DOI: 10.23968/2500-0055-2023-8-2-58-62

SIMPLIFICATION OF THE REINFORCED CONCRETE ARCHED ROOFING CONSTRUCTION

Irakli Kvaraia*, Ioseb Giorgobiani

Faculty of Civil Engineering, Georgian Technical University, Georgia

*Corresponding author's e-mail: irakvara@yahoo.com

Abstract

In this paper, we discuss issues arising in the construction of cast-in-situ reinforced concrete arched roofs and ways to simplify their design. Despite the versatility of existing mold systems in construction, shell-type roofing structures are entirely different from other structural elements widely used in construction practice in terms of their outline and overall dimensions. Therefore, to erect them, it is necessary to build an individual mold system, which would provide the appropriate spatial shape for cast-in-situ reinforced concrete roofing. Due to the scale of shell roofs, the installation of such mold systems is often associated with significant difficulties as it requires a large, bulky structure above the ground surface with the use of load-bearing scaffolding and planking. This results in issues of building individual elements and the entire mold system and accurately placing them in the design position, which can be solved quite easily using the experience gained from similar works. As a demonstration of this, an example of the arched roof construction for the church named after the Mother of God of Iveria, the second largest church in Georgia, was given a few years ago. At the time, the main difficulty was manufacturing and installing wooden arch molds, which was quickly overcome due to considering several practical measures in advance.

Keywords: shell, mold, column, roofing, reinforced concrete.

Introduction

Due to the dome and vault structural solution of the temple, the central, most significant, cast-in-situ reinforced concrete slab and beam roof served as the unifying part for the columns and walls. The roofing was intended to cover the space with dimensions of 10x24 m. A schematic representation of the roof is given in Fig. 2, where the arrangement of the shell roof and supporting arched beams is indicated, showing the corresponding circumference radii.

`From the schematic representation, it is clear that the arrangement of the arched beam and roof molds requires excellent precision. If we consider section 1-1 (Fig. 1) as a cross-section of the mold, there is a possibility to align and fix the forms within only 0.2 meters of the 10-meter-long beam. Therefore, the most crucial task was to arrange the five arched beam molds to create a complete spatial mold system. It was impossible to manufacture them directly at the site, on the planks arranged on the load-bearing scaffolding. In view of the fact that the ready-made forms must be placed between the reinforced frames of the columns and walls, and their axis of symmetry must coincide with the axes of the columns, it was decided to manufacture the arched beam forms using wooden material. This material made it possible to slightly adjust the dimensions of the molds when installed in the design position, which is impossible in the case of molds made of other materials (metal, plastic, etc.) (Artebyakina and Shcherbina, 2017; Ezugbaia et al., 2018; Kapanadze and Jankarashvili, 2021; Khmelidze et al., 2018; Kvaraia, 2017; Kvaraia and Firosmanishvili, 2019; Lebanidze et al., 2017; Obukhov et al., 2015; Yunusov, 2016).

During the construction of the arched beam molds, it was necessary to consider some issues in advance so that the installation of the entire mold system could be carried out as efficiently as possible. The most difficult was to comply with one of the seemingly contradictory conditions. In particular, the mold structure, in addition to high strength and stiffness, had to ensure the slightest possibility of expansion and contraction in the longitudinal direction so that, if necessary, it could be accurately fixed according to the design coordinates (Kvaraia, 2015; Kvaraia and Kanchashvili, 2015).

When lifted with a crane and delivered to the work area, the ready-made molds require the arrangement

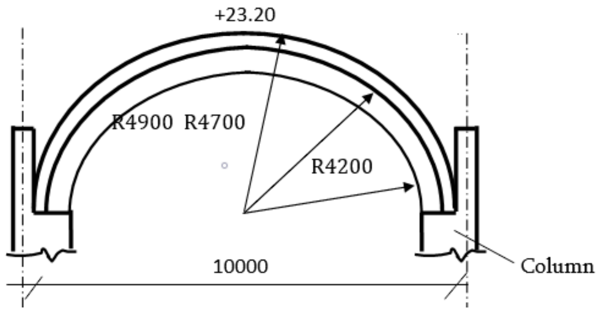

Fig. 1. Schematic representation of the shell roof

For citations: Kvaraia I. and Giorgobiani I. (2023). Simplification of the reinforced concrete arched roofing construction. Architecture and Engineering, No 2 (8), pp. 58-62. DOI: 10.23968/2500-0055-2023-8-2-58-62.

