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Research

Design and Tracing of Post-Byzantine Churches in the Florina Area, Northwestern Greece

Abstract. This paper constitutes an effort to investigate the application of specific design and constructional tracing in post-Byzantine churches situated in northwestern Greece, mainly in the wider area of the town of Florina and the Prespa Lakes, covering a period from the fifteenth to the nineteenth century. Firstly, a review of the relevant previous studies concerning the investigation of proportions and constructional tracing in Byzantine churches is presented. Secondly, a brief analysis of the metric systems of the Byzantine and the Ottoman period is given in order to define the applied modules. Furthermore, the typology of post-Byzantine churches is analysed. The main part of the paper includes the investigation of the constructional grid and the proportions in several plan drawings, in combination with the use of triangular tracing (right triangles). The analysis is also extended to façades and sections, in order to demonstrate the standardisation of the construction. Apart from the above, the application of the golden section in some examples is also examined. Finally, conclusions are drawn concerning the design and application of models and tracing on the construction of post-Byzantine churches.

1 Previous studies of tracing and proportion

The investigation of proportions and constructional tracing in Byzantine churches has been the object of many previous studies, both in Bulgaria and in Greece. In Bulgaria, concerning medieval churches, I. Popov [1955] investigated the proportions using diagonal tracing and squares (quadratura or ad quadratum), while G. Kozukharov [1974] used equilateral and right-angled triangles in order to explore circular and arched tracing. In Greece, N. K. Moutsopoulos [1956, 1963, 2010] applied geometrical tracing in sections of Byzantine inscribed cross-shaped churches and argued that there exist constructional tracings that define the proportions of their parts. Furthermore, K. Oikonomou [2003] analysed sections of Byzantine churches using diagonal and square constructional tracing (quadratura), while A. Prepis [2007] analysed plans of Serbian and Albanian post-Byzantine churches using diagonal circular tracing.

P. A. Rappoport [1995] analysed the building process of Russian Kievan churches from the tenth to the twelfth centuries, reported specific external dimensions (30x20 'belts' – measuring units) for these Byzantine monuments [Rappoport 1995: 163] and stated that:

> it has been supposed that the working system of a Kievan architect was based on geometrical constructions. However, in the absence of drawings, it is more likely that the dimensions of the building were determined arithmetically, in the form of simple proportional relationships, with linear measures as an initial unit' [Rappoport 1995: 167].

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Concerning Byzantine architecture between the ninth and fifteenth centuries, R. Ousterhout [1999] analysed the building methods of Byzantine master builders and emphasised on the use of modular systems based on the Byzantine foot and the existence of specific geometric ratios such as 4:3 and 2:1 [Ousterhout 1999: 80]. He characteristically states that "the application of geometry must begin with a system of measurement" [Ousterhout 1999: 75].

Apart from the above, B. Sisa analysed plans and sections of Protestant wooden bell towers in the Carpathian basin using as a starting point the medieval theory of the constructional principles of the circle-square-triangle,[1] which provides evidence that carpenters did not use drawings but applied these principles directly during the construction stage [Sisa 1990: 327]. Sisa's drawing analysis showed that these timber structures are based on a constructional grid with specified proportions [Sisa 1990: 338, 347].

Based on the afore-mentioned bibliographical review, it can be seen that apart from the studies by Ousterhout and Rappoport, who refer to specific module and dimensions in Byzantine feet, most of the other studies do not use or present a given module, but apply tracing of circles and diagonals which subdivide the façades or sections in smaller parts, without mentioning the use of the module.

This paper constitutes an effort to investigate the application of specific design and constructional tracing in post-Byzantine churches situated in northwestern Greece, mainly in the wider area of the town of Florina and the Prespa Lakes, covering a period from the fifteenth to the nineteenth century. The significance of the present study, in relation to previous ones that refer to the tracing of medieval churches, lies mainly on the detection of a specific construction module and certain metric models which were applied in churches of northwestern Greece, in combination with the use of constructional tracing based on the application of the Pythagorean Theorem.

2 Methodology

The starting point of this study is the author's Ph.D. thesis [Oikonomou 2007], which involved the analysis of the typological, morphological, constructional and environmental characteristics of forty traditional houses in Florina. An important part of this work was dedicated to the investigation of the application of the module in houses of the nineteenth century.[2] The research led to a scientific paper presented in Greece [Oikonomou and Dimitsantou-Kremezi 2009]. Afterwards, post-doctoral research conducted in the Laboratory of Architectural Form and Orders, N.T.U.A. School of Architecture, led to an extended paper presented in Turkey [Oikonomou et al. 2009] and a research article published in *Nexus Network Journal* vol. 13, 3 [Oikonomou 2011]. The research concerned the use of the module, metric models and triangular tracing in the traditional architecture of northern Greece.

