Methods of erection of high-rise buildings

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Abstract. The article contains the factors determining the choice of methods for organizing the construction and production of construction and installation work for the construction of high-rise buildings. There are also indicated specific features of their underground parts, characterized by powerful slab-pile foundations, large volumes of earthworks, reinforced bases and foundations for assembly cranes. The work cycle is considered when using reinforced concrete, steel and combined skeletons of high-rise buildings; the areas of application of flow, separate and complex methods are being disclosed. The main conditions for the erection of high-rise buildings and their components are singled out: the choice of formwork systems, delivery and lifting of concrete mixes, installation of reinforcement, the formation of lifting and transporting and auxiliary equipment. The article prescribes the reserves of reduction in the duration of construction due to the creation of: complex mechanized technologies for the efficient construction of foundations in various soil conditions, including in the heaving, swelling, hindered, subsidence, bulk, water-saturated forms; complex mechanized technologies for the erection of monolithic reinforced concrete structures, taking into account the winter conditions of production and the use of mobile concrete-laying complexes and new generation machines; modular formwork systems, distinguished by their versatility, ease, simplicity in operation suitable for complex high-rise construction; more perfect methodology and the development of a set of progressive organizational and technological solutions that ensure a rational relationship between the processes of production and their maximum overlap in time and space.

1 Introduction

The construction of high-rise buildings has a long history. The birthplace for them is the United States. For the first time in urban planning there were created skyscrapers that determined the business centers of New York, Chicago and other major cities. In the second half of the last century, the active urbanization of European cities caused a variety of high-rise buildings in London, Paris, Frankfurt-on-Main, etc. Particularly should be highlighted Défense multifunctional complex (France), which is distinguished by the originality of design solutions and high unification of structural systems of high-rise buildings. Later, the rapid economic growth ensured the construction of record high buildings in East and South-East Asia: Singapore, Hong Kong, Shanghai, Taipei, etc. [1].

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Our country has also got a certain experience of high-rise construction: erected buildings on the Smolenskaya Square, near Krasnye Vorota area, the construction of the New Arbat district, the construction of the buildings of the RF Government and CMEA (Council for Mutual Economic Assistance) headquarters, etc. [2].

Thus, the construction has gained a vast experience in the design and construction of high-rise buildings in various natural and climatic conditions, different design systems and complexity. This experience has been studied and widely used in our country, which has now begun a new stage in the construction of high-rise buildings in the cities of Moscow, Nizhny Novgorod, Krasnoyarsk, Kemerovo, St. Petersburg, Volgograd and other.

2 Materials and Methods

In our country the high-rise buildings are considered to be the structures above 100 m high. In accordance with the Urban Planning Code of the Russian Federation they are also considered to be unique buildings. The buildings with a height of 30 to 100 m are assigned to I, II and III category of storey number. As a rule, in Russia the priority is given to the construction of multi-functional complexes, which include not only office premises, but also residential floors, shops and cinemas. But at the same time, the low-capacity complexes are being built, for example, "Tricolor" and "North Park" residential complexes, offices of "Gazprom", "Sberbank" companies, etc.

The forms of a tower type of high-rise buildings are used, as a rule, in connection with large wind loads, but rather complex structural systems such as skeleton-frame, wall, barrel, shell, combined are used at the same time. Each of these constructive systems has its own rational area of use. For example, the wall system is used for residential buildings, the frame system is used when building up to 60 floors, the barrel system is functionally and constructively effective due to the load-bearing core, and the shell system provides the possibility of erecting buildings with a height of over 200 m [3,4,5,6].

There are also quite complex elements engineering systems for high-rise buildings as follows: plumbing, heating, ventilation, power supply, hot water supply, sewerage, drains, automatic fire extinguishing systems, automation and dispatching systems, electrical equipment, low-current systems, Internet networks, etc. For example, electrical equipment consists of emergency lighting systems, smoke removal, power supply of fire protection systems, security and fire alarm systems, and the water supply system, in addition to the traditional elements, includes a number of technical premises in 10-12 floors with an optional mounted pumps. Or, for example, the power supply system can be autonomous, which is actual in case of switching off the central power supply, the operation of elevators, supply of water and electricity to the apartments.

High-grade concrete, a wide range of metal structures and translucent materials, various construction equipment and equipment are used for the construction of high-rise buildings. A large number of organizations is directly involved in the creation of high-rise buildings: construction, assembly, specialized, design and research, transport, supervisory, as well as a number of organizations that perform the functions of testing, coordination, etc.
The described factors, as well as the construction conditions, including the influence of natural and climatic factors, ultimately determine the choice of methods for organizing construction and production of construction and installation works.