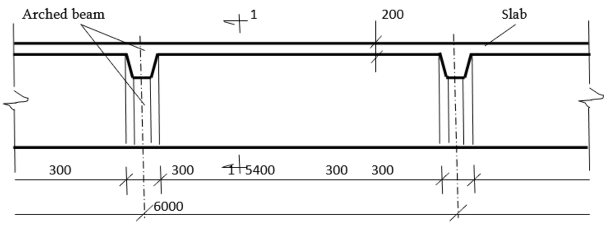

Fig. 2. Section 1-1

of additional reinforcements so that their separate constituent elements are not deformed during transportation and the overall dimensions of the mold are not changed. In addition, during the construction of the beam mold, it is necessary to consider the arrangement of nodes connecting the roofing arch slab to the mold to obtain a continuous mold system (Kvaraia and Dvalishvili, 2014a, 2014b).

Molding method

The arched beam mold was manufactured directly at the site, mainly using existing wooden planks, beams and plywood, which covered the mold surfaces. All five semi-circular molds 10 meters long and 5 meters high were made of the precise wooden details, and each of them represented a sizeable independent structure (Fig. 3). When being moved to the work site, to maintain strength, each of them was additionally reinforced with wooden frames, which allowed the mold structure to be attached to the crane and delivered to the site (Fig. 4).

The issue of fixing the supporting parts of the frame in the design position was also solved quite easily. For this purpose, directly at the work site, a movable wooden belt was arranged at the bottom of the mold, which, during the mold installation, allowed its supporting parts to move forward and backward using steel screw rods (Fig. 5). It should be noted that the presence of such a belt greatly facilitated the process of forming the concrete beam.

Fig. 4. Transportation of the arched beam molds

After fixing the arched beam mold in the design position, it was also easy to arrange the mold for the roofing slab. For this purpose, shelves made of laminated plywood strips were placed on both sides of the entire perimeter for laying the wooden planks connecting the molds of the adjacent beams (Fig. 6). Paired semi-circular (arched beam outline) laminated plywood elements were also used to reinforce the roofing slab mold, which was installed every 70 cm using jacks (Fig. 7).

After the arched roof mold system was built and adequately reinforced, the reinforcement work was carried out without any problems. The only difficulty was related to concreting the inclined surfaces near the arch supports and maintaining the design thickness of the shell. For this, it was necessary to install and fix the external molds, but within the minimal area, in the case of arranging a standard mold, it would be almost impossible to build it in full after concreting. A non-standard decision was made here as well. A flexible mold was arranged along the entire length of the arched roof, consisting

Fig. 3. Assembly of the arched beam molds

Fig. 5. Movable lower assembly of the arched beam mold

of plywood and spaced planks attached to it. The elastic structure was fixed using reinforcement rods placed every 50 cm from the sides of the planks, which, while maintaining the thickness of the shell, were fastened to the reinforcement frame of the roofing slab with a tie rod (Fig. 8).

Results

The arrangement of the mold of the supporting nodes made it possible to perform continuous concreting of the roof, which went from one support to another (Fig. 9) and finally took the form shown in Fig. 10.

Discussion

To maintain mold stiffness for complex shape building it is necessary to use non-standard mold, which is specifically designed for specific sections of the building. This method also reduces number of mold materials, which itself reduces construction cost.

Conclusion

In the construction of cast-in-situ reinforced concrete arched roofs, it is of particular importance to simplify the process of building the arched beam mold, which requires an individual solution for each

Fig. 6. Connection between the roof slab and the beam mold

Fig. 7. Reinforcement of the roof slab mold

Fig. 8. Assembly of the flexible external mold

Fig. 9. Concreting of the shell roof

Fig. 10. Finished shell roof

specific case. The need to create non-standard mold systems is due to the wide variety of the outlines and overall dimensions of envelope roofs, which radically differ from forms for other structural elements widely used in construction practice.

When constructing an arched beam mold, it is necessary to consider in advance several problematic issues that may occur during their on-site installation. Among them, the most important is the possibility of the slight movement of the mold's supporting parts, allowing them to be accurately fixed in the design position. In this regard, the most effective is the arrangement of a movable belt, which allows the longitudinal expansion and contraction of the mold structure.

When constructing arched roofs, it is difficult to concrete the inclined surfaces near the supports and maintain the design thickness of the concrete shell in these places. When conventional molds are installed, it is almost impossible to shape them further. In this regard, it is better to arrange flexible forms by gluing flexible plywood in a specific manner, which significantly simplifies the process of maintaining the thickness of the slab and concreting the places close to the supports.

