GEOMETRIC PROPORTIONAL MODEL OF THE CHURCH OF THE LJUBOSTINJA MONASTERY

Magdalena S. DRAGOVIĆ
University of Belgrade, Faculty of Civil Engineering, University of Belgrade, Department of Mathematics, Physics and Descriptive Geometry, Belgrade
Aleksandar A. ČUČAKOVIĆ
University of Belgrade, Faculty of Civil Engineering, University of Belgrade, Department of Mathematics, Physics and Descriptive Geometry, Belgrade
Jelena V. BOGDANOVIĆ
Iowa State University, Department of Architecture, College of Design, Ames, Iowa, USA
Svetlana J. ČIČEVIĆ
University of Belgrade, Faculty of Traffic and Transportation, University of Belgrade, Department of Traffic Psychology, Belgrade
Aleksandar V. TRIFUNOVIĆ
University of Belgrade, Faculty of Traffic and Transportation, University of Belgrade Department of Organization, Management and Economy of Traffic and Transport, Belgrade

Abstract: The use of proportions is one of the oldest theoretical issues in architecture. However, sometimes geometry, with its specific shapes and constraints between them, can fully describe the logic of architectural design. This paper presents geometric proportional schemas of the Serbian medieval church of the monastery Ljubostinja (built around 1387), the representative of so-called Morava architectural style.

The research is partly based on Ivo Štambuk's proportional canon, which he applied on several churches, in wider Mediterranean region during prolonged period of time (4th to 15th c.). Štambuk's proportional canon is based on two circles and one equilateral triangle constrained to each other and set relative to characteristic points of the church plan and cross-section, above all the location of the altar and the center of the church dome. By adding principles of triangulation and dynamic rectangles, this paper demonstrates more precise proportional model of the church plan and the cross-section through the dome. Results show that the proportions of the Ljubostinja's church can be interpreted by dynamic rectangles (their diagonals are square roots of full numbers) with ratios $1:\sqrt{2}$, $1:\sqrt{3}$, $1:\sqrt{5}$ and, in addition, by specific scheme of equilateral triangles which are constrained to the characteristic points of the church space: center point of the apse and the dome.

Keywords: Medieval churches, Morava style, geometric proportions, triangulation, dynamic rectangles

INTRODUCTION

The church of the Dormition of the Mother of God, in the monastery Ljubostinja (1387), near Trstenik, sponsored by Serbian princess Milica, wife of prince Lazar Hrebeljanović, is one of the most beautiful and representative medieval churches in the Morava valley in Serbia.[1] Like majority of churches built by the royalty, it is very sophisticated both in architectural design and decoration[2]. Its characteristic architectural style, so-called Morava school, here reached the maturity in harmony of architectural design, concept of the facades and decoration. The aim of this paper is to examine whether the proportions of the Ljubostinja monastery church can be interpreted by geometric patterns and constructions, and by extension, whether such geometric proportional model is applicable to other Morava churches, with their characteristic *trefoil* (triconch) plan[3]. Scholars, such as Ristić and Radujko, provide invaluable narratives of the general architectural concept of Morava churches, relative to their religious, monastic, and social aspects, and additionally provide mathematical ratios of characteristic dimensions (commonly width/length, or height/length) in their proportional analyses[4]. The general architectural concept of the floor plan of the Morava churches is recognized as inscribed cross shape (developed or compressed type) extended by the two side conches, with various dimensions, often explained as the result of the religious utilization of the church interior space, its funerary or liturgical function.[5]

This research recognizes particular geometrical attributes of the Ljubostinja's church design, both in horizontal and vertical sections. The authors use previous research methods applied to the Raška churches,[6] where the proportional canon of I. Štambuk[7] was enriched by the principles of triangulation and furthermore by dynamic rectangles. While Štambuk's principle of proportioning relies on geometric shapes, dynamic rectangles utilize geometric constructions and mathematical ratios (square roots of integers).

Many scholars share the opinion that Athonite monastic architectural concept of the triconch churches was arranged to fulfill the conditions of liturgical life of a monastic community, was brought from Mt. Athos to Serbia, and became characteristic of early Morava churches.[8] The two churches: the catholicon of the monastery of Rđavac and the church of Sts. Archangels in Kučevište, located in Skopje area share developed versions of inscribed cross plan with conches, although their structural concept is not fully

1 Morava Serbia (1371–1459) is the Serbian territory under expansion during the ruling of prince Lazar: V. Ristić, *Moravska arhitektura*, Kruševac, 1996, 28.

2 Gabriel Millet, French historian, assessed the church of the Ljubostinja as exceptionally achievement of *L' Ecole dela Morava*: S. Đurić, *Ljubostinja*, Beograd, 1985, 21.

3 Trefoil shape, known as *cella trichora* appeared in early Christian churches (4.–5. c) as a sanctuary inside several basilicas in Dalmatia: P. Vežić, *Ars Adriatica* 1/2011, 30.

4 V. Ristić in his historical context of development of Morava's churches expresses proportions of *naos* by coefficients (Drenča 1,38; Ravanica 1,75; Ljubostinja 1,33 etc.) Moravska arhitektura, 56; M. Radujko states that proportions of numerous Morava's churches appear in ratio 1:1 concerning length/height, e.g. at Ravanica (1:1,04), Lazarica (1:1,1), Kalenić (1:1,19) etc., *Koporin*, 2006, 83.

5 V. Ristić, *Moravska arhitektura*, 30.

6 M. Dragović et al., "Proportional schemas of Serbian medieval Raška churches based on Štambuk's proportional canon", *Nexus Network Journal*, 21 (1), 2019, 37.

