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DETERMINING THE DEGREE OF ADAPTABILITY OF MODERN LABOR COST TO INNOVATIVE CONSTRUCTIVE AND TECHNOLOGICAL SOLUTIONS OF FRAME CONSTRUCTION

ВИЯВЛЕННЯ СТУПЕНЯ АДАПТОВАНОСТІ СУЧАСНИХ НОРМ ВИТРАТ ПРАЦІ ДО ІННОВАЦІЙНИХ КОНСТРУКТИВНО-ТЕХНОЛОГІЧНИХ РІШЕНЬ КАРКАСНОГО БУДІВНИЦТВА

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Abstract. *The article considers the problem of determining labor standards in accordance with the application of modern structural and technological solutions of frame construction. The problems of applying the current labor standards of construction processes in Ukraine are noted, especially taking into account the specifics of the conditions of their implementation in post-war territories . It is noted that the main drawback of the vast majority of current standards is the inability to evaluate technological processes during variant design because they do not respond to innovative changes in mechanization and organization of processes. It all depends on at what level of the structure of the construction process the standards were determined, how the synthesis of these standards was carried out for transfer to a higher level of the structure.*

The paper analyzes the current labor standards taking into account the sequence of construction processes for monolithic works in frame construction, including the arrangement of foundations, the erection of columns, the arrangement of floors, in particular when using traditional methods of formwork installation and when implementing modern structural and technological solutions.

To take into account the variability of methods for performing construction operations, the use of variant design is proposed as a direction for solving construction problems from the system of constructive and technological proposals. The prospects of microelement modeling of construction processes, which takes into account the structural features of buildings, their components, engineering methods for ensuring the implementation of constructive and technological solutions for frame construction, features of mechanization of construction processes and methods of their monitoring, are also noted.

Unlike traditional modeling methods that operate with large objects, the microelement approach allows you to study the behavior of individual structural elements at the microlevel. For reasonable standardization of construction processes, the level of detail of construction process objects should not be less than LOD 300 , and it is desirable that it reach LOD 400.

All this together makes it possible to analyze existing methods and ways of implementing construction and technological tasks, in particular in frame construction.

Keywords*: frame construction, construction technologies, variant design, labor rates,* *formwork systems, reinforcement, concreting, mechanization of construction processes, microelement modeling*

Introduction

The system of making design decisions for innovative technologies of frame construction is associated with the possibility of simultaneously considering several options. Today, design engineers have the problem of choosing effective structural and technological solutions, which arises when assessing the labor intensity and productivity of technological construction processes. The problems of applying the current labor standards of construction processes in Ukraine are noted, especially taking into account the specifics of the conditions of their implementation in post-war territories . It is noted that the main drawback of the vast majority of current standards is the inability to evaluate technological processes during variant design because they do not respond to innovative changes in mechanization and organization of processes.

Presenting main material

Frame construction of industrial and civil facilities is the main type in which frame structural systems of buildings and structures are used. The construction of monolithic and prefabricated-monolithic frame buildings has become characteristic for Ukraine as the most effective of the entire set of technologies [1].

A feature of monolithic construction is that there is no need to build special factories for the manufacture of structures with significant capital investments, therefore it is cheaper and faster to organize construction using monolithic technologies, for the implementation of which there are enough factories for the manufacture of commercial concrete mix and the use of products of the metallurgical industry, which is one of the developed industries in Ukraine. Formwork for the manufacture of monolithic structures, as a rule, is rented from well-known companies from the logistics centers of leading European companies [2], which are also widely represented in Ukraine.

The main load-bearing structures of monolithic and prefabricated-monolithic frames are foundations, columns and pylons, beams, slabs and walls of staircases, elevators and stair-elevator blocks. Most structures are reinforced concrete.

Foundations for columns are designed as slab foundations with sub-column protrusions and columnar foundations. There are many variants of structural and technological solutions for foundations [9, 10]. Columnar foundations of monolithic and prefabricated-monolithic construction are more often used. When erecting high-rise buildings of more than 12…16 floors, slab reinforced concrete foundations with a thickness of 0.6…1.0 m are mainly used. For weak soils, pile foundations with grillages in the form of strip or slab structures are designed.

