

Optimization of parameters for the construction of prefabricated residential buildings

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Abstract. The development of prefabricated residential buildings construction is regarded. Organizational and technological features of building construction are disclosed. An approach to determine the period of the construction of buildings, taking into account serviceability is given. This serviceability is expressed in terms of the consolidation of prefabricated elements, using the example of the standard series of residential buildings (KOPE, I-155). The calculation formulas for determining the period of construction of substructure and superstructure are specified. The period depends on the average daily number of erected prefabricated parts. The resultant dependence between the period of the erection of prefabricated elements and the number of erected storeys is substantiated. The proposed optimization methods will reduce energy costs and make the construction process less energy intensive.

1 Introduction

Modern prefabricated building construction is distinguished by effective rapidly erected structural systems and a minimum period from the production of prefabricated structures to the setting to work. The main directions of continuous development of prefabricated construction are increasing the mass and reducing the range of products, consolidating the erected elements, the use of prefabricated models. Thus, the maximum aggregation of material resources and the transfer of labor-intensive manufacturing processes of structures into factory conditions ensure a highly efficient industrial complex and mechanized process of continuous construction of buildings, as well as a stable competition to monolithic construction. Prefabricated construction has been actively developed in the field of large-panel housing construction as a result of a significant improvement in space-planning and facade solutions, increasing the comfort and energy efficiency of buildings.

Currently, prefabricated residential buildings have a variety of typical section layouts – multi- and single-section (tower type) buildings, buildings with fixed and variable number of storeys, buildings with underground and attached underground parking, low-rise

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buildings, buildings with utility boxes in the basement, and buildings with increased total area of apartments.

The main stages of prefabricated buildings erection are the preparatory period, the construction of the substructure, the construction of the superstructure, the construction of external supply lines and site improvements.

Mobilization period of construction includes three stages - object stages for preliminary and engineering preparation of the construction site and one specialized stage for the construction of a domestic campus for builders. The structure and scope of work of the mobilization period depend on the adopted technological scheme for the construction of the building and the conditions of work. In any case, decisions of the mobilization period are always aimed at maximizing the use of permanent and inventory buildings and structures and at minimizing temporary construction.

The first stage of the main period of construction is footing excavation. Amounting crane is installed during the same period for the substructure construction. After the mechanized soil excavation and its manual refinement, a sand blanket is arranged. Monolithic slabs on a prepared foundation or on piles, pile slabs with a monolithic or prefabricated monolithic reinforced concrete raft, pile foundations without concrete pile caps, girder foundation, made from reinforced concrete blocks and slabs are used as foundations. The existing schemes for the substructure construction are oriented both on the advanced installation of exterior wall panels and the erection of internal walls, followed by the installation of elevator shaft elements and staircases, floor panels and entrance elements. Simultaneously with the foundation annular drainage is arranged. After wall drainage, the pit hollows are filled in and the floor is filled.

The construction of the superstructure includes the installation of load carrying and enclosure structures, as well as general construction, special, finishing and roofing works. The leading construction process for the superstructure construction is the installation of precast concrete structures, the technology of which is determined by ensuring the stability of the erected structures, the use of appropriate technological equipment, the complexity of structures fixing, etc. [2, 8]. The predominant option is when elevator shafts and exterior wall panels are first installed on the storey, which then includes interior wall panels. All parts are connected by welding or bolts, then butt joint grouting takes place. After this stage gypsum-concrete partitions, elements of the staircase, and loggia walls are installed. After the entire cycle of works on the storey, a covering is erected, which panels are also interconnected and joint grouting takes place.

Coordination of general construction, special and finishing works is particular difficult. Special works (plumbing, electrical) are performed in two stages.

At the first stage, plumbing works involve the arrangement of water-supply facilities (cold, hot), of heating and gas supply. Electrical works include routing of vertical and distribution cables in vertical shafts, as well as the installation of apartment electrical panels. At the second stage, plumbing works starts after the first cycle of coloring. After this stage it is possible to set up plumbing fixtures. As a rule, plumbing works are performed by one team, in which there are specialized units.

