Dome roofs and domes of orthodox churches

V D Olenkov, T A Kravchenko, A O Kolmogorova

Institute of Architecture and Construction, South Ural State University, 76, Lenin Avenue, Chelyabinsk 454080, Russia

E-mail: olenkovvd@susu.ru

Abstract. The article studies the shapes of the dome roofs of church monuments of architecture. The presentation is primarily based on the relative comparisons methods. The authors compare the shapes of the dome roofs of church monuments of the Orthodox architecture that relate to different styles and epochs, and emphasize the inviolability of the established canonical church requirements. They analyze the shapes of the dome roofs of Orthodox churches in the Southern Urals. The present paper is aimed at giving recommendations for the restoration of historical churches with a weakened ability of bearing walls, taking into account the improvement of the operation of enclosing structures. The authors study the aerodynamic characteristics of the church dome roofs for determining the most difficult areas (high wind pressure) and taking subsequent correct constructive decisions. Solid works suite-based visualization is used in the study.

1. Introduction

Orthodox churches are traditionally dominant buildings of cities and villages. A specific feature of church building is the need to follow the canonical church requirements based Orthodox dogmatism and the church tradition [1].

One of the most important architectural church elements is a dome roof. In architecture, a dome roof is a decorative coating located above the church dome and arranged on a light drum. A cupola is a dome roof arranged on the decorative (blind) drum. This is a formal definition of dome roofs. Nevertheless, in historical, architectural and restoration use, dome roofs are often spoken of in a broad sense - as a completion of a church consisting of a drum, a dome and a dome coating. Accordingly, the simplest top coatings (with metal or shingle directly on the top) are often referred to dome roofs. In this study, we will adhere to the formal definition of dome roofs as decorative dome coatings. [2].

2. Relevance

Unlike western religious architecture, the development of Russian church architecture was forcibly interrupted for more than 70 years. After that, for many decades no one in our country was engaged in this kind of architectural activity [3,4]. The changes that occurred in the 80s in the life and religious consciousness of people led to the need for massive construction of new churches and restoration of the old ones [1]. The absence of timely care for ancient Orthodox churches in Russia and the termination of their operation for a long period led to the fact that a significant part of these religious monuments of architecture is in an unsatisfactory condition. Restoration of churches is accompanied by several organizational and technological peculiar features, which are preconditioned by the complex architectural and spatial shape of the building and its architectural elements [5]. Based on this
assumption, studying of the shapes of dome roofs – main architectural church elements – is a relevant task.

The experience of church building presented in the literature is reduced to general recommendations that meet the canonical church requirements based on Orthodox dogmatism and the church building tradition [1]. Therefore, it becomes necessary to compare the architectural elements of churches - dome roofs - by the most characteristic features: shape and design.

After studying the literature dealing with the research subject, it has been established that most of works are devoted to the history of Orthodox architecture [2,6-9]. Scientific publications dealing with the research subject mainly reflect the problems of the development of Russian church architecture, the condition of the modern church design practice and organizational and technological solutions of church reconstruction [3,5,10].

Thus, the types of church dome roof designs are insufficiently studied. An analysis of the main types of dome roof designs should help to perceive them not only as works of architecture of some historical period and architectural style, but, first of all, to help to study the influence of aerodynamics on different shapes of dome roofs of religious buildings and compare the wind pressure on them.

The objective of the research is to determine the shapes of dome roofs most suitable for the restoration of ancient churches with a weakened ability of bearing walls, taking into account Orthodox traditions, the time of construction and the church location.

3. Theoretical part

3.1. Shapes of church dome roofs

The dome roof size and shape are determined by the size, type and design of the church coating (Figure 1). The following shapes of church dome roofs are distinguished: egg-shaped, helmet-shaped, onion, pear-shaped, cone-shaped and umbrella. The comparative characteristics of the shapes of church dome roofs are given in Table 1 [2,6-8,11].

![Figure 1. Types of church dome roofs: a) egg-shaped dome roof, b) helmet-shaped, c) onion-shaped, d) pear-shaped, e) cone-shaped, f) umbrella dome roof.](image)

According to the Russian Orthodox tradition, dome roofs are generally helmet-shaped or onion [1]. Let us determine the difference between helmet-shaped and onion dome roofs. Both helmet-shaped and onion dome roofs have an ogee top. The maximum diameter of the onion dome roof is larger than the diameter of the drum, i.e. there is a visual "crowning", and the height of the dome roof is not less than its width. The maximum diameter of the helmet-shaped dome roof does not exceed the diameter of the drum, and the height of the dome roof is always less than its width.

