Construction technology of fixed formwork and quality control

Yuliya Evstigneeva, Ruslan Ibragimov

Kazan State University of Architecture and Engineering, Kazan, Russia
E-mail: uliyaevstigneeva@mail.ru

Abstract. The main results of the research are to find numerical solutions for selecting effective fixed formwork material for columns and analysis of technological operations. The use of fixed formwork of glass-magnesite sheet allows improving quality and stability of the structure, increase fire resistance, which helps to extend the life of the concrete structure.

Based on numerical and experimental studies, a model of the formwork fastener for a round column of 3 m high, with a diameter 500 mm was developed. A calculation model was created and the design of the formwork made of glass-magnesite sheet was calculated. So, for the diameter of the concrete column from 300 to 600 mm, the thickness of the glass-magnesite sheet varies in the range: 7-23 mm.

A workflow has been developed for the installation of fixed formwork and for concreting columns with the determination of the required amount and type of work, with the determination of the complexity; a workflow for the quality control of work has also been developed. Such periods as: accepting of elements of fixed formwork, installation of fixed formwork elements, accepting of timbering construction operations must be monitored.

Keywords: column, fixed formwork, glass-magnesite sheet, fire resistance, operations and quality control, timbering

1 Introduction
Nowadays, one of the urgent problems in construction is the buildings erection duration and with the purpose of increasing civil engineering work and the high quality operations. Currently, despite the economic crisis, many countries continue active construction of buildings and structures. To increase the speed of construction and reduce costs, innovations in construction are applied. New structural and finishing materials are being used increasingly, more and more effective new construction technologies are being developed, engineering equipment and work are being automated. The use of fixed formwork is one of the ways to reduce the time of buildings and structures construction, as well as simplify the construction process. Fixed formwork is an innovation in construction, which provides the speed of structures construction, their strength and architectural expressiveness.

The study [1] discovered the advantages and disadvantages of permanent formwork of the following types: polystyrene foam, concrete blocks, high-cement blocks and slabs. However, methods for erecting permanent formwork from glass-magnesium sheets (GMS) have not been previously investigated.

In Russia such authors as Hohlov A. A [2], Sviridenko A. V. [3], Popov N.E. [4], Yakusevich V. V. [5], Averina G.F [6] formed the basis of knowledge about GMS. Their work compares GMS with gypsum board and analog materials and the use of this material. The researchers [7-9] studied the issues of GMS properties regulation, their field of application. In paper [10] construction technique and the computational method Extended Limit Analysis for Reinforced Masonry (ELARM) were
proposed to provide fast results for the user. Such scientists as Popov V. P. [11], Moriev A. V [12] have made a great contribution to the development of the technology of permanent formwork construction from GMS, as well as construction of monolithic buildings and structures in permanent formwork [13-14], especially columns [15].

Scientists from China researched questions of stay-in-place formwork [16], permanent formwork [17] site-made and proprietary formwork [18], and fire-resistance material for timbering construction [19-21]. Particular attention should be paid to the technology of the tiered monolithic structures heat treatment which is described in [22]. There are several types of fixed formwork for making load carrying structure, especially timbering types [23-25].

There are developments in the area of technology process, [26] quality control tools and tools to support the functionality of earthmoving equipment operators, [27] a real-time construction quality monitoring method, monitoring of building erecting [28-29] and statistical quality control [30] but issues of Operations and quality control remain unearthed.

When selecting the size of formwork sheets, it is necessary to study the technology of buildings construction in winter conditions, which has already been done in some works for example self-compacting concrete (SCC) [31] using controlled permeability formwork (CPF) or nano-modified additives allows winter concreting [32].

When selecting the size of formwork sheets, it is necessary to study the technology of buildings construction in winter conditions, which has already been done in the works [33-35].

The scientific works of the above-mentioned scientists deal separately with the following issues: improvements in the concreting method [36], determination of construction time of monolithic construction facilities [37], influence of material characteristics change on the structure [38-40], analysis of regulatory requirements for the development of construction projects and their impact on the quality of project documentation [41], the amount of fiber to achieve maximum electrical conductivity of the mixture, the effect of the fiber content on induction heating; using steel fiber to prevent the development of cracks in concrete, etc.

In accordance with state standard of the Russian Federation 34329-2017 fixed formwork is the formwork consisting of panels (panels, blocks, plastic) remaining after concreting in the structure, and inventory supporting elements. As a rule, the vast majority of fixed formwork types are not included in the design section.

However, despite such a large selection and widespread use of fixed formwork in construction, the possibilities of using fixed formwork for columns remain insufficiently studied. The purpose of this work is to develop and increase the effectiveness of the use of fixed formwork for round monolithic columns.

2 Materials and methods
There are several types of fixed formwork for making load carrying structure:
- blocks of foamed polystyrene with voids;
- facing fixed formwork;
- fixed formwork using PLASTBAU-3 technology;
- reinforced panels;
- wood-concrete panels or blocks.

Despite the large selection and their widespread use, all of the above types of fixed formwork are mainly used for wall structures. It has been established that the application of fixed formwork for columns remains poorly understood.

