

• temporary and final attaching;

• installation of adjusting hoisting module (lifts) on all columns that will serve as operational;

• verification of adjusting hoisting modules and attaching them for inclusion in the further operation.

Lifting of the covering is performed with the help of legged locomotion hoisting modules cyclically while arranging permanent columns. This technology allows to perform consistently (due to the specially designed program the following cycles of blocks or coverage mounting, such as:

• lifting of the coverage to the height of the stroke of lifting-jack piston;

• assembling and temporary attaching the following element on the head of the bearing column (lifting height is due to the calculation, depending on the scheme and the establishment of jacks and it should be sufficient for installing the column element in project position);

• verification – determines the position of the block in plan, down, across; captures, monitors and ensures adherence of the project requirements; controls corresponding correcting by the deviations;

• attaching and transfer of the load from the covering on the new column head; consistent repeating of all the cycle operations with the covering installation to achieving the intended design point. The number of cycles is determined by the ration of the project point height to the column element height.

The adjusting/setting hoisting module:

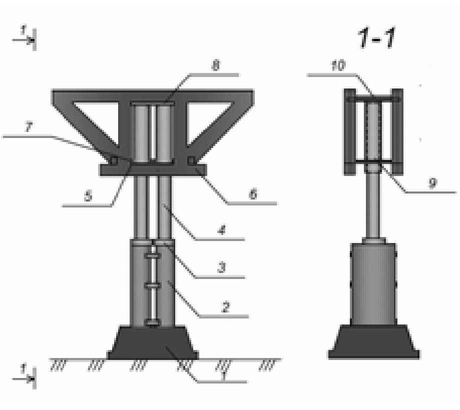

Fig. 1. The adjusting/setting hoisting module (1 - 1 – the setting hoisting module section): *1* – base, *2* – column, *3* – jack foot, *4* – jack rod, *5* – band for the lower stopper, *6* – frame *7* – lower stopper, *8* – top stopper, *9* – jack, *10* – try square

The work on establishing VPVM perform in the following way:[2]

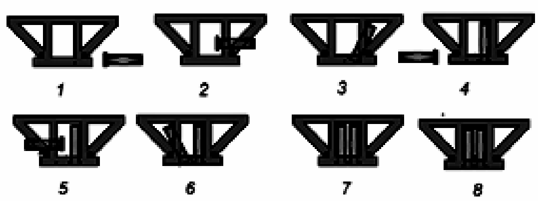

Fig. 2. Collection (VPVM: *1*- preparation of the 1st legged hoisting module lifting jack installation; *2*- installing of the 1st lifting jack due to the turning regarding the 1st point of turn, *3*- installing of the 1st lifting jack due to the 2nd point of turn, *4*- preparation of the 2nd lifting jack, *5*- installing of the 2nd lifting jack due to the turning regarding the 1st point of turn, *6*- installing of the 2nd lifting jack due to the turning regarding the 2nd point of turn, *7*- installing of the set that keeps the legged hoisting module lifting jack, *8*- the final form of the legged hoisting module (VPVM)

The way of installing the facilities covering using (VPVM):[3]

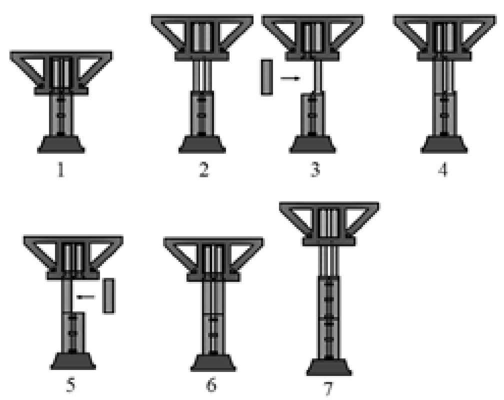

Fig. 3. Lifting stages (VPVM),: 1 - the original condition of the legged hoisting module (VPVM), *2* - the start of the hoist cycle (VPVM), 3- withdrawal of the first hoist rod (VPVM), *4*- the assembling and fastening of the first part of the column, supporting of the first part of the column by the first rod, *5*- withdrawal of the second hoist rod (VPVM), *6*- the assembling and fastening of the second part of the column, supporting of the second part of the column by the second rod, *7*- beginning of the next cycle of hoist work (VPVM)