In conditions of dense development, typical of large cities, for the arrangement of foundations, structural and technological solutions of “walls in the soil” and “Barrett” type piles are used, which are accompanied by the peculiarities of the construction of underground excavations [9].

The designs of columns and pylons of multi-storey monolithic frame buildings are carefully considered in [10], where their main geometric and physical and mechanical parameters are determined. In the projects of the arrangement technologies according to the technological flows, the designs of columns, pylons and walls are related to the flow of arrangement of vertical structures. The geometric parameters include the height in accordance with the height of the floors, the dimensions of the cross-section in accordance with the shape, which can be square, rectangular, oval and round.

Monolithic frame floors are designed without beams (ribs) and with beams. Detailed structural and technological solutions for floors are considered in [10, 11]. There are many variants of floors structural and technological solutions. In recent periods of development of monolithic construction, attention has been paid to structural and technological solutions of lightweight floors without beams, such as "Round Tube", "Bubble Deck, Cobiax", "Beeplate, U-BOOT Beton", etc. Lightweight two-layer floors belong to prefabricated-monolithic structural and technological solutions. Such floors are characterized by good technical and economic indicators. The technologies "Filigran" and "Quad-Deck" are known [1]. Floors with ribs have become widespread due to the economical consumption of concrete and reinforcement per square meter of floor. Two technologies are known: "Ribbed Slab" and "Waffle Slab" [11].

The process of considering options for technologies for the construction of monolithic and prefabricated-monolithic structures of frame buildings is very important from the point of view of making effective structural and technological decisions when developing design and technological documentation. An element of design and technological documentation is a work execution project, and its element is technological maps [9]. In the composition of technological maps, one of the main elements is the schedules of process execution, which are developed on the basis of labor cost standards [12] .

Labor cost standards and time standards are the main tool that ensures the correct ratio between the quantity and quality of work. The progressiveness of the standards lies in the fact that when designing them, advanced methods and methods of performing work, modern technologies and construction machines, equipment, inventory and tools, and the normal intensity of work must be taken into account.

An analysis of modern regulatory documents was conducted, according to which it is currently possible to estimate labor costs for construction and installation work. Resource element estimate norms for the main construction works during the construction of frame buildings are presented by collections for: monolithic concrete and reinforced concrete structures; prefabricated concrete and reinforced concrete structures, metal structures [15-17]. The norms have been in effect since 2022, which are the latest today. Prior to these norms, norms for the assembly and disassembly of formwork [18], for reinforcement work [19], for concrete work [20] were in effect, the effect of which was terminated in 2014, but there is no fundamental difference between them. 8 years have passed between the terms of the two documents, however, the principles of constructing norms and their content have hardly changed, and during this period much has changed in the field of construction technologies.

The main disadvantage of norms [13-21] is the inability to evaluate technological processes during variant design because they do not respond to innovative changes in mechanization and organization of processes. It all depends on at what level of the structure of the construction process the norms were determined, how the synthesis of these norms was performed for transfer to a higher level of the structure.

The composition of the process that is standardized shows the level of standardization of the technological process structure. Thus, in work [12], the composition of the process of assembling and disassembling wooden panel formwork is presented at the third level of the structure [2] with the disclosure of the content at the level of the set of operations (the fourth level of the structure). However, the norm is defined conditionally according to the specific type of formwork, which had subcircular boards, clamps, other fastening elements, etc. The process structure also includes the following operations: checking the marks on the axes and marks at the places of installation of the formwork; lubricating the surface of the formwork that is in contact with the concrete; installing the panels and fastening elements of the formwork; checking the formwork; dismantling the fastening elements, panels, boards; taking the formwork elements to the storage place and stacking them. There are no operations for feeding the formwork elements to the installation place, cleaning the working surface of the panels from concrete residues.

This process structure includes formwork stripping operations, which are performed in a different cycle after the concreting and concrete care processes. We see a mechanical combination of two different third-level processes, which is undesirable for the use of codes in variant design.