Egg-shaped dome roofs were borrowed from Byzantium. Pear-shaped dome roofs are typical of the "Ukrainian baroque", umbrella and cone-shaped - for Transcaucasian architecture; they were almost absent in Old Russian architecture and in the corresponding iconography [2].
Table 1. Comparative characteristics of the shapes of church dome roofs.

| Dome roof shape | Typical features | Genesis | Architectural example |
|-----------------|------------------|---------|-----------------------|
| Egg-shaped (Figure 1a) | The shape of the dome roof with a rounded top, similar to a spherical one. | It was borrowed from Byzantium. Used in most principalities of pre-Mongolian Rus (Kiev, Chernigov, Smolensk, etc.). | Church of St. John the Baptist in the Crimea, VIII century. |
| Helmet-shaped (Figure 1b) | The shape of the dome roof with an ogive top, similar to the Old Russian helmet. The maximum diameter of the dome roof does not exceed the diameter of the drum. The height of the dome roof is less than its width. | It appeared in Ancient Rus from the XI century, and in the XIV-XVI centuries, it became a mass phenomenon. | Cathedral of St. Demetrius in Vladimir, XII century |
| Onion-shaped (Figure 1c) | Convex form smoothly sharpening at the top, and similar to an onion. The maximum diameter of the dome roof is larger than the diameter of the drum. The height of the dome roof often exceeds its width. The ratio of the diameter of the drum (tower) to the diameter of the wide part (abyss) of the dome roof is 1:1.382, and to the height - 1:1.618. | Appeared in Ancient Rus in the XII-Assumption Cathedral in - XIII centuries, and became a mass phenomenon in the XVI-XVII centuries. Widespread in Russia and the Ukraine. Found in India, Turkey, Bavaria (some Catholic churches) and the Middle East. | Assumption Cathedral in Yaroslavl, XIII century |
| Pear-shaped (Figure 1d) | Convex form smoothly sharpening at the top, and similar to a pear. | It was practically absent in ancient Russian architecture and in the corresponding iconography, typical for the "Ukrainian Baroque". | St. Sophia Cathedral in Kiev, XI century. |
| Cone-shaped (Figure 1e) | Made of bricks. Has ribbed outlines and folded siding, which increases the strength of the dome roof and strengthens the decorative effect. | It was absent in ancient Russian architecture and in the corresponding iconography, typical for Transcaucasian architecture. Appeared in Armenia around the X century; in the XI century, it was borrowed by the Seljuks and transferred to their resettlement areas, from Cappadocia to the Bosporus. | Svetitshoveli Cathedral in Georgia, XI century. |
| Umbrella (Figure 1f) | Separated into segments by ribs diverging from the center to the base, which transfer the vertical load to the ribs. | It was practically absent in Old Russian architecture and in the corresponding iconography, typical for Transcaucasian architecture. | Kazan Cathedral in St. Petersburg, XIX century. |

As for the history of the development of the dome roof shapes of Old Russian churches, in the pre-Mongolian period:

- the simplest dome coatings, usually with a crooked stone, are widespread everywhere (including in the North-Eastern Russia);
- the existence of onion dome roofs is conditionally proved, but their widespread occurrence is not proved;
- the existence of helmet-shaped dome roofs is not proved, any statements about their existence as a "transitional form from the arch to the bulb" are conjectures;
• the existence of any other shapes of dome roofs (umbrella, cone-shaped, etc.) is not proved.

From the second half of the 13th to the end of the 16th century:
• onion dome roofs are widespread, including in the tent church architecture of the 16th century;
• the existence of helmet-shaped dome roofs is not proved;
• top coatings of the pre-Mongolian period could be theoretically preserved in some secondary churches during the entire period under consideration, but by the end of the 16th century they had already been replaced everywhere with onion ones;
• the existence of any other shapes of dome roofs (umbrella, cone-shaped, etc.) is not proved.

From the end of the 16th to the middle of the 17th century:
• onion dome roofs are widespread, including in the tent church architecture;
• the existence of any other shapes of dome roofs is not proved.