The current work is a further extension of the above-mentioned approach to selected post-Byzantine churches in the Florina area. This investigation is based on the application of the constructional module (a modular grid) and triangular tracing to original or redrawn plans and façades of selected churches. A total of seven representative monuments from the prefecture of Florina were selected and analysed. These are situated in the wider Florina area (Vevi), the Prespa Lakes area (Laimos, Platy, Kallithea, Agathoto) and the Greek-Albanian borders (Moschohori and Krystallopigi). The aim of this analysis is to investigate the influence of the module and triangles on the standardisation of the design of the plans and façades, as well as on the construction.

Apart from the above, the plans of eighty post-Byzantine churches of Florina prefecture drawn by Moutsopoulos [2003] were analysed using the same methodology, in order to obtain a better understanding of the standardisation of plans, their proportions and constructional dimensions.

First of all, the typology of specific churches and the metric systems in use are analysed. The older monuments are small single-nave churches and their design is based on the Byzantine metric system (*foot*, *spithamai* and *orgyia*), whereas the most recent examples are three-aisled basilicas, where the design and construction is based on the Ottoman architect's cubit (*mimar arşin*). Consequently, the first part of the paper also presents these two specific metric systems and the module.

Afterwards, specific metric models that are used in the construction of the designated churches are presented and, at the same time, the use of triangular tracing is analysed. The constructional grid and the proportions of the perimeter are investigated in several plan drawings, as explained above.

The extension of the analysis to the churches' façades and sections shows that there is a standardisation concerning the placement of structural elements, such as the roof trusses and the horizontal wooden ties. It also reveals that constructional tracings exist, but only in the plan and its tracing on the ground, whereas the proportions of façades and heights derive from the consequent subdivisions and not from circular tracing. Nevertheless, it is shown that the design and construction of façades is aided by the use of right triangles.

The final part of the paper draws conclusions concerning the design and the tracing of post-Byzantine monuments, as well as proposals for further research, which may include older examples (before the fifteenth century).

3 Investigation of the application of the module and triangular tracing in the post-Byzantine churches of north-western Greece

3.1 The Byzantine and Ottoman metric systems

The Byzantine metric system was based on two different measures: the Byzantine *spithami* (handbreadth equal to 23.4 cm) and the Byzantine *foot* (31.2 cm). The spithami is divided into 12 *daktyloi* (fingers), whereas the foot is equal to 16 *daktyloi*. It should be noted that 4 spithamai are equal to 3 feet (93.6 cm). During survey and construction the master builders also used the *orgyia* (210.8 cm), which was usually a reed or stick divided into nine spithamai or 108 daktyloi [Ousterhout 1999: 60]. For land measurement, the *schoinion* (rope) equal to 10 orgyai, was used. Ousterhout notices that "the use of ropes suggests a similarity between the process of surveying and the process of laying out a building on-site" [Ousterhout 1999: 60].

The Byzantine metric measures were used by Christian master builders in the construction of churches not only during the whole Byzantine period, but also during the fifteenth and sixteenth centuries (first centuries of Ottoman domination) (see also [Bouras 2001: 242], concerning the similar architectural proportions during these periods).

The measuring of plots and the construction of buildings in the Ottoman Empire was based on the mimar arşin or architect's cubit. The arşin is divided into 24 *parmak*, or fingers; the finger is divided into 12 *hatt*, or lines; and the line is divided into 12 *nokta*, or points [Cerasi 1988: 92]. The arşin is also divided into two equal parts called *kadem* [Özdural 1988: 113].

The Ottomans used the architect's cubit from the beginning of the sixteenth century, though its precise measurement varied. A. Özdural [1988: 103] mentions that the imperial measuring unit was equal to 72.1 cm in 1520; 73.4 cm during the last quarter of the sixteenth century; and 76.4 cm during the third quarter of the eighteenth century. The architect's cubit of 75.8 cm was the fourth and final version, assigned as the imperial measuring unit by Selim III, during the years 1794-95; it remained in use until 1934, when it was replaced by the metre [Özdural 1988: 106].

