Research Article

BIOMEDICAL Journal of Scientific & Technical Research

ISSN: 2574 -1241

DOI: 10.26717/BJSTR.2022.47.007523

Accelerated Construction of Multi-Storey Residential Facilities in A Monolithic Design

Sokolov NS*

Chuvash State University named after I.N. Ulyanov, Russia

***Corresponding author:** Sokolov NS, Chuvash State University named after I.N. Ulyanov (prosp. Moskovsky, 15, Cheboksary 428015, Russian Federation), Russia

ARTICLE INFO

Received: November 18, 2022

Published: December 12, 2022

Citation: Sokolov NS. Accelerated Construction of Multi-Storey Residential Facilities in A Monolithic Design. Biomed J Sci & Tech Res 47(4)-2022. BJSTR. MS.ID.007523.

ABSTRACT

This article describes a method of reducing the construction time of buildings and structures erected from ready concrete mixture in the conditions of a construction site with the illumination of techniques for choosing the technology of building, the introduction of a "construction conveyor" and ways of reducing the time of concrete strength set, developed by the author in the process of building objects in the city of Cheboksary of the Chuvash Republic and the city of Tsiolkovsky, located on the territory of the Vostochny cosmodrome.

Keywords: Technology, Winter Concreting, Hardening of Concrete, Temperature Mode, Heating

Introduction

In connection with the increase in the level of consumer demand for the quality of housing under construction, construction of monolithic load-bearing structures has now become particularly popular in Russia. The design solution for connecting flat slabs with vertical elements in the absence of capitals in the units has determined the priority in connection with the possibility of adapting it for high-speed construction technology.

Materials and Methods

In 2003, a method of organizing the work of the construction stream with the application of the principle of "industrial conveyor" was introduced into the practice of construction management when erecting a monolithic reinforced concrete frame on one of the high-rise buildings. The tools used were:

a) A well-trained team of workers,

b) A set of large-panel formwork firm "PERI",

c) A tower crane type KB-403,

d) A field version of equipment of the reinforcing shop,

e) A standard tool set for the crew of installers. The achieved rate of construction of the monolithic frame amounted to 12 floors per month.

The output was about one cubic meter of freshly laid concrete per workday. The first designed monolithic load-bearing framework had a flat monolithic floor slab of 160 mm thickness, was non-regal and non-capillary. The vertical structures were made in the form of columns and small-in-length stiffening diaphragms. This most simple design solution has subsequently become mass in its application [1-5]. The technology used to construct the buildings had one major drawback. Since the construction of the walls made of single-piece materials was carried out in the space of the already built monolithic frame, then based on the conditions of work of masons, their production must be half the size (0.5 cubic meters) reached across the country when working as a masonry worker in conditions "from under the tower crane" (1 cubic meter).

Results

Therefore, in 2010, the construction of residential buildings along Karl Marx Street, 54, and along Korolenko Street in the city of Cheboksary with a monolithic bearing frame, the construction technology of buildings was changed. The order of building structures was changed:

1. First, all five entrances, starting from the first floor of the building, were erected first of all vertical structures of monolithic frame;

2. Second, the stonemason's brigade erected the outer and inner walls to the floor level. Furthermore, the supply of mortar and brick was carried out by a tower crane directly to the workplace, which provided for a replaceable production in the volume of one cubic meter of masonry per masonry worker;

3. Thirdly, after the stone works were finished, the slab formwork was installed and filled with concrete, with the slab structure supported directly on the vertical monolithic concrete structures and on the stone walls. Such construction technology of the building, in addition to shortening the construction period, has made it possible to increase in principle the quality of the construction of the attachment units of stone structures and reinforced concrete monolithic floors. As a result of the accumulated experience, skill has come to the team at the end of the building construction. The construction stream of 30 concrete workers and 45 masons, with two tower cranes on the five entrance building, mastered the pace of the construction of the building of 16 floors in one month.