7 I. Štambuk, „Zaboravljene proporcije: Kanon za projektovanje crkava", *Prilozi istoriji otoka Hvara*, XI, 2002, 95.

8 The monastic concept of the church space assumes side conches as extensions of the altar, i.e. the place for singers who participate in liturgical service. B. Vulović presented this as "organic link of choirs with organism of the church". B. Vulović, *Ravanica*, Saopštenja VII, Beograd 1966, 54; G. Millet, *L' ancient arte serbe*, Paris, 1919, 152–153; S. Ćurčić, *Architecture on the Balkans*, New Haven, 2010, 671–682.

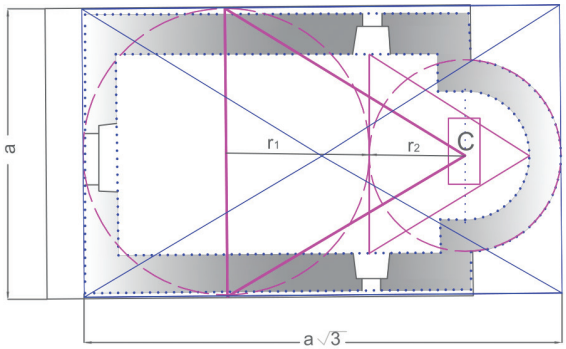

Fig. 1

defined as in Morava style.[9] These churches are dated to the mid and the second half of 14th century.[10] Beside obvious similarity in proportioning (the ratio of interior dimensions – width/length) of the churches in Ljubostinja and Rđavac[11], as well as the overall architectural concept of developed inscribed cross plan, the reason why those churches are included into geometric analysis is to refine and test their design connections through historical context.

METHODOLOGY OF THE APPLIED PROPORTIONING

Štambuk's canon and additional triangulation

In his proportional study of several churches in the wide region of the Mediterranean, built during prolonged period of time (4th–15thc), I. Štambuk introduced the concept of the composition of regular geometric shapes (two circles and an equilateral triangle), mutually constrained and related to the characteristic points of the church plan and cross-section (Fig. 1). Based on Štambuk's concept, the authors tested the application of geometric schemas on the three representatives of Raška monuments, the churches of the medieval monasteries Studenica, Žiča and Gradac.[12] The results have demonstrated significant potential of the applied canon both in revealing proportions and determining geometric schemas for the chosen sample of churches. Although the design concept of Morava churches significantly differs from the Raška churches both in plan and vertical cross-section, the authors have found that geometric interpretation of proportions on the church of Ljubostinja, obtained by the same methodology, reveals the repetition of geometric rules.

Proportional analysis of the church plan

I. Štambuk's construction is applied both on the plan and cross-section of the Ljubostinja monastery church in unique setting: the center ***C*** of the main apse and dome coincides with the center of the circle k_1 which is inscribed in the main church apse and dome. Simultaneously, point ***C*** is the top vertex of the

9 B. Vulović defines a combination of Greek elongated cross and trefoil, *Ravanica*, 1966, Beograd, 55.

10 B. Vulović, *Ravanica*, 55.

11 V. Ristić, The coefficients of length/width ratio are 1,27 (Rđavac) and 1,33 (Ljubostinja), *Moravska arhitektura*, 56.

12 M. Dragović et al., "Proportional schemas of Serbian medieval Raška churches based on Štambuk's proportional canon", *Nexus Network Journal*, 21 (1), 37.

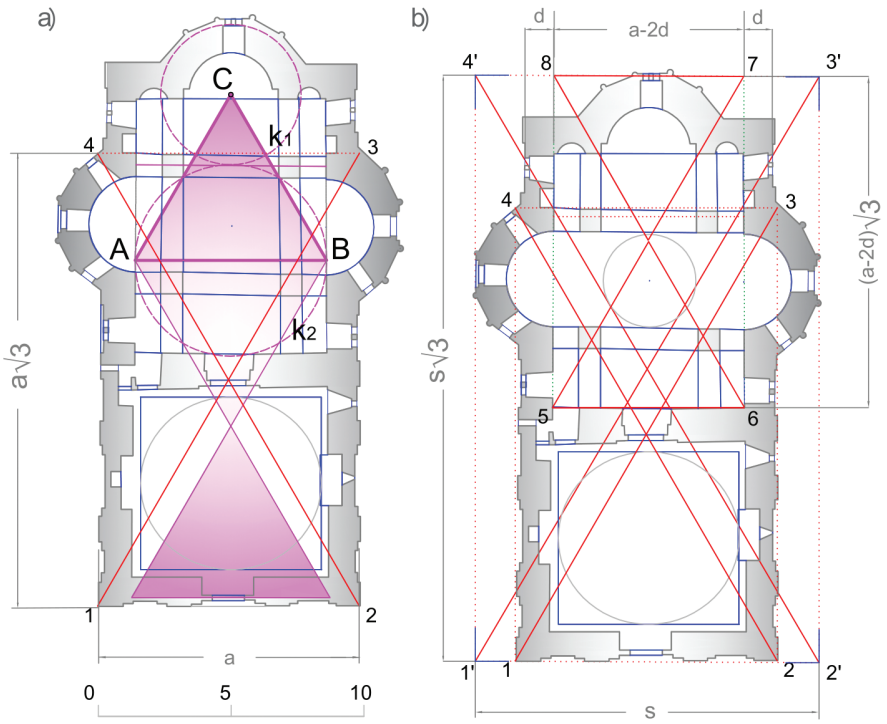

Fig. 2

equilateral triangle ***ABC*** – the *holy triangle*[13], which edge equals to the width of the church nave. The other circle k_2 is set so that its diameter coincides with the edge ***AB*** of the *holy* triangle (Fig. 2a). Štambuk's geometrically constrained construction applied on the ground plan, with negligible inaccuracy defines the proportions of the altar and the naos, where ***AB*** is the nave interior width ***(a–2d)***, while the sum of the diameters of the two circles is ***(a–2d))√3***[14].The tangent line of the two circles (k_1 and k_2) represents the boundary between the sacred (altar) and public spaces.