The arşin, similar to the old English yard, was both an instrument and a measuring unit [Cerasi 1988: 92]. As an instrument, it was usually made of ebony, wood, bronze, copper or bone and could be folded into two (*kadem*) or four parts. As mentioned, it was subdivided into parts of 12 or 24 [Özdural 1988: 113].

3.2 The basic metric models

Based on the analysis of the plans, the monuments are divided into five basic categories:

i. Churches with plan proportions 3:2, where the tracing is based on two consecutive right 3-4-5 triangles (21 churches);
ii. Churches with plan proportions 4:3, where the tracing is based on one right 3-4-5 triangle (13 churches);
iii. Churches with plan proportions 1.618:1, 21:13 or 13:8, where the tracing is based on the golden section (√5+1:2) (5 churches);
iv. Churches with plan proportions 8:5, where the tracing is based on right triangles and circles (5 churches);
v. Churches with plan proportions 2:1, where the tracing is based on triangles and multiple circles (12 churches).

The metric models, which can be found in the post-Byzantine churches of north-western Greece, as well as in the wider Balkan area, are possibly based on rough plans *(skariphos)* [Ousterhout 1999: 62] that master builders widely used.

In the church architecture of the Florina area, the most common metric models that are observed are:

a. Church with a plan of 20x15 Byzantine feet (ratio 4:3);
b. Church with a plan of 24x16 Byzantine feet (ratio 3:2);
c. Church with a plan of 16x10 arşin (ratio 8:5);
d. Church with a plan of 24x12 arşin (ratio 2:1);
e. Church with a plan of 24x16 arşin (ratio 3:2);
f. Church with a plan of 32x20 arşin (ratio 8:5).

All the above numbers refer to the exterior dimensions of the plan. At this point, a standardisation concerning the interior dimensions should be noted. This is closely related to the standard thickness of the walls, which is 3 spithamai or 1 arşin. For instance, a church with exterior dimensions 20x15 Byzantine feet (app. 26 x 20 spithamai) and walls that are 3 spithamai thick, has interior dimensions 20 x 14 spithamai.

Finally, it should be noted that the metric system of the Byzantine foot or the architect's cubit is also applied to the churches' façades, where, similar to the plans, a standardisation of sizes is also observed. The total height of small churches (fifteenth-sixteenth centuries) without the roof (pediment) is usually 9 or 12 Byzantine feet. In contrast, during the eighteenth and nineteenth century, large basilicas with a total height of 9 or 12 arşin are constructed.

3.3 The use of triangular tracing

The metric models that are analysed contribute to the standardisation of the construction of the post-Byzantine church. Most of the churches presented have a fully rectangular plan. At the same time, the constructional module is applied accurately, not only in the placement of the basic wooden structural elements and the openings, but also in the dimensions of the spaces. All the above lead to the conclusion that before the construction of the church, certain basic architectural tracing, which assumes basic knowledge of geometry, took place.

For the tracing of the rectangular perimeter of the church and its main walls, the Pythagorean Theorem with the basic right-angled triangle 3-4-5[3] is applied with the use of knotted ropes. Stoichkov has proven that master builders in Bulgaria used the 3-4-5 triangle during the eighteenth and nineteenth centuries [Stoichkov 1977: 126, 145]. It is also mentioned that "the masters of Bratzigovo … traced their plans directly on the site, which would sometimes result in harmonic relation and even in golden rule proportions" [Cerasi 1988: 93].[4] Furthermore, Cerasi mentions that "the analysis of plans and elevations of buildings by Balkan masters has shown the existence of proportions and tracing inscribed in circles" and also notes that the use of long leather strips in Bulgaria for the measuring and tracing on the site encourages circular and diagonal tracing [Cerasi 1988: 95].

The same methods certainly apply in northwestern Greece during the eighteenth and nineteenth centuries, but also during the whole post-Byzantine period. Ousterhout characteristically states for the construction of churches in Western Europe that "to lay out a building, one simply had to *know the ropes*" [Ousterhout 1999: 60].

The 3-4-5 triangle can be multiplied by various factors to produce triangles of the necessary dimension; thus multiplication by a factor of 2 produces the 6-8-10 triangle; by a factor of 3, 9-12-15; by a factor of 4, 12-16-20; by a factor of 5, 15-20-25; and so forth. Furthermore, the use of circular auxiliary tracing can not be ruled out, especially in the case of churches that have a plan with a ratio of 13:8. These numbers are related to the subdivision of a line with a length of 13 into two parts with lengths of 8 and 5 (extreme and mean ratio) and the Fibonacci series [see Konstantinidis 1961: 190-191].