The second stage of electrical work starts after ceilings coloring and paper hanging on walls. It includes installation of holders and lamps, installation of sockets, switches, plafonds, and calls. After the finishing works, the installation of fire alarm, dispatch communication and radio broadcasting is carried out.

In prefabricated buildings, plaster and tiled works are carried out on the storey by integrated teams. Painting work is performed in two stages. At the first stage, puttying and painting of ceilings, loggias and balconies is carried out, walls are prepared for wallpapering and painting of walls and joinery. Flooring with parquet and linoleum is

carried out after the end of the "wet" processes. At the second stage, wallpapering and painting of walls and joinery are carried out.

Large-panel residential buildings can be multi- and single-sectional. Depending on space-planning and constructive decisions, multi-sectional buildings are divided into bays and sections. For example, the size of the bay is equal to the minimum of the section floor and to the maximum of the building floor. Installation work is performed in two streams of 3-5 sections, each of which uses its own installation crane. At the same time, general construction and special works are performed with a gap from installation work with one or two storeys in areas where erection work is not performed at the time.

Single-sectional buildings (tower type) are single-gripping and therefore erection, general construction and special works are carried out simultaneously, but in different areas. Therefore, the building is vertically divided into tiers equal to one storey and to two storeys for frame buildings with columns in two floors.

2 Materials and Methods

The construction of prefabricated residential buildings can be carried out according to various schemes, differing from each other both in the degree of combination of erection, general construction, special and finishing works, and by the intensity of their production [1, 5]. Most often, in practice, two- and three-cycle technology schemes are used. At the same time works can be performed in various shifts, etc. Such schemes use DSK-1, DSK-3, "Inzhstroy", "Fundamentstroy" and others. In this case, the construction of engineering networks and works on the improvement of the territory (Table 1) is carried out in parallel with special and finishing works inside the building after the crane dismantling [7, 11].

The total period of the residential building construction in this case is determined as follows.

$$T = T_1 + T_2 + T_3 \quad (1)$$

when $T_4 \leq T_3$, $T_5 \leq T_3$,

where T is the total period of the residential building construction, days;

T_1 , T_2 , T_3 is the period of the preparatory period, the construction of the substructure and superstructure, respectively, days;

T_3' , T_4' , T_5' is the completion date of work on the construction of the superstructure, on the construction of external supply lines and site improvements, respectively.

Table 1. The structure of work on the construction of external supply lines and site improvements.

The structure of work	
Construction of external supply lines	Site improvements
Laying of heat supply system	Ground leveling of the territory
Sewer laying	Road and pavement construction works
Laying of rainwater system	Asphalt laying
Laying of water supply system	Laying of the lawn
Construction of individual heating unit (constructional work, installation of heat mechanics, automation)	Roadside planting
Laying of telephone conduit	Installation of landscape products
Laying of low-volt cable	
Laying of canalization of unified dispatcher service and TV	
Installation of external lighting	
Installation of radio input device	

It should be noted that the period of the superstructure construction is determined taking into account the combination of work:

$$T_3 = t_1 + \sum_{i=2}^n (1 - \Psi_i)t_i, \quad (2)$$

Where t_1 is the installation time, days;

t_i is the period of the i -th work, days; $i = \overline{2, n}$;

Ψ_i is the coefficient of combining i -th work with previous works:

$$\Psi_i = \frac{t_i^c}{t_i}, \quad (3)$$

where t_i^c is the period of the i -th work in combination with previous works.