In addition, specific triangulation is applied to the church floor plan. By mirroring the geometry of the *holy* triangle ***ABC*** along the longitudinal axis of the church, the length of the church plan without apse (the distance from the entrance to the center of the main apse) equals ***3/2(a–2d)√3***. Such geometric shape, consisting of three equilateral triangles (highlighted in pink color in Fig. 2a), resembles a *fish*, with "mouth" set at the most sacred place of the church – the altar table in the main apse. The "fish" pattern is an early symbol of Christianity.[15] Here, it consists of three equal equilateral triangles and reveals the symmetry along the longitudinal axis of the church. As such, it may be an original response of the geometric-symbolic approach in proportioning of the church plan.

13 This is the common place of the altar table, where the central part of the liturgy takes part.

14 Štambuk's canon in general represents the ratio 1:√3 , where diameter of a larger circle equals 1. I.Štambuk, „Zaboravljene proporcije: Kanon za projektovanje crkava", *Prilozi istoriji otoka Hvara*, XI, 95.

15 The known fact that acronym ἰχθύς of the expression "Jesus Christ son of God, the Saviour" in Greek language which means – the fish, N. Ozimić, „Simbolika ribe i hrišćanstvo", *Društvo za antičke studije Srbije, Arhiv Srema*,Beograd, 2008.

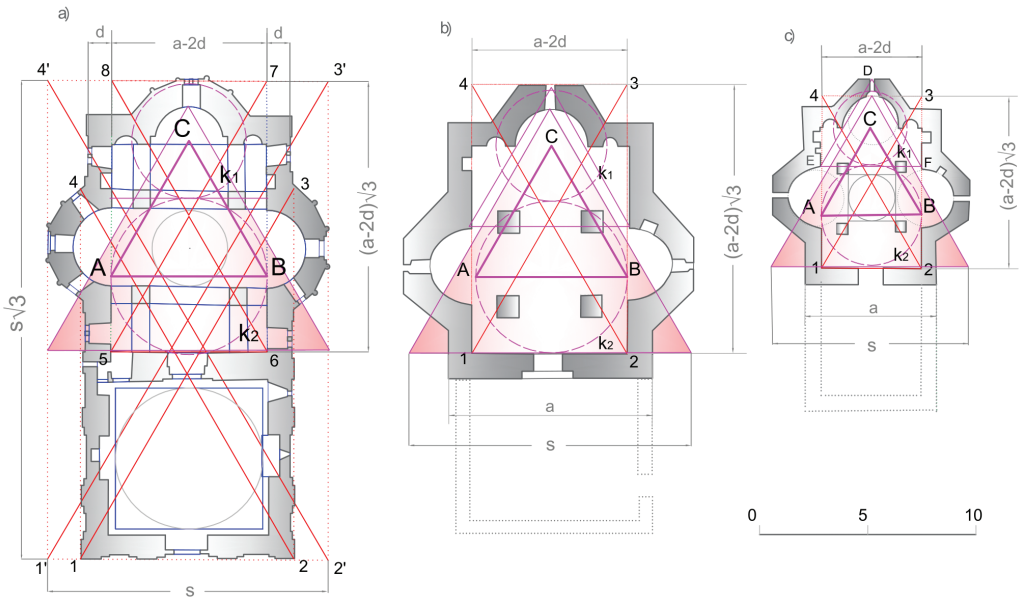

Fig. 3

The important fact, that enabled such geometric approach, is that the narthex of Ljubostinja's church was built simultaneously with the rest of the building, which was not a common practice in construction of early Morava's churches[16]. V. Ristić noticed the same pattern in his proportional analysis of Lazarica church. More ideal proportion is within interior proportional of the of length and width, revealing the three equilateral triangles inscribed in the interior contours of the walls[17].

Additionally, the characteristic rectangle ***1234***, composed of the two equilateral triangles, obtains the ratio ***a:a√3*** (Fig. 2a). Previous analysis of Raška churches revealed the rectangle of ratio ***a:a√3***, edging joined *naos* and *altar* spaces, without semicircular apse[18], while here, in the ground plan of Ljubostinja church, it appears as a boundary of joined *narthex* and *naos*, without altar space. In particular, the two equilateral triangles, inscribed in rectangle ***1234***, in Ljubostinja, underline the hidden geometry and the spatial balance of the two important spaces – *narthex* and *naos* (Fig. 2a). However, this is not the only regularity which gathers two equilateral triangles inside rectangle, that of ratio ***1:√3***, as recognized in the ground plan. Namely, the two rectangles: ***1'2'3'4'*** and ***5678***, presented in Fig. 2b, share the same ratio, while the edges ***3'4'*** and ***78*** overlap each other. The rectangle ***1'2'3'4'*** represents ratios of the total width and total length of the church ***s:s√3*** (Fig. 2b), while the ratio ***(a–2d):(a–2d)√3*** of the rectangle ***5678*** determines geometrical constraints between interior walls of the naos (***a–2d*** is nave width) and exterior contour of the polygonal apse.