The following diagrams include observations concerning the various metric models and their way of tracing (fig. 1). In this way, the relationship with the above-mentioned, characteristic right-angled triangles is investigated and conclusions concerning the possible tracing of the churches' walls and their design can be drawn.

At this point it is useful to cite the definition given by Jouven concerning the (harmonic) tracing:

> A harmonic trace is a geometric figure whose design coincides with the main lines of a building (or what amounts to the same, its graphic representation in geometrical projection). The choice of this geometric figure, conceived at the same time as the building by the architect, is based on the remarkable properties that are included in it [Jouven 1951: 7].

Jouven also explains:

> We mean by main lines those whose knowledge is sufficient to determine the elements of construction (perimeter, axes, lines of change, etc.). We can say in a quick way that they are the main lines of a first rough drawing of the building" [Jouven 1951: 7].

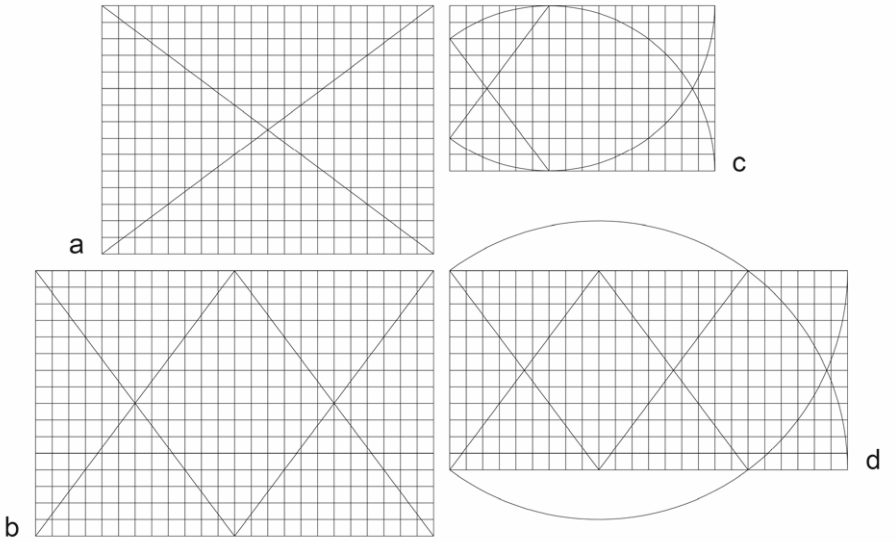

Fig. 1. Use of the module and triangles 6-8-10, 9-12-15, 12-16-20, 15-20-25

We must bear in mind that the tracing of the perimeter and the elements of the church's upper part (dome, roof or upper storey) is also made on the ground, and the construction is based on the specific grid and module (foot or architect's cubit). This can result in a rather complex triangular tracing, without necessarily meaning that the diagonals are in fact traced on the ground: only the corners of the church walls are marked by small stones and then the plan is laid out with knotted ropes [Ousterhout 1999: 60]. A stone is placed the centre of the altar and uncut stones mark the four corners. Then, the master architect traces the plan with the use of a measuring instrument and finally the perimeter of the church is marked with a help of a cord. [Rappoport 1995: 162]

In this way it is impossible to find any sign or mark of the presented tracings as they were made on the ground before the churches were actually built. Nevertheless, master builders often used on the façades circumscribed symbols like the five-pointed star (pentalpha), the six-pointed star (double triangle) and the double square. It is a scientific question if these symbols are in any way related to any possible geometrical tracing on the ground, or if they stand for other purposes.

3.4 Building typology

The basic building type of the post-Byzantine churches of the fifteenth and sixteenth centuries is that of the single-nave church *(monohoros dromikos)*, whereas in the eighteenth and nineteenth centuries, the type of the single-nave church with portico and the type of the three-aisled basilica *(trikliti basiliki)* are commonly used in the wider Balkan area. Christians were not allowed to build churches of great size, nor to use marks and signs such as the cross. As a result most of the post-Byzantine churches have a small size and many of them resemble to houses or farmhouses (see also [Bouras 2001: 267]).

This prohibition of building grand churches by the Christians concerns mainly the towns and villages that were predominantly inhabited by Muslims. Nevertheless, between the sixteenth and the eighteenth centuries, important churches in terms of size and

intentions, of the Athonite cross-in-square type, have been built in monasteries [Bouras 2001: 279].