From the middle of the 17th to the end of the 18th century onion dome roofs on many churches are replaced with helmet-shaped ones for the purpose of "semi antique" styling. In most cases, in several decades, onion dome roofs are again erected on these churches [2].

Until the end of the 17th century, ancient Russian church architecture developed according to the religious canons and local traditions. With the adoption of Christianity as the state religion in 988 the first stone churches erected under auspices of invited Byzantine masters began to appear in Rus. With the beginning of the reign of Peter I and the orientation towards Western profane art, the external appearance of Orthodox churches became also closely connected with the development of artistic styles (such as baroque, classicism, Empire style, various styles of modernity) [10,12].

3.2. Analysis of the shapes of dome roofs of Orthodox churches in the Southern Urals
In the 5-8th centuries the Byzantine style developed in the Orthodox Church both in the construction of churches and in church service. Preserving the main architectural features of Byzantine churches, Russian churches have a lot of original features. The spherical Byzantine shape of the dome coating was replaced by a helmet-shaped one. In the 15-17 centuries, a style different from Byzantine one characterized by onion dome roofs was formed in Russia.

An analysis of the Orthodox architecture of the Southern Urals has shown that most churches in Chelyabinsk region have onion dome roofs, some churches have helmet-shaped and egg-shaped domes, a small number of churches have pear-shaped dome roofs and umbrella domes. There are no cone-shaped dome roofs in the Orthodox architecture of the Southern Urals [13].

The first Chelyabinsk churches built in the 18th century had onion dome roofs, including the Cathedral of the Nativity in Chelyabinsk (1766-1932) blown up in 1932, the Holy Trinity Church in Chelyabinsk (1768) restored in 1987-1988, the first monastery in Chelyabinsk - the Odigitrievsky Convent (1848-1930) dismantled for building materials in the 1930s [14].

There are churches with helmet-shaped domes among the churches built in the 18 and 20th centuries. They include: the Church of the Transfiguration of Our Lord in Chebarkul (1745, 2007), which architecture reminds of the ancient churches of Vladimir-Suzdal Rus, The Holy Trinity Cathedral in Troitsk (1754), which is the only pre-revolutionary cathedral in Chelyabinsk region that survived to this day, the Cathedral of the Nativity in Chelyabinsk (1766) blown up in 1932, as well as the Church of the Archangel Michael in Krasnokamenka village of Uysky district (1914) built in the Russian-Byzantine style[15].

Among the churches of the Southern Urals built in the 19th century we can outline churches with spherical egg-shaped domes and umbrella domes. Churches with egg-shaped domes include the Church of the Apostles Peter and Paul in Miass (1815) destroyed in the 1930s. The restored Church of the Presentation of the Blessed Virgin in Minyar of Asha district (1819) and the restored Church of the Icon of the Mother of God "Znamenie" in village Voskresenskoe in Kasli district (1835). The Cathedral of the Holy Trinity in Zlatoust (1842) destroyed in the 1930s had umbrella domes. Besides,
there is a church with pear-shaped dome roofs referring to the classical type with baroque elements - the Church of St. Demetrius of Thessaloniki in Troitsk [9].

3.3. Study of aerodynamic characteristics
SolidWorks suite, as well as FlowSimulation complement was used for the study. We created a simplified model of the building, on the tops of which we placed complexes of dome roofs of different sizes and shapes (two most common shapes - spherical and onion we considered). The height of such architectural structures is more than 20 meters, so for this task it was necessary to take into account the wind profile. The wind profile was determined graphically at the wind speed of 10 m/s.[16-20]

In the first experiment, we considered the volume of a church with spherical dome roofs. The central dome roof has a larger diameter than the other four dome roofs. In the second experiment, we considered the volume of a church with five onion dome roofs, where the central one was larger than the others. As a result of the calculations, we obtained diagrams of the wind speed and pressure on the hemispherical dome roofs and onion dome roofs (Figures 2,3).

The wind pressure images show that the dome roofs do not experience any pressure larger than the pressure on the facade of the building, and the wind speed images show strong whirlwinds only in case of the onion dome roof.

![Figure 2. Wind speed. Onion dome roof.](image)

![Figure 3. Wind pressure. Onion dome roof.](image)

4. Conclusions.
The practical value of the work consists in studying the influence of aerodynamics on different shapes of dome roofs, comparing the wind pressure on them, determining the shape of the dome roof most suitable for the restoration of old churches with a weakened ability to bearing walls, taking into account Orthodox traditions, the time of construction and the church location.