16 The churches in the monasteries Ravanica and Resava were initially built without narthexes, that were added in later construction phases. S. M. Nenadović, *Arhitektura u Jugoslaviji od IX – XVIII veka*, Beograd 1987, 158.

17 V. Ristić, *Moravska arhitektura*, 71.

18 Each of the three studied churches confirm this regularity, M. Dragovic et al., *Nexus Netw* J21(1), 2019, 33–58

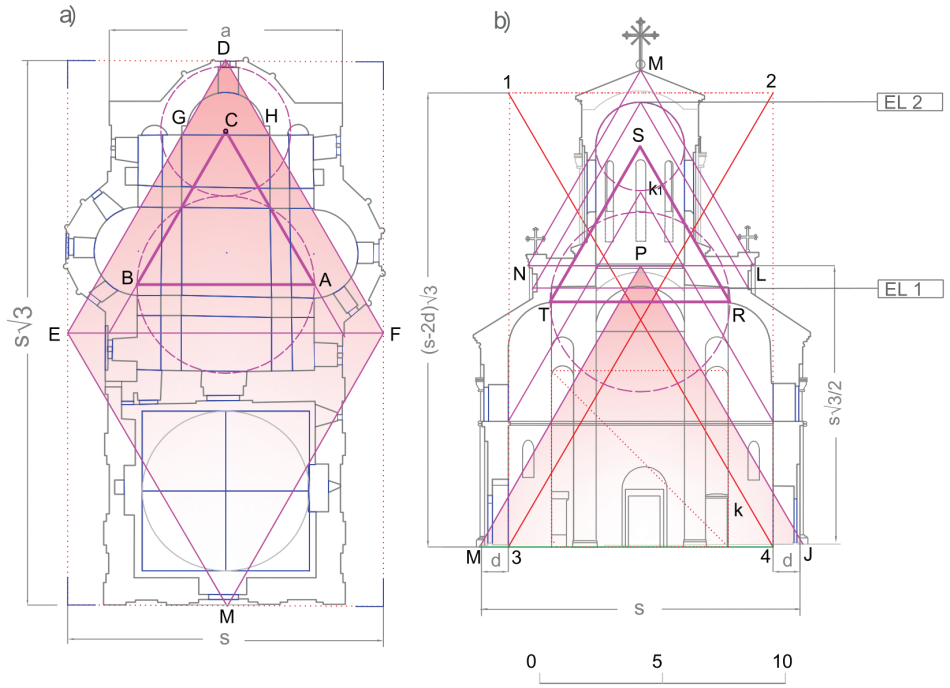

Fig. 4

The same geometric principles are tested on the ground plans of the two smaller triconch churches: Rđavac and Sts. Archangels in Kučevište. The comparative analysis of the three plans confirms the applicability of Štambuk's canon regarding the ratio of interior dimensions of the churches. The ratio ***(a–2d):(a–2d)√3*** is defined by the rectangles ***5678*** (in Ljubostinja – Fig. 3a) and ***1234*** (in Kučevište and Rđavac – Figs. 3b–c), while the unique equilateral triangle (light red colored) defines interior length of the naos extended with apse. The edge of the triangle equals the total exterior width ***s*** in each of the three ground plans. This regularity points to the key dimensions: interior length/ exterior width of the churches is performed in the same geometric manner.

Proportional analysis of the cross-section through the dome

In the proportional analysis of the cross-section of the church, positioned through the center of the dome structure and side conches, the *holy* triangle was constrained to the key point ***S*** – the center of the dome, while its edge corresponds to the interior nave width ***a–2d*** (Fig. 4b). The two circles k_1 and k_2 from Štambuk's canon, here do not maintain tangent constraint. The reason is probably the fact that the churches being built in Morava style had specific additional ring, i.e. an extension of a tambour, of the dome structure, following the tendency of master builders to increase the height of the church.[19]

However, by applying the triangulation methodology, several characteristic equilateral triangles appeared as guiding in the concept of the main core of the church, i.e. the core vaults bearing the dome structure. The key equilateral triangle ***STR*** shows direct correspondence of the dome center with the top points (***T*** and ***R***) of side semi-calottes. The base edge ***NL*** of the triangle ***MNL***, where ***M*** is the highest