The result in physical volumes was: 1. Laid 800 cubic meters of masonry; 2. Laid 900 cubic meters of monolithic concrete. The same construction technology was also used to build multi-storey apartment buildings along Korolenko Street in Cheboksary [6-8]. This simple, but effective technological solution allowed to significantly increase the productivity of labor, reduce the construction time of the facility and, as a result, to attract investment (by the middle of the construction period of the facility, all the apartments were sold out). In 2012-2013, in addition to technological design solutions and well-established labor organization with the application of the principle of "industrial conveyor", the technology of reducing the period of concrete strength set in construction conditions equal to 100% of the design for one day (the object is a group of residential houses on Afanasiev Street in the city of Cheboksary) was developed and introduced into construction practice. Application of three technical solutions on one object: 1. Choice of building technology; 2. Introduction of the conveyor method of labor organization; 3. Introduction of the process of reducing the period of concrete strength recruitment in the construction site conditions – according to the speed of building structures construction in Cheboksary city in the competitive row monolithic house building is close or on equal footing with panel house building.

Discussion

The main points of the decisions taken are discussed in more detail below:

Preparation of Project Solutions

High labor productivity is the result of multifaceted work of engineering and technical staff. And one of the aspects is the work to improve the project solution. It begins at the moment when the designer has prepared the design scheme of the supporting structures of the future house. During this period, the chief engineer of the construction organization, in terms of increasing the productivity of the collective labor during the construction process, considers in detail the adopted planning decision. And together with the designer, he outlines the boundaries of the grips, as well as the technology of erecting a ladder and lift node as a concentration of time-consuming processes located at one point of the application. As an example, the result of the work done in this direction during the design of a residential building on Karl Marx Street, 54 Cheboksary city should be recognized as a positive one: before the end of the whole project of the building with the housing and communal services plant, an agreement was reached on the manufacture in factory conditions of floor elements of the elevator shaft. During the construction of the building, the floor element of the lift shaft on a tractor semi-trailer was delivered to the construction site. Then the elevator shaft was fed to the floor under construction. One lifting tower crane "off the wheels" – and the lift shaft is mounted in the design position.

Introduction of the "Industrial Conveyor" Principle into the Organization of Collective Labor on the Construction Site

The modern level of development of the productive forces, characterized by the use of complex and varied techniques, large scale of production, involves the joint work of a large number of people. Such work is inconceivable without a proper organization of labor, acting as an orderly system of interaction of workers with the means of production and with each other in a single production process. In itself, the method of labour organization using the "industrial conveyor" principle, compared with other methods of labour organization, for example, organization at a site of a complex construction crew, has a number of advantages, namely:

1. For each worker, in accordance with his profession, an equipped workplace is created, at which the worker will perform the same simple operations every day until the end of the construction of the facility, which will allow him as he gains experience to manufacture more products in one and the same period of time;

2. It is possible to organize hard work in a single cycle of the whole team, which makes it possible to reduce the time losses due to the inconsistency of the actions of individual workers (to remove the stick from the wheel) and to produce more products. This leads to the conclusion that the most correct decision should be considered to implement the organization of collective labor in the construction system with the application of the principle of "industrial conveyor". At the same time, we assign the pipeline cycle as short as possible – in the size of one day.

Traditionally, in an industrial enterprise, future finished products move along the assembly line, for example, the movement of the body of the watch during the assembly process along the assembly line of the workshop, and in our building site, the construction building as "on the assembly line" will move production facilities. However, further on the process of moving production capacity on the object for short we shall call "construction conveyor" or simply "conveyor". The process of constructing cast-in-situ reinforced concrete structures consists of technologically connected and consecutively executed simple construction processes. The time required for the concrete to set the break-out strength is part of the overall technological cycle. The composition of simple processes, their labor intensity and the order of execution depend on the type and specifics of monolithic constructions being erected, the mechanisms used and the types of formwork, the technological and local features of work production. Each simple process is carried out by specialized units, which are combined into a complex brigade. The structure is divided in height into tiers, in plan into grippers, which are necessary for the organization of the production of operations by flow. Deconstruction is a height cut, which is caused by the permissibility of concrete breaks and the possibility of formation of temperature and working seams.