3 Results

Studies have shown that the most important factor in achieving high levels of continuity, uniformity, alignment and rhythm of the construction of prefabricated buildings is the constructionability. According to experts [4, 5], the constructionability of structures' fabrication is 65-80%, transport constructionability is 5-6%, and serviceability is 15-30%. It should be noted that the indicator of consolidation of prefabricated parts, determining as the ratio of the number of prefabricated parts to the total area of the building, for prefabricated buildings of the fourth industrial generation varies greatly. For example, in standard series KOPE, this indicator is 442.3-498.7, and in I-155 series it is 212.0-355.7. Thus, installation time can be expressed through the indicators of the average daily number of the erected prefabricated elements.

For the substructure construction:

$$T_2 = \frac{H_1}{m_1}. \quad (4)$$

For the superstructure construction:

$$T_3 = \frac{H_2}{m_2} + \frac{H_3}{m_3}(K - 1) + \frac{H_4}{m_4}, \quad (5)$$

Where H_1, H_2, H_3, H_4 is the number of prefabricated elements at erection of a technical underfloor space, the first floor, the typical floor and a mechanical floor, respectively; m_1, m_2, m_3, m_4 is the average daily number of the erected prefabricated elements of a technical underfloor space, the first floor, the typical floor and a mechanical floor, respectively;

K is the number of storeys.

With reference to the standard series KOPE, the following formulas can be used [2].

For the substructure construction:

$$T_2 = \frac{140}{m_1}, 6 \leq m_1 \leq 15. \quad (6)$$

For the superstructure construction:

$$T_3 = \frac{215}{m_2} + \frac{215 \cdot 21}{m_3} + \frac{150}{m_4}, \quad (7)$$

$$12 \leq m_2 \leq 50;$$

$$12 \leq m_3 \leq 50;$$

$$8 \leq m_4 \leq 30.$$

At the same time, the indicators of the average daily number of the erected prefabricated elements vary greatly, and since they represent statistical data, they therefore express the totality of the influencing factors (the discrepancy of personnel to the number of simultaneously constructed buildings, climatic conditions, etc.) [3, 9-15]. Therefore, to determine the average number of prefabricated elements erected per day, it was constructed a histogram on the example of the erection of a prefabricated I-155B residential building. This histogram made it possible to hypothesize a normal skew-symmetric distribution of the average number of prefabricated parts erected per day and take the most stable value of 22-23 elements per day.

In the result of processing of a representative array of source information, it became possible to establish a relationship between the period of erection of prefabricated residential buildings and the number of erected storeys. This relationship is approximated by linear regression better than quadratic and logarithmic:

$$T_3 = 0,25 + 0,21K. \quad (8)$$

To confirm the consistency of these empirical dependencies, it is advisable to compare the results of determining the period of the superstructure construction of the I-155B building using formulas (5) and (8).

For 22-storey buildings:

$$T_3 = \frac{144}{23} + \frac{144 \cdot 21}{23} + \frac{172}{19} = 146.7 \text{ days};$$

$$T_3 = 0.25 + 0.21 \cdot 22 = 4.87 \text{ month}, \quad \text{or} \quad 4.87 \cdot 30 = 146.1 \text{ days.}$$

For 24-storey buildings:

$$T_3 = \frac{144}{23} + \frac{144 \cdot 23}{23} + \frac{172}{19} = 159.31 \text{ days};$$

$$T_3 = 0.25 + 0.21 \cdot 24 = 5.29 \text{ month}, \quad \text{or} \quad 5.29 \cdot 30 = 158.7 \text{ days.}$$

The convergence of the results is quite high.

4 Conclusions

One of the most important factors in the effectiveness of installation work on the construction of prefabricated buildings is the construction ability, an indicator of which may be the consolidation of prefabricated elements. The period of building installation is expressed by the indicator of the average daily number of the erected prefabricated elements.

A method for determining the average number of the erected prefabricated elements per day is proposed. For residential prefabricated I-155B buildings it is 22-23 elements per day. A linear relationship between the period of erection of prefabricated residential buildings and the number of erected storeys was established. Its viability is proved.

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