Work on the VPVM dismantling is performed as follows:[3]

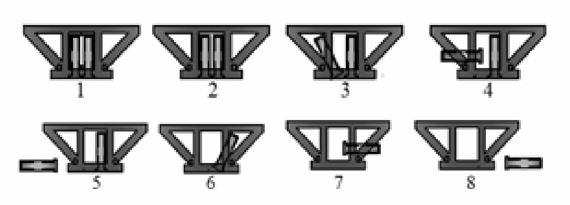

Fig. 4. Dismantling **(**VPVM),: *1*- the original form of the setting hoisting module (VPVM), *2*- withdrawal of the mounting holding setting hoisting module lifting jack (VPVM), *3*- pushing the 1st lifting jack 1st through the 2nd turning point, *4*- pushing the 1st lifting jack due to the turning regarding the 1st point of turn, *5*- complete removing of the first jack, 6- pushing the 2nd lifting jack through the 2nd turning point, *7*- pushing the 2nd lifting jack due to the turning regarding the 1st point of turn, *8*- removal of 2nd setting hoisting module lifting jack (VPVM)

The sequence of stages fulfillment:

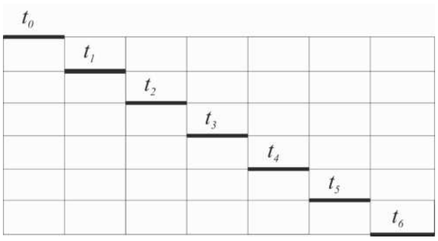

Fig. 5. The scheme of stages completion sequence

Here the value of time $t_0 \dots t_6$ – meet stages of installation work sequence 0...6. Thus: the duration of the zero cycle preparation does not affect the speed of installation covering, but only determines the start of the lifting cycle. Initial fastening of the hoist on the support element head with the work duration *t*1 depends [30…30/3] on the method of installation work and is reduced through increased mechanization level at the section [5]. This level (%) is found with the following formula:

$$У_{MP} = \frac{У_{MT}^{\mathrm{I}} \cdot d_0^{\mathrm{I}} + У_{MT}^{\mathrm{II}} \cdot d_0^{\mathrm{II}} + \ldots + У_{MT}^{n} \cdot d_0^{n}}{100},$$

Where d_0 is the level of operation mechanization,%: $У_{MT}$ is the specific weight of the operation;

$$У_{MT} = \frac{t_M}{t_0} \cdot 100,$$

where t_M is the spending of mechanized labour on the operations completion using selected mechanization methods, person/hour; t_0 – general labour intensity of the operations completion, pers./hour.

•t_2 – "coverage lifting" is characterized by the ratio of the velocity of the hoist to a modular step of the supporting elements:

$$t_3 = \frac{V_П}{l_K + l_{MП}},$$

where l_K is a modular step of the supporting element; $l_{MП}$ is the mounting limits height.

In contrast to the proposed lifting method, t_2 is sufficiently influenced by external natural factors: wind, ice, moisture etc, when lifting the load with the help of the devices with flexible link (the method of pulling up). When selecting values for module step l_K one should consider the following: an increase in the value of step reduces the total time of installation, however, it reduces the stability of constructions at the in-process stages and increases the size of the mounting devices. Conversely, though excessive reduction of the modular step leads to the construction resistance, however it significantly increases the duration of the installation and the material capacity of the supporting elements, because of the presence of a big quantity of elements in the bearing element.

The present study found that the best value modular step l_K is 0,8 ... 1,2 m.

• The duration of the stage 3, corresponding t_3, depends on the level of mechanization of the operation elements.

• The duration of stage 4 can be approximately determined by the formula:

$$t_4 = \frac{V_П}{l_{MП}},$$

where $l_{MП}$ is the mounting limits height, *m*.