Thus, a single-story building is usually divided into two tiers: the first – foundations, the second – all other structures of the framework. In a multi-storey building, an entire floor with floors is taken for a tier. Gripper is a horizontal cutting, which involves the work of the link throughout the cycle. So, let's start organizing the flow of construction. For this purpose, we allocate space for the organization of simple construction operations on the installation horizon, that is, we form production grabs. The basic principle of design works: how many processes, how many grips. Based on the greatest number of simple construction operations on the most time-consuming structure of a typical floor of a residential building – and this will be the process of erecting a monolithic slab – we assign grippers to perform the following simple operations:

1. Formwork and scaffolding installation;
2. Installation of reinforcement;
3. Concrete laying and maintenance;
4. Dismantling of formwork and scaffolding;
5. Installation of prefabricated reinforced concrete and erection of the next floor structures.

Thus, to create comfortable conditions for the construction of the structures of the typical floor, it is necessary and sufficient to assign five production grippers (4 – from the top of the floor and 1 – from the bottom of the floor). Special-purpose objects, which are shaped in a special way due to the special technological processes, are constructed using the formwork designed for the construction of such types of buildings.

Below is the organization of the production process on each gripper:

Production Arrangements at First Sight: For high-quality production of monolithic structures of buildings with high construction rate, it is recommended to use the inventory formwork, manufactured at the enterprises of both domestic and foreign companies. The formwork and scaffolding must be installed strictly according to the process map. WARNING: The attempt to use non-certified elements (beams and posts) in scaffolding structures automatically endangers the life and health of employees of construction organizations.

Organization of the Production Process on the Second Capture: On the second gripper is installed reinforcement frame and heating wire. The work is carried out in strict accordance with the working project of reinforcement of reinforced concrete structures and is completed by delivery of the finished products to the representative of technical supervision of the Customer with registration of acts for hidden works. To achieve high labour productivity, the reinforcement unit is equipped with a machine for cutting and bending of the reinforcement. In the event that it is not possible to fulfil orders for labour-intensive structures in the construction industry, the facilities must be equipped with conductors for the manufacture of grids and other reusable parts.

Organization of the Production Process in the Third Capture: On the third gripper:

1. The heating wire is switched in the first shift;
2. During the second shift, the cast-in-place concrete is placed and the remaining times of the 2nd and 3rd shifts are used to electrothermally treat the finished concrete mixture.

The formwork of structures cast in winter should be dismantled after the concrete has achieved the design strength measured by one of the methods described in SP 70.13330.2012 "Load-bearing and separating constructions" (hereinafter – Rulebook). Paragraph 5.3.15. of the Rulebook states: "When laying a concrete mixture with reduced positive (below +5 °C) and negative or increased

positive temperatures (above +25 °C), "Special arrangements" shall be provided to ensure the required concrete quality [9-12]. To solve this engineering problem, the work of scientists of the Research Institute of Concrete and Reinforced Concrete of the USSR is taken as the basis. From the Handbook "Production of prefabricated reinforced concrete products. Under the editorship of K.V. Mikhailov and K.M. Korolev, PhD in Technical Sciences, it is known that in the technology of moulding monolithic concrete various methods of intensifying concrete hardening are used, including:

1. Increase of cement activity by cement grain house;
2. Application of super fast hardening cements;
3. Application of chemical additives;
4. Increase of rigidity, decrease of mobility by one mark;
5. Complex technological method: this is the activation of cement + chemical additives + increase of the hardness of the mixture on one brand.

As a result, "Special measures" were developed, providing in the construction site conditions a set of full (100%) design strength in one day.

Organization of the Production Process on the Fourth Capture: On the fourth gripper, located at the bottom of the finished floor, the formwork is dismantled according to the process map on its dismantling. The process of dismantling the formwork of the structures must ensure that the safety and safety rules for the installation work are followed and that the formwork to be removed is protected.

Fifth Capture Production Process Organization: On the fifth newly built gripper we perform the construction of vertical structures (columns, stiffening diaphragms, lift shaft walls) of the building, including the installation of reinforcement frames, the installation of heating wires, the installation of formwork and the set of concrete strength using techniques for the installation of formwork, reinforcement and achievement of project strength by concrete, used when erecting monolithic structures on the first, second and third grippers.