Funding

This research PHDF-21-1399 has been supported by the Shota Rustaveli National Science Foundation of Georgia (SRNSFG).

References

Artebyakina, G. I, and Shcherbina, V. A. (2017). Review of structural solutions for durable roofing of public buildings. *Young Scientist*, No. 6 (140), pp. 29–31.

Ezugbaia, Z., Kvaraia, I., Iremashvili, I. & Mskhiladze, N., 2018. *Construction production technology.* 1st ed. Tbilisi: Georgian Technical university.

Kapanadze, L. & Jankarashvili, D., 2021. Calculation of shells and slabs (literature review). *Construction,* I(57), pp. 116–120.

Khmelidze, T., Kipiani, G. & Khmelidze, K., 2018. *Monuments of Georgian architecture.* 1st ed. Tbilisi: Universal.

Kvaraia, I., 2015. *Solving arising problems during concreting of reinforced concrete shells.* 1st ed. Tbilisi: Georgian Technical University.

Kvaraia, I., 2017. *Methods of building mold systems for reinforced concrete dome-arch roofs and examle of their use.* 1st ed. Tbilisi: Georgian Technical University.

Kvaraia, I. & Dvalishvili, T., 2014. Arranging the mold of reinforced concrete arched beams. *Construction,* II(33), pp. 102–104.

Kvaraia, I. & Dvalishvili, T., 2014. Simplification of reinforced concrete constructions. *Construction,* III(34), pp. 75–77.

Kvaraia, I. & Firosmanishvili, A., 2019. Technological features of the arrangment of reinforced concrete arch beams. *Construction,* I(50), pp. 53–55.

Kvaraia, I., Kanchashvili, S. & Dvalishvili, T., 2015. Arrangment of simple moving nodes during the construction of reinforced concrete formwork systems. *Construction,* IV(39), pp. 54–56.

Lebanidze, A., Maisuradze, G. & Vardiashvili, D., 2017. Large reinforced concrete constructions. *Construction,* III(46), pp. 41–44.

Obukhov, A. Ye., Leonovich, S. N., and Bursov, N. G. (2015). Technology of constructing temple structures out of cast-in-situ reinforced concrete in modern formwork systems. In: Zverev, V. F., Koleda, S. M., and Delendik, S. N. (eds.) *Current Issues of Implementing European Standards in Construction: Collected International Research and Technical Papers (Proceedings of the Research and Methodological Conference)*. In 2 parts. Part 2. Minsk: Belarusian National Technical University, pp. 58–74.

Yunusov, A. S. (2016). Arch designs demanded by the time in building sciences and architecture. *Engineering Journal of Don*, Issue 2. [online] Available at: http://www.ivdon.ru/en/magazine/archive/n2y2016/3586 [Date accessed December 1, 2016].

УПРОЩЕНИЕ ПРОЦЕССА УСТРОЙСТВА ЖЕЛЕЗОБЕТОННОЙ СВОДЧАТОЙ КРОВЛИ

Иракли Квараия* (Irakli Kvaraia), Иосеб Гиоргобиани (Ioseb Giorgobiani)

Факультет гражданского строительства, Грузинский технический университет, Грузия

*E-mail: irakvara@yahoo.com

Аннотация
В данной статье рассматриваются проблемы, возникающие при устройстве монолитных железобетонных сводчатых крыш, и способы упрощения их проектирования. Несмотря на универсальность существующих в строительстве опалубочных систем, оболочечные кровельные конструкции по своим очертаниям и габаритным размерам совершенно не похожи на другие структурные элементы, широко применяемые в строительной практике. Поэтому для их устройства необходимо формировать индивидуальную опалубочную систему, которая обеспечит соответствующую пространственную форму для монолитной железобетонной кровли. В связи с размером оболочечных покрытий устройство таких опалубочных систем зачастую сопряжено со значительными трудностями, поскольку требует возведения над поверхностью земли громоздкой конструкции с использованием несущих лесов и настилов. В результате возникают проблемы с изготовлением отдельных элементов и опалубочной системы в целом, а также их точным размещением в проектном положении, которые можно достаточно легко решить, используя опыт, полученный в ходе аналогичных работ. В качестве наглядной демонстрации несколько лет назад был приведен пример устройства сводчатой кровли для церкви в честь Иверской Божией Матери, второй по величине церкви в Грузии. В этот период основная сложность заключалась в изготовлении и установке арочных деревянных опалубочных форм, которую удалось быстро преодолеть благодаря заблаговременному применению ряда практических мер.

Ключевые слова: оболочка, опалубочная форма, колонна, кровля, железобетон.