The process of assembling and disassembling modular formwork from the Doka company [18] (which is innovative in design) consists of the following operations: cleaning the base with compressed air; installing and securing the formwork elements in the design position; applying a layer of paraffin; disassembling the formwork elements and fasteners; sorting, cleaning the formwork elements from adhering concrete; lubricating the formwork; feeding the formwork elements to the work area; transporting the formwork elements to the storage location and stacking them.

Here, when considering the structure of the formwork installation process, there are processes of different levels. Installing and securing the formwork elements in the design position is no longer an operation, but a third-level process, which is decomposed into operations. Thus, the same operation is taken into account twice - applying paraffin and lubricating the formwork. There is the same mechanical combination of two different third-level processes, which is undesirable for using standards in variant design.

Variant design involves the selection of different methods of performing actions. For example, if we consider cleaning the base before installing the formwork, the following methods can be adopted: cleaning with brushes; cleaning with compressed air; cleaning by pushing, etc. It is clearly shown that the labor cost rate for such an selection will be the same. g. Formwork lubrication can be applied by roller, spray or paint brush. In particular, the regulatory values do not take into account changes within the process structure.

The list of processes standardized in works [13-21] shows that innovations in the technology of erecting frame building elements cannot be evaluated even by analogy.

Many questions arise regarding the units of measurement of process products. It is proposed as a unit of measurement of 100 m^3 of concrete and reinforced concrete in the product. For estimates, such a unit of measurement is very convenient for quickly calculating the cost of work, and for designing technological maps, labor costs for all components of the process with the ability to change their content and when choosing a variant solution are very important. The quality of work, productivity and occupational safety depend on this.

According to tables [13, 18], for the standardization of the processes of arranging the formwork of walls and partitions, the thickness of the structure is taken as an indicator of the change in labor costs. If we imagine that the area of the vertical surfaces of the structure is unchanged (the area of the panels is also unchanged), it is logical that the labor intensity of the process will be approximately the same in the main value and does not depend significantly on the thickness of the structure. It is understandable to use a coefficient to convert from a square meter of wall area to a unit of measurement of products in cubic meters of concrete. With this approach, the direct dependence of the labor intensity of the formwork arrangement process on the size of the surface area is lost, which is important in variant design of technologies.

According to the standards [18], labor costs for the installation and dismantling of formwork vary depending on the square meters of the formwork surface adjacent to the concrete. The technical approach to determining the scope of work is correct - it is permissible for the formwork panels to protrude above the vertical structures by no more than 50 mm, but modern modular formwork systems can exceed the structure by the size of the panel module (100...300 mm). The situation is similar with determining the scope of work when installing the floor formwork (time rates per 1 m^2 of the formwork surface adjacent to the concrete), where the installation of the side panels of the slabs requires an increase in the area of the horizontal formwork to ensure normal dimensions of the workplaces for the performers and to install a temporary fence according to the rules of safe working conditions. The extensions of the formwork beyond the slab are not always the same and depend on the design of the formwork systems and geometric dimensions of the board, therefore it is better to use the actual formwork area for variant design of processes.

The main factors in the collections [13, 18] that influence the choice of labor costs for assembling and dismantling formwork are: the size of the formwork panels (up to 1 m^2, from 1 to 2 m^2, more than 2 m^2); the volume of concrete in the structure (up to 3 m^3, from 3 to 5 m^3, more than 2 to 4 m^3, up to 10 m^3, etc.); for columns, the cross-sectional dimensions are selected as a characteristic factor (up to 600 mm, from 600 to 700 mm, etc.); for horizontal flat structures, the thickness of the slab is taken as an influential factor (up to 100 mm, more than 100 mm to 120 mm, etc.). It is clear that this approach to determining gradation by factors was adopted purely for practical reasons for manual calculation on calculators, but with the development of computer technology, it would be more convenient to use mathematical formulas that would provide greater accuracy of assessment, which is very important for variant process design.