As a result of the analysis of the Orthodox architecture, we determined the following main shapes of church dome roofs: egg-shaped, helmet, onion, pear-shaped, cone-shaped and umbrella. Most churches of Chelyabinsk region have onion dome roofs, some churches have helmet-shaped and egg-shaped domes, an insignificant number of churches have pear-shaped dome roofs and umbrella domes. There are no cone-shaped dome roofs in the Orthodox architecture of the Southern Urals.

The aerodynamic characteristics of the church dome roofs are quite favorable, since they have a streamline shape. But when constructing a whole composition of dome roofs, it is necessary to analyze
the design in terms the wind exposure due to the possible appearance of twirling between the dome roofs, which increase the wind pressure on them.

References

[1] Orthodox churches. Orthodox Churches and Complexes: Design and construction manual 2 (to SP 31-103-99). MDS 31-9.2003/AHC "Arkham" 2003 (Moscow: Sate Unitary Enterprise Center of Design Products in Construction)

[2] Zagraevsky S V 2008 Shapes of dome roofs of ancient Russian churches (Moscow: ALEV-V) p 46

[3] Milchenko E A and Kayumova N A 2014 Orthodox church architecture. Analysis of the current state of foreign and Russian church design practice New Ideas of the New Century 2 pp 194–202

[4] Pokrovsky N V 2000 Analytical Review of the Christian Art Monuments (St. Petersburg: Liga-Plus)

[5] Likhograi V V 2017 Organizational and technological solutions for restoring dome roofs of stone Orthodox churches Bulletin of the Pridnestrovsky State Academy of Construction and Architecture 2 pp 227–228

[6] Voronin N N 1954 Architectural monument as a historical source (notes to the problem statement) Soviet Archeology. XIX (Moscow) pp 41–76

[7] Gulyantyuk N F 1962 The history of architecture (Moscow) p 284

[8] Orthodox churches. Idea and Image. MDS 31-9.2003/AHC "Arkham" 2004 (Moscow: Sate Unitary Enterprise Center of Design Products in Construction) 1 p 332

[9] Olenkov V D 2008 Orthodox churches of Chelyabinsk region: history and architecture (Chelyabinsk: Auto Graf) p 256

[10] Ishinova N V and Rautkin A I 2013 Problems of the development of modern church architecture in Russia New Ideas of the New Century 3 pp 153–159

[11] Orthodox churches. Examples of Architectural and Building Solutions. MDS 31-9.2003/AHC "Arkham" 2005 (Moscow: Sate Unitary Enterprise Center of Design Products in Construction) 3 p 237

[12] Surin D N and Tereshina O B 2017 Modern Church Construction in Urals. Problems and Prospects IOP Conf. Ser.: Mater. Sci. Eng. 262 012132

[13] Alektorov A E 1883 History of Orenburg Governorate (Orenburg: Orenburg Governorate Statistical Committee)

[14] Vesnovsky V A 1904 Illustrated Guide of the Urals (Yekaterinburg: Typography Uralskoy zhizni (of the Ural Life))

[15] Dobrohotov F P 1917 North, Middle and South Urals (Petrograd: B V Suvorin’s Publishing house)

[16] Olenkov V and Puzyrev P 2017 Study of Wind Effects on Unique Buildings IOP Conf. Ser.: Mater. Sci. Eng. 262 012154

[17] Churin P S, Poddaeva O I and Egorychev O O 2014 Designing Mock-Ups of Unique Buildings and Structures in Experimental Aerodynamics Scientific and Technical Volga region Bulletin 5 pp 332–335

[18] Retter E I and Strizhenov S I 1968 Buildings Aerodynamics (Moscow, Stroyizdat Publ.) p 240

[19] Poddaeva O I and Dunichkin I V 2017 Architectural-Building Aerodynamics Vestnik MGSU 12 6 (105) pp 602–609

[20] Egorychev O O, Churin P S and Poddaeva O I 2014 Experimental Study of Force-Moment Wind Loads on High-Rise Buildings Industrial and Civil Construction 9 pp 28–30

Acknowledgments

The work was supported by Act 211 Government of the Russian Federation, contract no.02.A03.21.0011.