3 Methods of organization and production of works

The construction of the underground part of high-rise buildings is associated with the need to build powerful pile-slab foundations of high-strength concrete. Constructive solutions of

such foundations, for example, in Moscow, are dictated by the ground conditions and the technology of their arrangement is similar to foundations of the multi-storey buildings. But at the same time, the installation of foundations and bases under assembly crane that stand the large ground loads. In addition, large volumes of excavation work are typical with the burial of the basement into several tiers for building the underground part of high-rise buildings.

The above-ground part of high-rise buildings is most often single-sectioned and compact enough; it is less often performed as multi-section. The structural basis of buildings is usually a steel, reinforced concrete or combined frame with a hard core or with flat diaphragms. The load-bearing core is arranged mainly in a monolithic variant in sliding or shuttering formwork. There are two schemes for building up the structures. In the first scheme, the concreting of the load-bearing core outruns the mounting of the frame by 1-2 tiers, and in the second scheme, the mounting of the load-bearing core lags behind the carcass assembly. In this case, it is recommended that the maximum height of the backlog must be no more than 8 storeys, but we must also take into account the obligatory welding and concreting of the structures [7, 8, 9].

When applying a reinforced concrete frame, we can use prefabricated structures (columns, crossbars, slabs), monolithic structures, complex structures (monolithic frame, prefabricated slabs). Then, the technology of erecting a high-rise building includes the following cycles: concreting the load-bearing core, assembling prefabricated structures or erecting a monolithic frame, general building work on a tier (partitioning, welding, preparing for laying utility networks, etc.), special building work (building of engineering systems, laying of networks, installation of equipment, etc.) and finishing works [10, 11].

Decisions on the organization of construction should be based on the principles of in-line production of construction and installation works, providing the fragmentation of the work process into the tiers and construction staging. A tier consists of one floor, and the number of construction staging is from 2 to 4 per section. Each cycle of work is performed by a corresponding specialized brigade (unit) or several brigades in the case of a large amount of work. The leading flow is the installation of the framework and therefore the rhythm of the performance of other works is linked to it according to temporal and spatial parameters [12, 13].

The main condition for the erection of high-rise buildings from reinforced concrete is compliance with the requirements for achieving the design strength of concrete, including in the nodes and joints of bearing structures.

In the case of arrangement of a steel or composite frame, there are used columns and crossbars (joined in two directions by rigid welded assemblies into frame systems). The columns are made of standard rolling profiles and must be concreted to increase their fire resistance, and the crossbars are made of welded I-sections. The slabs of inter-storey floors are laid on their broadened lower shelf. The load-bearing core can be either reinforced concrete monolithic, or in the form of a closed shaft of steel structures; all elements of the frame are attached to steel structures and, together with the slabs, form a hard disk.

Fastening of crossbars is made immediately after installation and alignment of the whole cell.

The construction of a high-rise building with a steel or combined frame can be carried out in separate or complex method. With a separate method, the steel frame is mounted to its full height and only then the general construction, special and finishing works are performed. The application of the integrated method provides for simultaneous execution of all types of work on approximately 10 floors. On the upper 2-4 floors, the steel structures of the framework are assembled according to the scheme "installation - reconciliation - connection", below 2-3 floors the assembly of prefabricated or monolithic ceilings is carried out, the framing of the frame is provided on the lower floors, and the special and

finishing work is organized at the very bottom. Here we should take into account that the installation of steel structures is necessarily carried out tier by tier. At the same time, the first work is performed on the central load-bearing core of building and the installation of other structures is proceeded only after reconciling all of its elements. Stability of the columns is achieved with the help of conductors or temporary braces before they are being fixed. The fastening of crossbars is made after installation and alignment of the entire cell.

The main condition for the construction of high-rise buildings with a steel frame is to ensure the strength and stability of each tier.

4 Formation of organizational and technological solutions

When building high-rise buildings in Russia, there is a tendency for a widespread use of monolithic reinforced concrete structures. In addition to reducing the weight of the building, compared to buildings with a steel frame, the economic effect is also provided by the absence of the need for additional fire protection of load-bearing structures. The development in the native practice of monolithic housing construction is promoted by a diverse range of formwork systems capable of performing the most sophisticated production technology works.

The choice of formwork system is determined not only by the complexity and scope of work, but also by climatic conditions. Strong winds, fogs, precipitation make it difficult to work at height, and in some cases they cause the halt. Therefore, self-elevating shuttering systems with hydraulic drives are getting serious development. Such systems include shuttering panels, anchors, locks, scaffolding elements, etc. For their application, it is advisable to develop projects that include the layout of the shuttering boards and their movement along the height.

To ensure a high rate of erection of monolithic high-rise buildings, we require a clear organization of continuous production of concrete in large quantities and serve it over long distances, both vertically and horizontally. The concrete shall be presented fairly stringent requirements for durability, frost resistance, resistance to aggressive chemicals. According to experts, the most optimal is the concrete of S60 - S80 classes [14, 15].