The installation of the floor formwork can take place at different heights depending on the height of the floors. To support the panels, scaffolding (framework) is assembled from sliding racks. It is proposed to consider the standardization of the assembly and disassembly processes separately from the formwork panels. The main factor influencing the standard is the height up to 6 m and more than 6 m. The unit of measurement is 100 m of racks. The frame system of the floor formwork scaffolding has a specific number of racks, crossbars, beams, etc. First, the labor cost standard depends on the number of scaffolding elements, and not on the total footage of the racks, therefore the standards [13-21] are not acceptable for evaluating scaffolding options. In addition, the designs of racks, crossbars and fasteners vary depending on the manufacturer, which is not considered in these standards at all.

The disadvantages of the regulatory framework for the processes of reinforcing monolithic structures are the unit of measurement in tons of reinforcing products. For example, in collections [13, 15, 17], the standards for installing reinforcement with individual rods with knitting are given with a unit of measurement of 1 t. with a selection factor for rod diameters of 12-18 mm and more than 18 mm. Reinforcing products are characterized by the number of rods and the length of each rod. The diameter of the rod affects only the mass of a rod of a specific length. According to the composition of the process (unloading and feeding the reinforcement to the installation site; cleaning the reinforcement from rust; sorting; straightening, bending and cutting reinforcing steel; installing (inserting) reinforcement with individual rods with knitting of connection nodes; securing the protective layer clamps), not all operations depend on the diameter of the rods. It would be more accurate to measure products by the geometric parameters of the structure. For example, for monolithic columns - by cross-sectional dimensions (use the column height as an additional factor), and for floors - by area in square meters, since the reinforcing structure is mainly flat mesh.

Regarding the processes of placing concrete mix in the formwork of structures, the standards provide for a limited number of laying methods: laying concrete mix in structures with buckets; by concrete pumps and laying concrete mix in the floor structure with truck-mounted concrete pumps. It is unclear why concrete pumps are offered for laying the mix only in floors. The main factors influencing the labor rate are: for columns, the size of the smallest side of the cross section is up to 300 mm, over 300 mm to 500 mm and over 500 mm; for floors - the area between the axes of the columns is up to 10 m^2, over 10 m^2 to 20 m^2 and over 20 m^2.

Concrete placing by buckets depends on the productivity of the crane, which in turn depends on the lifting speeds, changes in the boom reach, the rotation of the crane tower and the speed of movement of the crane itself from one parking lot to another. The norm includes a constant productivity value of 2 m^3/h. From practical experience, the productivity of the crane can be from 4 to 8 m^3/h depending on the bucket capacity, type and brand of the crane [2, 9]. When designing a variant, a specific bucket capacity and a specific crane are included in the technological map of the concreting process, therefore it is desirable to have a variable labor rate. In our opinion, it is better in these cases to use calculations using the appropriate process productivity formulas.

For concrete pumps, the standards set the process productivity at 4 m^3/h, and for truck-mounted concrete pumps - 10 m^3/h. The productivity of truck-mounted concrete pumps with a distribution boom (which is not specified in the standards [13, 15]) is higher than the productivity of stationary concrete pumps because it involves bringing the truck-mounted concrete pump into the working position, unlike assembling and disassembling concrete pipes with connection to the concrete pump, which is lost up to 50% of the working cycle time. Many factors affect the variability of the standards, such as the type of concrete pump, the height and range of concrete supply, the thickness of the concrete layer, the process organization scheme on the grabs, the method of performing operations of leveling the concrete mixture, compacting the concrete mixture, smoothing the exposed surface of concrete, etc. Therefore, when designing a variant process, it is better to use calculations using the appropriate formulas for process productivity according to the method [2].

Finite element modeling is a modern powerful tool that allows for detailed analysis and optimization of construction processes. Unlike traditional modeling methods that operate on data regarding generalized characteristics of large objects (e.g., buildings as a whole), the finite element approach allows for the investigation of the behavior of individual structural elements at the micro level.

Microelement modeling involves considering the overall building system in terms of its component structures, elements with the determination of the properties of each of them, as well as the analysis of their interaction. Next, a mathematical description of the components of the system is performed, and with the help of digital means their calculations, visualization of the results, and modeling of behavior in various operating conditions are performed [22].

