Studying Specific Features of the Monolithic Construction Technology Based on Systemic Analysis

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Abstract. A scientific study was conducted, the main goal of which is to improve the quality of the monolithic construction by grouping and systematizing the main characteristics of the monolithic construction technology, especially those that affect its safety and quality, as well as identifying the most important and unresolved problems affecting the security of monolithic reinforced concrete buildings and structures using systems analysis. To systematize the monitored quality indicators, a decision tree was developed. Based on the quality monitoring of the construction sites, a grouping was carried out according to the nature of the violations and a chart was constructed showing the distribution of violations identified during the construction control of the construction organizations. The research and analysis of the scientific support of construction sites show that it is possible to obtain reliable results during quality control only by using several methods at the same time. Apart from that, the issue of choosing a method for testing concrete in the winter conditions still remains relevant. Even with a large number of papers being devoted to this issue, it needs a further research. The conducted system analysis showed that the main cause of defects in the buildings and structures is the inability to provide the necessary characteristics of concrete both during the preparation of the concrete mix and during the construction phase of the finished monolithic structure. The research results allowed: to note the effect of production control on the quality properties of monolithic structures; identified the main causes of defects in buildings and structures at each stage of the monolithic construction, identified and justified the need to develop recommendations and experimental studies to improve production operations, including non-destructive testing methods for the strength of the monolithic structures.

1. Introduction

Currently, many researchers seek ways to improve the monolithic construction technology and bring the project management to the higher quality and reliability standards. The analysis of scientific works in this field, as well as the statistical data published in our earlier works, bear witness to a large number of violations and inconsistencies being found over the course of monolithic reinforced concrete construction [1-3]. It has been found that more than 50% of monolithic structure collapse cases account for the violation of construction and erection technology. The technological process quality [4] must guarantee the reliability and safety of the construction products, both structures and the building itself. Therefore, it is of great importance that an efficient and well-coordinated system of the production quality control is in place to avert the technology violation causes.
2. Materials and methods

The purpose of this scientific study is to group and systematize the main features of monolithic construction technology, especially those affecting its safety and quality, as well as to identify the most important and unsolved problems affecting the safety of monolithic reinforced concrete buildings and structures using systemic analysis [1].

The authors pursued the underlying principles of the systemic approach to achieving a goal in addressing the following problems:

- the main features of works in monolithic construction are considered, the most important of them are highlighted;
- data on inconsistencies and violations identified as a result of the scientific and practical activity of the Research Institute “MGSU STROY-TEST” on quality monitoring at construction sites for the period from 2012 to 2014 were collected;
- statistical processing and systemic analysis of these instructions and discrepancies in monolithic construction shown on a representative number of construction organizations is performed;
- the main types of damage and defects in monolithic reinforced concrete structures are classified;
- the key causes of defects in buildings and structures at each stage of monolithic work are identified.

Let us first consider the main features of erecting structures using monolithic technology [2]:

- Buildings and structures made of monolithic reinforced concrete have the most varied, original architectural and planning solutions. Monolithic technology makes it possible to build public and residential buildings of any shape, geometrical parameters, configuration and reinforcement type.
- The entire monolithic construction cycle is run on an open construction site, which implies hard work conditions for workers. Widely used manual labor and minimum level of mechanization and automation both account for a large human factor’s impact rate on product quality.
- Monolithic erection process consists of several main technological stages: preparation and delivery of concrete mixture, preparation of formworks, installation of reinforcement and other embedded products and elements, laying of concrete mixture in the structure, concrete holding in formwork, maintenance of concrete, stripping, etc.
- Year-round erection of buildings made of monolithic reinforced concrete, including the possibility to perform construction works in negative temperatures. In winter, construction of monolithic structures must necessarily provide technological solutions to ensure the optimum temperature regime of concrete hardening and gaining strength.
- The system of in-process quality control of monolithic works, including input control of design and organizational and technological documentation, input quality control of materials (primarily concrete mixtures), operational and acceptance quality control of works and structures.