The use of glass-magnesite sheets (GMS) as a fixed formwork for columns is insufficiently studied today.

In comparison with other types of materials of fixed formwork, GMS has the following advantages:
1. Increased installation speed, due to the light weight of the main structural elements;
2. Facilitation of the installation process, due to the reduction in the number of technological operations;
3. Reducing the cost of plastering a monolithic structure (the surface of fixed formwork is smooth and ready for finishing with other materials, such as decorative plaster, products from ceramic materials, painting, etc.);

4. Convenience in transportation and storage of sheet material and fasteners;

5. Reduction of labor costs when combining the processes of erection and fire protection of a structure.

During the research, the construction technology of the permanent formwork from GMS was studied in details, which includes the main operations: reinforcing work; installation of GMS sheets; fastening and fixing the formwork; monolithic work; concrete laying and formwork maintenance.

To determine the complexity of mounting fixed formwork and monolithic round columns as a result of the calculation, the following column sizes and formwork designs were adopted (figure 1).

![Formwork model](image)

**Figure 1.** Formwork model, where 1 – clamp with the step 1000 mm, 2 – cast-in-situ column with d=500 mm.

According the results of numerical studies in the LIRA software package the following column parameters and formwork designs were adopted: column height 3 m, diameter 500 mm, GMS thickness 10 mm, tube clamp (figure 2) h = 100 mm, ring diameter d = 530×10 mm, pitch 1000 mm.

In order to determine the composition and the complexity of the work performed, a technological map has been developed for the production of works and the construction of monolithic round columns in fixed formwork made of glass-magnesite sheet. Types of work under consideration in the technological map:

- arrangement and fastening of reinforcing bars;
- installation of formwork with fastening and fixing;
- assembling and analysis of the scaffolding;
- preparation and placement of concrete in the formwork.
Figure 2. Schematic diagram of the construction of the clamp, where 1 is a hairpin; 2 – corner (№ 8); 3 – nut; 4 – clamp made of steel sheet (100 mm thick).

The composition of the formwork installation includes the following types of work:
- the first clamp is fastened by welding to the embedded parts previously left in the plate;
- 3 metal strips along the entire height of the column are symmetrically attached to the first clamp by welding;
- the second and third clamps are welded with a step of 1 m in height;
- pre-prepared glass-magnesite sheet is attached to the mounted clamps.

Table 1. Technical and economic parameters.

| Indicator                  | Units measuring | Amount |
|----------------------------|-----------------|--------|
| Scope of work              | m³              | 7.85   |
| Labor costs                | man-days        | 15.36  |
| Machine time               | mach-change     | 0.15   |
| Duration of work           | days            | 7      |

For a practical assessment of the results obtained, the complexity of the installation of twenty columns was determined, and the total installation duration was calculated, which amounted to 7 working days. The results are shown in table 1.

3 Results
At the period of performing construction and installation works, the following operations will be monitored: reinforcement work, marking and installation of formwork, concrete work. The composition of operations, control methods and the used instrumentation are shown in table 2.

Table 2. Operations and quality control.

| Work stages                          | Controlled operations                                                                 | Monitoring method | Documentation                      |
|--------------------------------------|---------------------------------------------------------------------------------------|-------------------|------------------------------------|
| Accepting of elements of fixed formwork | Verify: - availability of a quality document on the SML sheet; - availability of a quality document for fasteners (clamps) | Visual            | Passport (certificate), general work log |
| Installation of fixed formwork elements | Installation of fixed formwork elements in the design position; compliance with the rules for the assembly of formwork sheets, installation of fasteners, embedded elements; the | Visual, measuring | General work log, project layout |
horizontal position of the mounted elements; existence of a gap between wall elements.
Precision of elevations.
Reliability of installation of formwork elements, lack of gaps at the joints of elements

Accepting of a timbering

Compliance of actual and geometrical dimensions of non-removable formwork elements with design requirements.
Correct installation and safe attachment of LSU parts, embedded parts.

Visual, measuring

General work log, project layout

Instrumentation: tape rule, construction weir, level-theodolite, tacheometer, metal ruler, construction level

Thus, the construction of permanent formwork from GMS requires multilateral, thorough and rigorous quality control at every stage of construction. To eliminate the occurrence of defects and damages following requirements must be fulfilled: timely monitoring by construction participants, compliance with the production technology, verification of certification of all fixed formwork elements for compliance with the project and regulatory documents.

4 Discussions

Glass-magnesite sheets are proposed as a material for fixed formwork of round columns.

The calculation model was created in the LIRA software package and the design of the formwork made of glass-magnesite sheet was calculated, as a result of which the dependences of glass-magnesite sheet thickness on the pitch of the clamps and the diameter of the column were obtained. So, for the diameter of the concrete column from 300 to 600 mm, the thickness of the glass-magnesite sheet varies in the range: 7-23 mm.

A workflow for the construction of monolithic round columns in fixed formwork from glass-magnesite sheet has been developed, technical and economic indicators of work are presented, and a technological sequence of work quality control is developed.

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