19 S. M. Nenadović, *Arhitektura u Jugoslaviji od IX – XVIII veka*, Beograd 1987, 158.

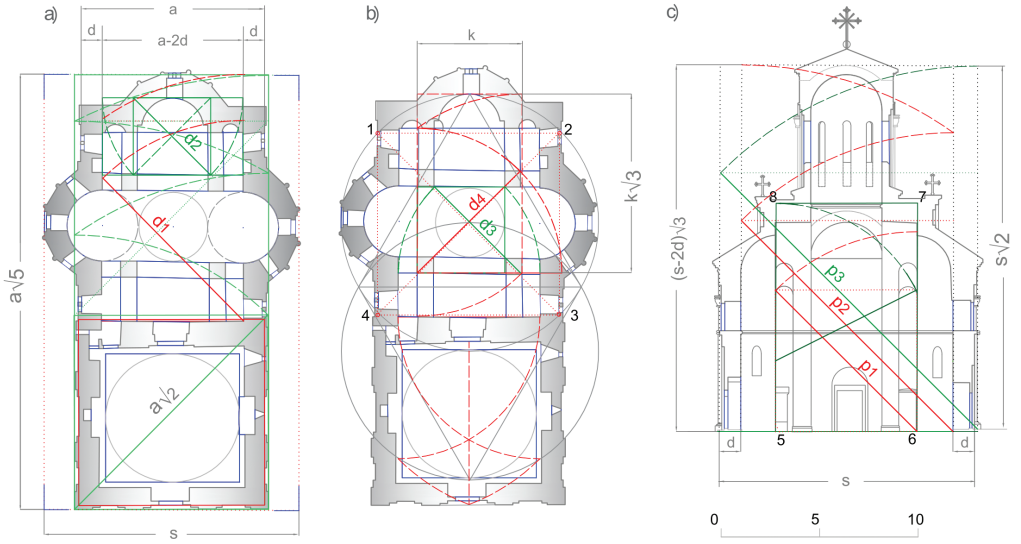

Fig. 5

point of the church (before the reconstruction in 1966[20]), defines the elevation of the cornice on the cubic pedestal. The third triangle, set at the apex of the dome, defines the elevation (marked as EL 1 in Fig. 4b) of the two side vaults, i.e. *transept*, as well as the width of a cubic pedestal.

The correlation of the dome structure and the total interior width ***s*** of the nave is obtained by the triangle ***PMJ***, where ***P*** is the midpoint of the tambour's bottom (Fig 3b.). The three identical triangles: ***PMJ*** (cross-section), ***DEF*** and ***MFE*** (ground plan) appear in the pedantic geometric conception of the total structural design of the church (Figs. 3a–b). In accordance to such concept, the ratio width/length of the ground plan exterior is ***s:s√3***. The proportions of the central core of the church (cross-section), i.e. the lower part of the structure, relay on the ratio ***s:s√3/2***, while the ratio ***(s–2d):(s–2d)√3*** defines its total height (rectangle ***1234***).

The dynamic rectangles in the proportioning

The use of dynamic rectangles in the proportioning is a well known geometric method, among the ones applied on medieval sacral architectural monuments.[21] However, some scholars believed that medieval master builders or architects rather used intuition, than complex geometric knowlegde that would include the use of irrational numbers in geometric designing of the church plans/cross-sections.[22] Hence, it became

20 Amongst other interventions, the covering of the dome was changed in 1966, based on copyrighted drawings of the Republic institute for the protection of cultural monuments of Serbia.

21 M. Čanak Medić speaks of application of proportions guided by principles *ad quadratum* and *ad triangulum* (which include values √2 and √3 respectively) on designs of Gothic cathedrals, "Postupci starih neimara", *Razvoj nauke u oblasti građevinarstva i geodezije u Srbiji*, 1996, 39; V. Ristić in his analysis of the floor plan of Lazarica church found proportions of the spaces with irrational numbers *a*√2, *a*√3, *a*√5 achieved by a compass, in order to get precise disposition of the walls, *Moravska arhitektura*, 57;

22 M. Mitrović, and Z. Đorđević stated that "M. Zloković (G. Millet's student) opposed the mainstream believe that proportional application depends only on artist's intuition, as it is innate and thus cannot be contemplated", "Zloković's understandings of reciprocal catenuation", *Nexus Netw J* 20, 2018, 194.

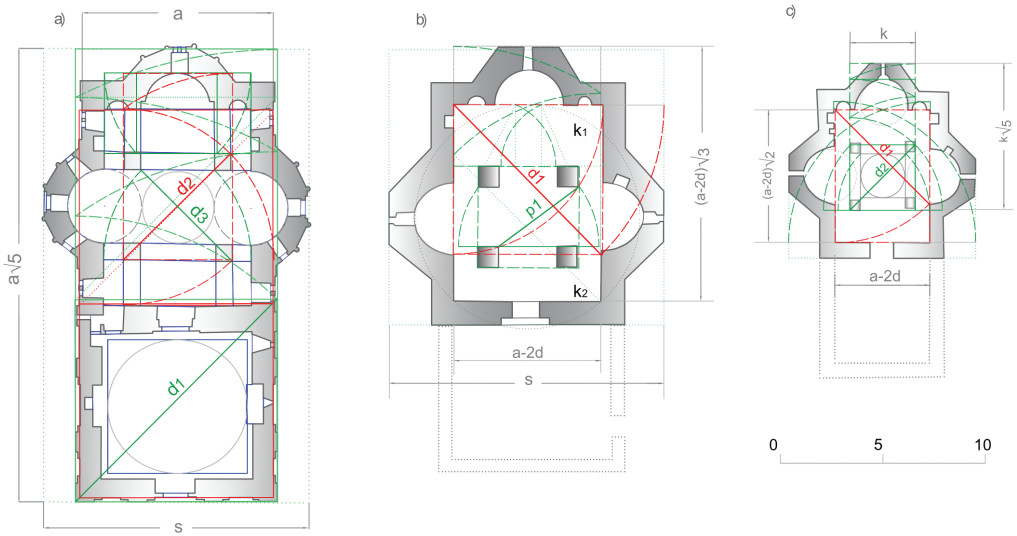

Fig. 6

common opinion that the proportioning was performed by the ratios expressed in integers, e.g. 3:5; 4:7[23] etc. Often applied modular approach, whereby the module is equal to a single of multiple measuring unit – "feet", or "elbow"[24], and which length varied from place to place, to the studies of proportions of Serbian medieval monuments, however, is not in contradiction to the methodology applied in this research. V. Ristić in his analysis of the proportions of Lazarica church proves that the operating module, equal to the length of a brick (28,2 cm), fits in the specific geometric concept, which applies dynamic rectangles, obtaining the ratios: 1:√2, 1:√3 and 1:√5[25]. The concept of dynamic rectangles was applied even to a rather simple architectural concept of the catholicon in Koporin monastery in the work of M. Radujko, in order to present corresponding harmony of the proportions applied on the church plan and the elevation[26].