This scope of work, in addition to the tasks solved on the first, second and third grippers, has a very significant labor intensity, a large variety in the designs and the need to solve a set of tasks within the strict time limits defined by the cycle of movement of the "conveyor". Since one rhythmically working construction stream builds 2000 square meters of total area per month, this volume of work brings the enterprise considerable profit. In order to achieve such a high and desired result, it is necessary for the entire apparatus of management of the enterprise to be taught to adopt and implement current moment solutions in a mode that ensures all necessary cycle of movement of the "conveyor" on the object under construction. So, using the above technique, a new fifth gripper was erected, which is the first gripper, with ready-made structures of the next floor.

The next day, workers from the first gripper move to the second gripper, from the second - to the third, from the third - to the fourth, etc., and all operations are carried out again. In such a manner, work on erecting a building box by the construction flow forces is carried out prior to the construction of the covering plates. The volume of finished products is 1/2 of the typical floor of a monolithic building frame every working day. The developed technology of accelerated construction was also tested at the construction of the Vostochny cosmodrome in the city of Tsiolkovsky. The object of the cosmodrome "Vostochny" in the city of Tsiolkovsky is unique in status, and in terms of engineering tasks - it is very complex, therefore it is very interesting to implement the developed technology. It is designed on the territory of about 700 square km. In addition, the climate is sharply continental with summer temperatures up to +40 °C and winter temperatures up to -52 °C. In addition, every day the increase in outdoor air temperature from morning to lunch is up to +20 °C, and from lunch to night the drop in temperature is -20 °C. In addition to climatic difficulties, the territory of the cosmodrome construction belongs to a seven-point seismic zone. The structures of residential and public buildings (walls and floors) are designed from monolithic concrete and have a labor capacity of 2.5 more than the buildings designed in the European part of the country.

In order to improve the organization of work on the construction of the city, two global objectives were achieved:

Implementation of labor management principles in construction as an industrial conveyor. For this purpose:

a) Technological maps and charts were developed, which allowed to triple productivity,

b) A number of design solutions for reinforcement of monolithic structures were simplified,

c) At the first stage construction of structures in the city of Tsiolkovsky reduced the number of rebar binding units for more than 2.5 million operations,

d) As early as March 1, the period of concrete strength recruitment at the city's facilities was reduced from 5 to 1.5 days.

Research work was carried out to find technological solutions for the climatic conditions of the construction of the spaceport:

To determine the influence of the Sun, research work was carried out with a monolithic reinforced concrete structure of the foundation under the tower crane. Studies have shown that the Sun

does not interfere with builders, but on the contrary, it helps.

A technological solution has been found to provide the process of concrete strength set in one day at any low temperature. Thus, in 2015, together with the construction workers, a total of 300 apartments were prepared for the commissioning, and a building block in the form of ready-made solid-cast reinforced concrete structures of buildings in the volume of another 200 apartments was created.

Technical and Economic Effect

The innovative experience of increasing productivity in construction is a good tool for solving a number of the following problems:

1. As a result of the introduction of the "construction conveyor" principle into the organization of work of the construction flow, when mastering the technology of a set of design strength of concrete (100%) in one day, the output of finished products (a box of a building, ready for the installation of a thermal circuit and installation of engineering systems) - 8 floors per month, and in the case of the shift method of organization of work on the object - 10 floors per month;

2. This rate is twice the current average rate for the construction of stone buildings and monolithic structural buildings;

3. Reduction of construction costs in the amount of 8.5 % due to reduction of expenses on the following items: operation of machines and mechanisms (tower cranes), as well as overhead expenses for the maintenance of the control apparatus;

4. Halving of energy consumption for heat treatment of concrete;

5. 100% increase in the monthly wages of workers. Workers are physically unable to perform two volumes but using the "conveyor" method of labor organization can increase labor productivity by twice.

Conclusion

1. Since in order to achieve the results set out above, methods and methods have been applied in practical work within the requirements of the existing SP and GOST, the proposed method of reducing the time for concrete hardening can be used at any construction site of our country for any climatic conditions.

2. If the solution of the technical and organizational problems described in this article is used, will be adopted by colleagues for practical application, then the construction industry of the country in its development will take a broad "step forward".

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ISSN: 2574-1241

DOI: 10.26717/BJSTR.2022.47.007523

Sokolov NS. Biomed J Sci & Tech Res

Submission Link: https://biomedres.us/submit-manuscript.php