• The duration t_5 of the phase 5 depends on the lifting lack speed characteristics:

$$t_5 = \frac{V_П}{l_P},$$

where l_P is the value of the hydraulic cylinder rods moving forward at which the output of the forks from the projection of the supporting elements occurs, m; the duration t_6 of the stage 6 is determined by the speed characteristics of the lifting mechanism. Empirically found that the velocity of rods pulling in V_B is determined by the formula:

$$V_B = V_П(1{,}5...2{,}0).$$

At the projecting stage it is necessary:

1. To determine the construction features of the high-size covering and places of its leaning on the supporting element head, coverage weight, maximum spans a and b, and projected coverage lifting height H.

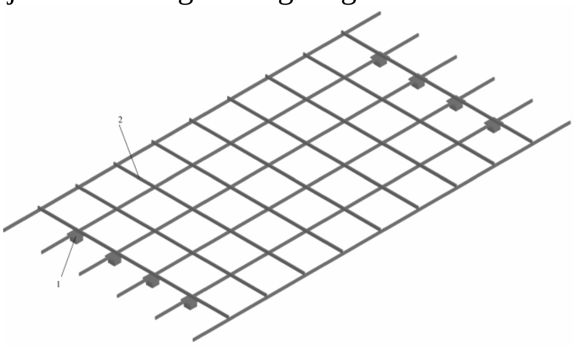

Fig. 6. The calculating covering scheme: *1* - lifting jack, *2* - covering

2. To set the operating parameters of the hoist hydraulic system due to the jack technical indicators (nominal pressure p_H and the flow of the working fluid Q_H) and to select power hydraulic cylinders according to the data.

3. To determine the necessary quantity of hoist devices and their technical characteristics (according to the number of resistance places of the high-size coverage (number of columns or supporting elements) that would satisfy the following essential requirements defined: load-carrying capacity

$$G_П = G_K / n,$$

where *n* is the number of jacks (in the case of the use of proposed hoist device for the conditions of lifting large-covering shown in Figure 6), distributed between 2 hydraulic cylinders $G_П = 4F_Ц$, lifting velocity (Fig. 7) $V_П$

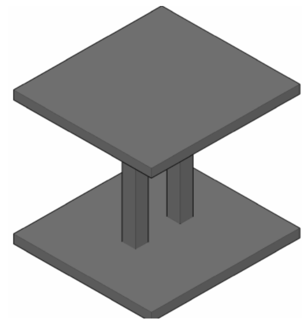

Fig. 7. The calculating lifting device scheme

The allowable load by the calculations for resistance should not exceed the value:

$$P \le \frac{P_{KP}}{n_y}.$$

We believe that the load forcing the rod is static, then we can use the formulae to calculate the critical (Euler) forces (Fig. 8) for the analysis of rod resistance.

This condition should be kept:

$$\sigma_{KP} = \frac{P_{KP}}{F} = \frac{\pi^2 E}{\lambda^2} \le \sigma_П,$$

where – σ_{KP} critical pressure; *F* – cross-sectional area; *E* – modulus of longitudinal elasticity of the material (E=2·10^5 for steel materials); $\lambda = \mu l / i_{\min}$ – the flexibility of the longitudinal rod when bending lengthwise; $i_{\min}$ – the smallest radius of inertia of the cross section; μ – coefficient of the given length (μ=2); 1 – the length of the rod.

In general case of the compressed homogeneous rod, the critical force is determined:

$$P_{KP} = \eta \frac{EJ_{\min}}{l^2} = \frac{\pi EJ_{\min}}{(\mu l)^2}$$

where $J_{\min}$ – is the smallest of the main central moments of inertia of the section; L- full rod length; $\eta = (\pi/\mu)^2$ – the coefficient of the critical load.