Several results presented here regarding the application of dynamic rectangles on the plan and cross-section of the church in the Ljubostinja monastery are aligned with previous triangulation method of the proportioning. Namely, the diagonal ***a√2*** of the square, i. e. the basic shape overlapping the contour of the narthex, is rotated towards the side wall, thus obtaining the first dynamic rectangle, after which in successive repetition of rotations the final ratio of ***a√5*** is obtained. Here, ***a*** is the nave exterior width, while ***a√5*** is the total length of the church (Fig. 5a). The other regularity appears if rotating the diagonal $\boldsymbol{d_1}$ towards right side wall, while defining the boundary rectangle of the *naos* and small side apses of the altar space (*pastophoria*), thus obtaining the ratio ***(a–2d):(a–2d)√2***. Rotation of the diagonal $\boldsymbol{d_2}$ of a square that is defined by the total depth of the altar space (the rectangular part attached to the semicircular apse) reveals the geometric scheme behind the architectural disposition of its walls (Fig. 5a). Furthermore, the diagonals $\boldsymbol{d_3}$ and $\boldsymbol{d_4}$ of the central core are rotated towards horizontal (left/right side

23 N. Petrović, „Proporcije crkava u Caričinom gradu", *Starinar VII–VIII*, 1956–57, 169.

24 Đ. Bošković, B. Vulović, „Caričin grad – Kuršumlija – Studenica", *Starinar 23*, 1953, 177–178.

25 The value ***a*** is equal to the smaller dimension of the transept. V. Ristić, *Moravska arhitektura*, 71.

26 M. Radujko, *Koporin*, Beograd, 2006, 82–84.

walls of the *naos*) and vertical (frontal altar wall) positions, respectively, while defining the contours of the interior walls of the church (Fig. 5b).

The compatibility of the ground plan and cross-section proportioning is tested by rotation of square diagonals $\boldsymbol{p_1}$, $\boldsymbol{p_2}$, and $\boldsymbol{p_3}$, corresponding to the three width dimensions ***k***, ***s–2d*** and ***s***, respectively, towards the vertical position of the walls. The square which edge is ***s–2d***, determines the height of the core vaults, and simultaneously, by repetitive rotating its diagonal $\boldsymbol{p_2}$, $\boldsymbol{(s–2d)\sqrt{3}}$ geometry is obtained, due to the height of the dome cornice. Similarly, rotation of the diagonal $\boldsymbol{p_3}$, reveals $\boldsymbol{s\sqrt{2}}$ geometry, concerning the ratio of total width and cornice height. Rectangle ***5678***, defining the ratio of central core width ***k*** and the height of the tambour cornice, is in the proportion of a golden mean (Fig. 5c).

Geometric concept with dynamic rectangles is applied similarly on the ground plans of the Skopian churches in Kučevište and Rđavac. Beside geometric construction of the rectangle edging *naos*-interior and *apse*-exterior contours (ratio $\boldsymbol{a:a\sqrt{3}}$) of the church plan of Rđavac, rotations of the diagonals $\boldsymbol{p_1}$ and $\boldsymbol{d_1}$ define disposition of the interior and exterior wall contours respectively. The distance of the two columns (closer to the altar) from side walls is defined by the golden section ratio (Fig. 6b).The ground plan of the church in Kučevište, although significantly smaller in dimensions, shows several regularities. Dynamic rectangle obtained by successive rotation of diagonal $\boldsymbol{d_2}$ (diagonal of the central core), reveals the ratio of the length of the naos joined with apse (the distance from central core up to the exterior wall of the apse) and core width, i.e. the ratio $\boldsymbol{k:k\sqrt{5}}$. Interior dimensions of the church, without apses, are defined by rotation of the diagonal $\boldsymbol{d_1}$ towards the side wall of the naos, obtaining the ratio $\boldsymbol{(a–2d):(a–2d)\sqrt{2}}$. If added the radii of the smaller apse to the interior length, and rotated towards exterior contour of the conches, the new association of dimensions appears (Fig. 6c).

CONCLUSION

After thorough geometric analysis of the ground plan and cross-section through the dome of the church in Ljubostinja monastery, it can be stated that this church is very carefully designed with harmonic proportions of the spaces included in its architectural program.

The fact that Štambuk's canon, the specific construction consisting of the two circles and an equilateral triangle (mutually constrained), is successfully applied for the proportioning of the ground plan of the church, confirms the importance of this geometric construction, as well as the significance of the two geometric shapes: the circle and equilateral triangle in the context of designing Serbian medieval churches, regardless their architectural typology or groups. The setting of this shapes, related to the characteristic points of the church (center of the apse/dome), highlights their symbolic role regarding liturgical context of the church. The edge of the *holy* triangle corresponds to the interior width of the church, and the smaller circle defines the apse, while retaining defined constraints. Tangent of the two circles corresponds to the altar barrier, as well.

Similar results concerning Štambuk's construction are found for the two early Morava churches: catholicon of the monastery of Rđavac and the church of Sts. Archangels in Kučevište, where the main elements of the construction (the two circles and an equilateral triangle) define the key interior dimensions of the church ground plan.