Reliable and time quality control plays the most important role in the monolithic construction. Unfortunately, practice suggests that the existing system of production quality control fails to ensure a required quality level. A probability often exists that in the course of conducting monolithic works concrete mixtures are delivered from various factories, with different types of cement, aggregates and chemical additives being used to manufacture them. This complicates quality control of incoming concrete mixtures. An absence of a well-coordinated monitoring system poses a problem for many construction projects [1, 3, 5-7].
Let us consider several examples of how the efficiency and quality of monolithic construction can be enhanced [4]:

- introduction of innovations and improvement of technologies of formwork, reinforcement works and concrete works;
- development of high-strength structural design materials and concrete for special purposes, taking into account the features of monolithic construction;
- reduction of manual labor share, in particular, in the production of reinforcement and concrete works;
- application of methods for the concrete curing acceleration (heat treatment of concrete in construction, use of chemical hardening accelerators, modern technologies for modifying monolithic concrete, the technology of concrete synergy, activation of cement and mixing water, etc.) [5, 8]
- improvement of the technical quality control system of monolithic construction (input quality control of materials, operational and acceptance quality control of works and structures).

Let us closely consider the study of the construction quality control system at all stages of monolithic construction. In order to systematize the monitored quality indicators, a decision tree has been developed. The tree allows us to consider construction control by detailing its elements at various levels (figure 1). In addition, the use of statistical methods makes it possible to identify and rationalize all the potential causes of the problem considered [6].

Thus, all the work performed must be followed by timely commissioning of the construction object at the required level of quality, and in accordance with the design documentation, ensuring the reliability and safety of buildings and structures [4, 9]. However, the practical experience shows that errors and violations occur at each works production stage. The evidence of this is shown in the registered data on violations and prescriptions issued as a result of the scientific and practical activity of the Research Institute “MGSU STROY-TEST” on the quality monitoring at construction sites. This material was systematized by the nature of the violations into the following groups:

- Violations at the implementation of preparatory work;
- Violations at the implementation of earthworks;
- Violations at the implementation of pileworks;
- Violation at the implementation of formworks;
- Violations at the implementation of reinforcement works;
- Violations at the implementation of concrete work.
The registered prescriptions and violations in monolithic construction are statistically processed and shown in the diagram below (figure 2).

**Figure 1.** Decision tree “Construction control in monolithic and reinforced concrete works”
Figure 2. Diagram showing the distribution of violations identified during the construction control of a representative number of construction organizations

As Figure 2 shows, about 56% of all violations occur in the stages of concreting works and reinforcement works. The greatest number of inconsistencies identified by the construction control was found at the concreting stage, including the performance of concrete works in winter. Thus, the elimination of the causes of damage and defects caused in the process of concrete and reinforcement works will generally improve the quality of construction of monolithic reinforced concrete.

However, it is necessary to determine the damage level to the monolithic structure to identify the causes of defects in buildings and structures. Therefore, the next task is to classify the main types of defects and damage in monolithic reinforced concrete structures according to their importance [8].

For this purpose, the defects and damages recorded during the most critical technological stages of the work were studied in detail. Further, the data collected on defects in monolithic structures is to be classified according to the nature of their influence on the carrying capacity into three main groups (figure 3).
3. Results and discussions
The performed systemic analysis has concluded that the key cause for defects in buildings and structures consists in a failure to ensure the necessary characteristics of concrete, both at the concrete mixture preparation stage and at the finished monolithic structure construction stage. Often, especially dangerous defects affecting the bearing capacity of a structure arise as concrete is being unduly treated while gaining strength including poor heating conditions in winter.

Ensuring the required level of construction quality assumes scientific and technical support, which also includes effective quality control over the course of the structure manufacturing process with a wide use of modern tools and equipment as well as the experience of previously conducted tests [1-3, 6].

With a wide variety of destructive and non-destructive concrete strength testing methods being used, the analysis of the quality control indicators of monolithic reinforced concrete structures shows that there is no universal method for determining the characteristics of concrete, which would be informative, accurate, simple and convenient to use at an open construction site. Research and analysis of the scientific support of construction sites show that it is possible to obtain reliable results during the quality control only by using several methods at the same time. Apart from that, the issue of choosing a method for testing the concrete in the winter conditions still remains relevant [7]. Even with the large number of papers being devoted to this issue, it needs a further research.

4. Conclusions
This research is called for in the field of applying various methods for the concrete strength non-destructive testing. There is a need to develop recommendations and to conduct an experiment to improve the technological operations, including methods for non-destructive testing of the strength of monolithic structures.

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