In view of the above given materials, we find the maximum height of load-lifting with the help of the jack systems.

$$l = \sqrt{\frac{\pi EJ_{\min}}{P_{KP}\mu^2}}.$$

When lifting load the cylinder rod works for compression. Strength condition:

$$\sigma_{CT} = \frac{F}{\pi d^2/4} \le [\sigma_{CT}].$$

Consequently, the diameter of the rod can be determined from the expression

$$d = \sqrt{\frac{4F}{\pi[\sigma_{CT}]}}.$$

The safety factor of stability

$$[S]' = 1{,}25[S],$$

Where [S] is the coefficient of safety, [S]=3.

We can determine the diameter of the rod with Euler's formula (taking into consideration the maximum height of lifting jack)

$$d = \sqrt[4]{\frac{64\mu^2 l^2 F_{KP}}{\pi^3 E}}.$$

Effort on the hydraulic cylinder rod is given by the formula:

$$F_{Ц} = p_H \cdot S_П,$$

where p_H is the nominal pressure in hydraulic drive, Pa; $S_П$ is the area of the piston in the pressure chamber, m^2,

$$S_П = \pi \cdot D^2/4,$$

where D is the diameter of the piston in the pressure chamber, m.

Under the terms of GOST 12445-80 the values are selected from a number of normal values of the nominal pressure:

p_H = [6,3 ...; 10; 12.5; 16; 20; 25; 32; 40; 50; 63 ...] MPa.

Then the values are determined from a number of normal values of the piston cylinder diameters to the GOST 6540-68 conditions:

D = [... 150; 160; 180; 200; 220; 250; 280; 320; 360...], mm.

In the given figure the curves show the actual efforts data on the hydraulic cylinder rod by changing the diameter of the piston at different pressures.

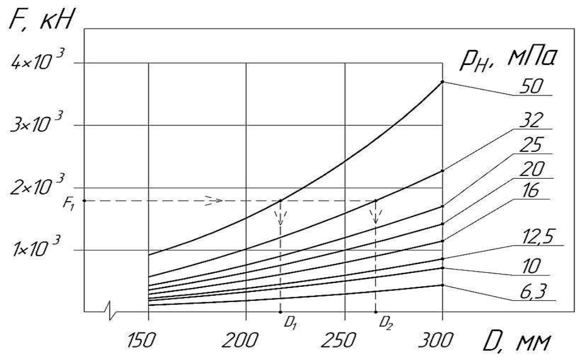

Fig. 8. Dependence of the actual efforts on the hydraulic cylinder rod on the diameter at pressures from 6.3 to 50 MP

Conclusion: A new lifting jack system is a device and method having advantages over other systems of mechanization of lifting large-coverings, namely, provides the workers (for the duration of lifting coverage) with many of the single-type operations and techniques: installation, concreting, verification, placing, welding, bolts installing, etc. And the most labor-intensive operations can be automated, such as lifting and moving lifting lack systems. The proposed adjusting hoisting module (VPVM) enables step-by-step lifting due to the fact that the installation can take place while arranging the permanent supports (columns).

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КОМПЛЕКСНАЯ МЕХАНИЗАЦИЯ ПОДЪЕМА СТРУКТУРНЫХ ПОКРЫТИЙ ГРУЗОПОДЪЕМНЫМ УСТАНАВЛИВАЮЩИМ МОДУЛЕМ

Аннотация. Выполнен анализ комплексной механизации монтажа с помощью грузоподъемного устанавливающего модуля (ВПВМ). Грузоподъемные системы позволяют выполнять основные монтажные операции, а именно много однотипных операций. А именно: монтаж конструкций покрытия, выверка положения элементов и конструкций, монтировались, окончательное закрепление конструкций. Основной задачей при подъеме крупноразмерных структурных покрытий является повышение производительности монтажа. Определение конструктивных особенностей при монтаже с помощью грузоподъемного устанавливающего модуля (ВПВМ). Предложенный монтаж позволяет выполнять подъем за счет того, что наиболее трудоемкие операции могут быть автоматизированы. Способ монтажа покрытия методом выталкивания домкратными системами имеет основное преимущество над существующими методами возведения - монтаж может происходит с одновременным устройством постоянных опорных элементов (колонн).

Ключевые слова: комплексная механизация, грузоподъемные системы, монтаж, структурные покрытия.