Here applied geometric methodology for proportioning, that utilizes dynamic rectangles (successive rotations of diagonal of rectangle) resulted in several ratios confirming geometric regularities of the church design. The irrational ratios $1:\sqrt{2}$, $1:\sqrt{3}$ and $1:\sqrt{5}$, which appear while obtaining mutual relations of interior, or exterior dimensions of the separate spaces or the whole, point to the sophisticated sense and skills of the

masterbuilder or the architect, regarding proportioning. Namely, the three rectangles, recognized in the ground plan of Ljubostinja, share the ratio 1:√3, while determining spatial relations of the naos and altar, narthex and naos, as well as total dimensions (width/length) of the church. The same ratio of boundary rectangles of the naos and altar spaces (extended by their apses) share the two early Morava churches.

The shape of an equilateral triangle found multiple roles in proportioning of the church. Beside the rectangle, that of ratio 1:√3 and consisting of two equilateral triangles, previously elaborated, the sequence of the three equilateral triangles, resembling symbolically a "fish" shape, measures the distance of the church entrance wall to the center point of the apse. The unique equilateral triangle, inscribed in the interior of the church, such that its vertex coincides with the top point of the apse, while the opposite edge overlaps west wall edge of the naos (its width) and simultaneously defines exterior edges of the side conches. This regularity appears in each of the three ground plans of the analyzed churches, and points to the fact that determination of the key dimensions: interior length/ exterior width of the churches is performed in the same geometric manner.In these cases, equilateral triangle plays modular proportioning role.

An important geometric regularity concerns the relations of a central core (four columns bearing the dome structure) and side walls of the naos, as well as the altar wall. Rotation of diagonals of the central core, at Ljubostinja's ground plan, towards side walls leads to their interior and exterior edges. The same geometric regularity is applicable to the back wall of the altar space. Moreover, the same geometric constructions applied to the two early Morava churches of Rdjevac and Kučevište show similar results, although their builders did not achieve precision during construction, related to the parallel disposition of the walls and the symmetry of the ground floor plan.

The geometric proportional model of the church in Ljubostinja monastery point to architectural language used by Morava medieval master builders or architects. It is obvious that it is complex, as it revealssseveral ratios and key geometric shapes, but remains pure in its appearance and harmony of the spaces which it describes.

ILLUSTRATIONS

1: Canon for designing churches of I. Štambuk. Drawing: Magdalena Dragović, after Ivo Štambuk (in Zaboravljene proporcije: Kanon za projektovanje crkava, Prilozi istoriji otoka Hvara, XI, 2002). This is slightly revised figure 1a from Dragović et al. "Proportional schemas of Serbian medieval Raška churches based on Štambuk's proportional canon", Nexus Network Journal , 21(1), 2019, 38.
Канон за пројектовање цркава И. Штамбука. Цртеж: Магдалена Драговић, по Иви Штамбуку (у Заборављене пропорције: Канон за пројектовање цркаве, Прилози историји отока Хвара, КСИ, 2002). Ово је незнатно измењен цртеж 1а из рада Драговић и др. „Пропорционалне шеме српских средњовековних цркава рашког стила засноване на Штамбуковом пропорционалном канону", Nexus Network Journal, 21 (1), 2019, 38.
2: Proportions of the ground plan of the church in the Ljubostinja monastery: I. Štambuk's canon and additional triangulation. Drawing: Magdalena Dragović, after materials by courtesy of Republic Institute for Protection of Cultural Heritage of Serbia
Пропорције основе цркве манастира Љубостиња: канон И. Штамбука и додатна триангулација. Цртеж: Магдалена Драговић, према материјалима доступним љубазношћу Републичког завода за заштиту културног наслеђа Србије
3: Proportions of the ground plans of the three churches in Ljubostinja monastery (a), Rđavac (b) and Kučevište (c): the triangulation. Drawing: Magdalena Dragović, after materials by courtesy of Republic Institute for Protection of Cultural Heritage of Serbia and after Vladislav Ristić (in Moravska arhitektura, Narodni muzej, Kruševac 1996)
Пропорције основа три цркве – манастир Љубостиња (а) Рђавац, (b) и Кучевиште (ц): триангулација

Цртеж: Магдалена Драговић, према материјалима доступним љубазношћу Републичког завода за заштиту културне баштине Србије и Владислава Ристића (у Моравска архитектура, Народни музеј, Крушевац 1996)

4: Triangulation: the ground plan (a); cross-section (b) of the church structure
Drawing: Magdalena Dragović, after materials by courtesy of Republic Institute for Protection of Cultural Heritage of Serbia.

Триангулација: основа (a); пресек (b) структуре цркве. Цртеж: Магдалена Драговић, према материјалима доступним љубазношћу Републичког завода за заштиту културног наслеђа Србије

5: The application of dynamic rectangles construction on Ljubostinja's church: ground plans (a–b); cross-section (c)
Drawing: Magdalena Dragović, after materials by courtesy of Republic Institute for Protection of Cultural Heritage of Serbia

Примена конструкције динамичких правоугаоника на цркви Љубостиње: основе (a–b); попречни пресек (c)
Цртеж: Магдалена Драговић, према материјалима доступним љубазношћу Републичког завода за заштиту културног наслеђа Србије

6: Comparative application of dynamic rectangles construction on the ground plans: Ljubostinja (a), Rđavac (b) and Kučevište (c). Drawing: Magdalena Dragović, after materials by courtesy of Republic Institute for Protection of Cultural Heritage of Serbia and after Vladislav Ristić (in Moravska arhitektura, Narodni muzej, Kruševac, 1996)

Упоредна примена конструкције динамичких правоугаоника на плановима основа: Љубостиња (a), Рђавац (b) и Кучевиште (c). Цртеж: Магдалена Драговић, према материјалима доступним љубазношћу Републичког завода за заштиту културног наслеђа Србије и Владислава Ристића (у Моравској архитектури, Народни музеј, Крушевац, 1996)

LITERATURE

Бошковић, Ђ., *Архитектура средњеī века*, Научна књига, Београд, 1976.