Delivery of concrete mix is carried out either by truck mixers from the district and central factories of ready-mixed concrete or from an automated concrete unit located directly on the site. The second technological scheme of delivery of a concrete mix is certainly more effective.

Feeding of the concrete mixture to the object is carried out with the help of powerful concrete pump installations in the form of truck-mounted concrete pumps and stationary concrete pumps. The truck-mounted concrete pumps are used mainly for the erection of the underground part of the building and its lower floors. For this purpose, the truck is equipped with a distributing boom. For continuous supply of concrete mix to the upper floors, stationary concrete pumps are used, which have concrete conveying pipes connected to a hydraulic distributor boom. Such a boom is mounted on the monolithic structures of the corresponding catch and carries out the supply and distribution of the concrete mixture to the mounted formwork.

Additional requirements are also applied to the installation of reinforcement. In view of the fact that welding of reinforcement for high-rise buildings is unacceptable, therefore, couplings or wire bindings are used to connect it.

A set of lifting- transport and auxiliary equipment is also significantly different from the traditional construction. For example, the tower cranes are not advisable when building buildings above 60-70 m high. Therefore, for work up to a height of 130-140 m, it is necessary to use attachable tower cranes, which are attached to the structure of the building., Self-lifting assembly cranes attached to the central load-bearing core of building

are used when erecting a building over 130 m. Such cranes provide work on a level with a height of 30 to 40 m.

Special cargo-passenger lifts are used for the supply of other cargoes (finishing materials, sanitary and electrotechnical products, small-piece loads) to the tiers, as well as lifting of workers; the number and type of them are selected depending on the organization of work. The lifts with a capacity of up to 20 people and a lifting capacity of up to 3 tons are most commonly used. As a rule, lifts are installed after the erection of 8-9 floors.

The solutions for the installation of facade systems are also important in the construction of high-rise buildings. As practice shows, it is most expedient to perform facade works in combination with the erection of a frame of a building with a gap of 5-7 floors. To date, a number of effective facades has already been created to meet modern requirements for thermal properties, noise insulation, air permeability, water permeability and fire resistance. For example, the facade series of the "TATPROF" system was highly appreciated. In particular, the facades of the series EK-40V and EK-69V are made in the form of multicellular structures made of frame elements that allow the glazing of almost all types of facades - straight, vertical, hinged, built-in, etc. The glazing of the building is made indoors and can be applied for different climatic zones.

The efficiency of building of high-rise buildings depends to a large extent on the qualitative development of organizational and technological solutions as part of construction projects and projects for the production of works. To the present moment, the speed rate of construction of high-rise buildings is characterized as not less than 4-5 floor construction per month. The available reserves for reducing the duration of construction can be used by creating:

- complex mechanized technologies for the efficient construction of foundations in various soil conditions, including in the heaving, swelling, hindered, subsidence, bulk, water-saturated, etc.;
- complex mechanized technologies for the construction of load-bearing monolithic reinforced concrete structures, taking into account the winter conditions of work and using mobile concrete batching complexes and new generation machines;
- modular formwork systems, distinguished by their versatility, ease, comfort of operation, taking into account the features and complexities of high-rise construction;
- more perfect methodology and the development of a set of progressive organizational and technological solutions that ensure rational relationship between the processes of production and their maximum combination in time and space.

5 Conclusions

At present, a new stage in the construction of high-rise buildings of different design systems and degree of complexity is being implemented in Russia, based on the use of progressive foreign and native experience in their design and construction in various natural and climatic conditions.

In the native practice, both single-section and multi-sectional high-rise buildings are built. The structural basis of buildings, as a rule, is a steel, reinforced concrete or combined frame with a hard core or flat diaphragms. The construction of such buildings is carried out according to two basic schemes - the advanced creation of the central load-bearing core and the advanced assembly of the frame.

When using a reinforced concrete frame, the technology of erecting a building includes cycles of concreting the load-bearing core, assembling prefabricated structures or building a monolithic frame, performing general, special and finishing works. The leading flow is the installation of the frame, with the rhythm of which the performance of other types of work on temporal and spatial parameters is coordinated.

In the case of arrangement of a steel or composite frame, all work is performed in separate or complex methods. With a separate method, the steel frame is mounted to its full height and only after that other work is performed. The application of the integrated method provides the simultaneous execution of all types of work on approximately 10 floors.

The rate of construction of high-rise buildings provides construction of no less than 4-5 floors per month. The available reserves for reducing the duration of construction include the creation, of complex mechanized technologies for the erection of load-bearing monolithic reinforced concrete structures, modular shuttering systems and improved methodology of interconnection and maximum combination of technological processes.

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