The advantages of such modeling are the expected increase in the accuracy of research with increasing detail of consideration of the components of the building system, the possibility of optimizing structural and technological solutions taking into account the priority requirements for the construction object as a whole. Modeling the components of the building system also allows predicting their behavior throughout their life cycle, taking into account the geographical specificity of the work, requirements for environmental friendliness, identifying potential problems in the building, its structures at different stages of the life cycle , etc. The usefulness of using microelement modeling in construction from the point of view of construction technologies lies in the possibility of early modeling of construction operations using innovative engineering and technological solutions, taking into account that their development on real objects is not provided for by construction standards. For reasonable standardization of construction processes, the level of detailing of objects of the construction process should not be less than LOD 300 , and it is desirable that it reach LOD 400.

With the development of computer technology and software, the capabilities of microelement modeling, in particular for construction processes, are constantly expanding. In the future, we can expect even greater detailing of models, consideration of nonlinear effects and interaction of various physical processes when considering construction processes, taking into account mechanized means of performing work, geoinformation methods of control and management of construction operations. This will allow creating competitive engineering and technological solutions, in particular in frame construction.

Conclusions

1. There is a low level of adaptation of modern labor standards to innovative design and technological solutions for frame construction. The main disadvantage is the inability to evaluate technological processes in variant design because there is no dependence of standards on innovative changes in mechanization and process organization.

2. The gradation by factors affecting labor costs was adopted purely for practical reasons for manual calculation on calculators, but with the development of computer technology, it would be more convenient to use mathematical dependencies that would provide greater accuracy of estimation, which is very important for variant process design.

3. The development of the system of standardization of construction processes in the direction of creating a methodology for microelement modeling based on the experience of microelement standardization on the example of the machine- building industry is considered promising.

4. For a reasonable standardization of construction processes, the level of detail of construction process objects should not be less than LOD 300 and it is desirable that it reaches LOD 400.

5. In the future, we can expect even more detailed models, consideration of nonlinear effects and interaction of various physical processes when considering construction processes with regard to mechanized means of performing work, geoinformation methods of control and management of construction operations

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***Аннотация**. У статті розглядається проблема визначення норм праці у відповідності до застосування сучасних конструктивно-технологічних рішень каркасного будівництва. Відзначено проблематику застосування діючих норм праці будівельних процесів в Україні, особливо зважаючи на специфіку умов їх виконання на поствоєнних терирорiях. Зауважено, що основним недоліком переважної більшості діючих норм є неможливість оцінювати технологічні процеси при варіантному проєктуванні тому, що вони не реагують на інноваційні зміни в механізації і організації процесів. Все залежить від того, на якому рівні структури будівельного процесу здійснювалося визначення норм, як виконувався синтез цих норм для перенесення на вищий рівень структури*

В роботі проведено аналіз діючих норм праці з урахуванням послідовності будівельних процесів для монолітних робіт при каркасному будівництві, включаючи улаштування фундаментів, зведення колон, улаштування перекриттів зокрема при використанні традиційних методів всатновлення опалубки та при впровадженні сучасних конструктивно-технологічних рішень.

Для врахування варіантності способів виконання будівельних операцій пропонується застосування варіантного проєктування в якості напряму широкого вирішення будівельних задач з системи конструктивно-технологічних пропозицій. Відмічено також перспективність мікроелементного моделювання будівельних процесів, що враховують конструктивні особливості будівель, їх складових, інженерних методів забезпечення виконання конструктивно-технологічних рішень каркасного будівництва, особливості механізації будівельних процесів та способів їх моніторингу.

На відміну від традиційних методів моделювання, які оперують з великими об'єктами, мікроелементний підхід дозволяє досліджувати поведінку окремих елементів конструкції на мікрорівні. Для обгрунтованого нормування будівельних процесів рівень деталювання обєктів будівельного процесу не повинен бути меншим LOD 300 а бажано, щоб він досягав показників LOD 400.

Усе це разом дає змогу виконувати аналіз існуючих методів та способів реалізацій будівельно-технологічних задач, зокрема в каркасному будівництві.

***Ключові слова**: каркасне будівництво, будівельні технології, варіантне проєктування, норми витрат праці, опалубні системи, армування, бетонування, механізація будівельних процесів, мікроелементне моделювання.*

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