Бошковић, Ђ., Вуловић, П., „Царичин град – Куршумлија –Студеница", *Старинар 23*, 1956–1957, 173–180.

Bogdanović, J., "Triconch Churches Sponsored by Serbian and Wallachian Nobility", in *Byzantium in Eastern Europe in the Late Middle Ages*, eds. M. A. Rossi and A. I. Sullivan, Leiden and Boston: Brill 2020, 167-199.

Чанак Медић, М., „Поступци старих неимара при пројектовању и извођењу грађевина", *Развој науке у области грађевинарства и геодезије у Србији*, Грађевинска књига, 1996, 29–50.

Ćurčić, S., *Architecture in the Balkans,* Yale University Press, New Haven, 2010.

Dragović, M., Čučaković, A., Bogdanović, J., Pejić, M., Srećković, M., "Proportional schemas of Serbian medieval Raška churches based on Štambuk's proportional canon", *Nexus Network Journal*, 21 (1), 2019, 33–58.

Dragović, M., Čučaković, A., Pejić, M., Srećković, M.,"The language of proportions in the parametric frame: Exquisite Serbian medieval churches of Raška style group", in the book of abstracts of *Int. Conf. "MoNGeometrija 2018"*, ed. V. Stojaković, 2018, Novi Sad, Serbia, 42.

Dragović, M., Čučaković, A., Bogdanović, J., Čičević, S., Trifunović, A. "Triangular proportional scheme and concept of the two Serbian medieval churches", in *Proceedings of ICGG Conf. on Geometry and Graphics*, ed. L. Cocchiarella, Milano, Italy, 2018, 677–689.

Ђурић, С., *Љубостиња – црква Успења Богородичиног*, Београд, 1985.

Millet, G., *L' ancien arte serbe. Les eglises*.Ed. E. de Boccard, Paris, 1919.

Mitrović, M. and Đorđević, Z., "Zloković's understandings of reciprocal catenuation", *Nexus Network Journal* 20, 2018, 187–213.

Ненадовић, С., *Грађевинске технике у средњевековној Србији*, Просвета, Београд, 2003.

Ozimić, N., „Simbolika ribe i hrišćanstvo", *Društvo za antičke studije Srbije,* Arhiv Srema, Beograd, 2008.

Петровић, Н., „Пропорције цркава у Царичином граду", *Старинар* 22, 1956–1957, 165–171.

Ристић, В., *Моравска архитектура*, Народни музеј, Крушевац, 1996.

Štambuk, I., „Zaboravljene proporcije: Kanon za projektovanje crkava", *Prilozi istoriji otokaHvara*, XI, 2002., 91–109.

Vežić, P., „Dalmatinski trikonhosi", *Ars adriatica* 1, 2011, 27–66.

Магдалена С. Драговић
Александар А. Чучаковић
Јелена В. Богдановић
Светлана Ј. Чичевић
Александар В. Трифуновић

ГЕОМЕТРИЈСКИ ПРОПОРЦИЈСКИ МОДЕЛ ЦРКВЕ МАНАСТИРА ЉУБОСТИЊА

Резиме: Употреба пропорција је једна од најстаријих теоретских тема у архитектури. Истраживачи интерпретирају пропорције радије нумерички – као однос два броја, него геометријски – као геометријску шему, или конструкцију, било да је примењена на основи објекта, пресеку или на његовом изгледу. Међутим, у неким случајевима, једино геометрија, са својим специфичним облицима и њиховим међусобним односима, може у потпуности да опише логику архитектонског пројекта. Овај рад приказује геометријске пропорцијске шеме цркве манастира Љубостиња (датиране око 1387), представника такозваног моравског архитектонског стила средњевековне Србије.

Истраживање је делом базирано на пропорцијском канону за пројектовање цркава Ива Штамбука, који је применио на неколико цркава у широј медитеранској регији, током дужег временског периода (4. до 15. век). Штамбуков пропорцијски канон базира се на геометријској конструкцији сачињеној од два круга и једног једнакостраничног троугла, повезаних међусобно и постављених у односу на карактеристичне тачке основе и попречног пресека цркве, пре свих, локације свете трпезе, у центру апсиде и центра главне куполе. Додајући принципе триангулације и динамичких правоугаоника, у овом раду се прецизније дефинише пропорцијски модел цркве Љубостиње, у основи и попречном пресеку кроз куполу. Резултати анализа показују да се пропорције цркве Љубостиње могу приказати помоћу динамичких правоугаоника (њихове дијагонале су величине квадратног корена целих бројева) у односима страна $1:\sqrt{2}$, $1:\sqrt{3}$, $1:\sqrt{5}$ и посебно, помоћу шеме једнакостраничних троуглова који су везани за карактеристичне тачке простора цркве: центре апсиде и главне куполе. Додатно, у раду је иста геометрија тестирана на још две преморавске цркве са сличним пропорцијама – Рђавац и св. Архангели у Кучевишту.

Кључне речи: средњевековне цркве, моравски стил, геометријске пропорције, триангулација, динамички правоугаоници.