It was only after the first Ottoman Tanzimat Reform (Hati Serif of Giullhane - 1839) that Christians throughout the Empire were widely allowed to build large basilicas and to use the sign of the cross on the façades, although there are some exceptions built in the eighteenth century, in areas like Voio, Zagori and Pelion [Bouras 2001: 284-285].

4 Presentation of the study

4.1 St. Nikolaos in Vevi (1460)

St. Nikolaos church in Vevi (Banitsa) is a small single-nave church covered with a timber roof, which was built, according to the founder's inscription, in 1460 [Subotić 1980: 86-94].

The analysis of the plan and its comparison with other churches of the same period that can be found in the wider area, reveal a series of important data. The plan is inscribed in a rectangle with proportions 3:2 and mean dimensions around 7.50 x 5.00 m. (24 x 16 Byzantine feet of 31.2 cm). The constructional tracing of the walls is probably based on the use of two right-angled triangles (12-16-20) placed consecutively (fig. 2), while the 6-8-10 triangle (in spithamai) is most likely used for the tracing of the apse and the recess (fig. 3). The mean internal dimensions of the church are 5.40 x 3.50 m (23 x 15 Byzantine spithamai).

It is noted that the tracing includes the three-sided apse, whereas in churches with semi-circular protrusions (see §§ 4.2-4.3), the tracing of the perimeter does not incorporate the recess. The deviation of the northern wall from the traced perimeter is most likely to be attributed to a constructional error. Thus only the southern and eastern walls are perpendicular, whereas the shape of the plan is slightly asymmetrical.

The height of the western façade up to the roof level is equal to 12 Byzantine feet, while the total height including the pediment is 16 Byzantine feet, because the roof height is 4 Byzantine feet. In this way, the western façade is inscribed in a square with dimensions 16 x 16 feet. The design of the façade is aided by the use of two 12-16-20 triangles (fig. 4).

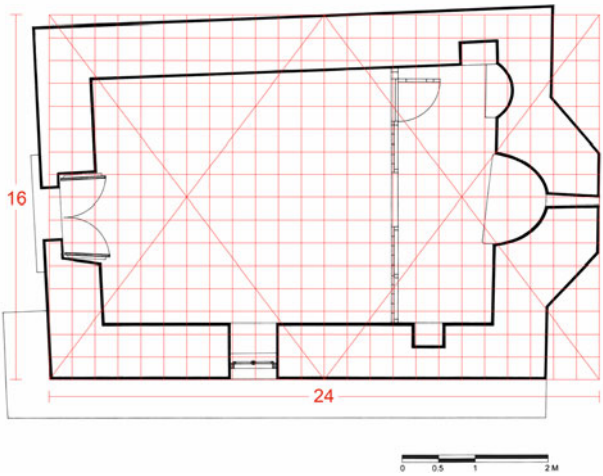

Fig. 2. St. Nikolaos in Vevi. Plan (Byzantine feet grid)

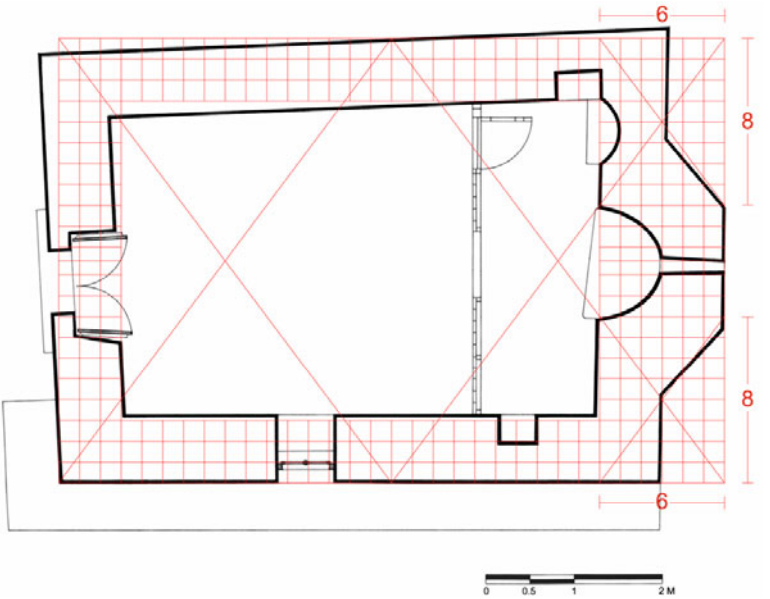

Fig. 3. St. Nikolaos in Vevi. Plan (Byzantine spithamai grid)

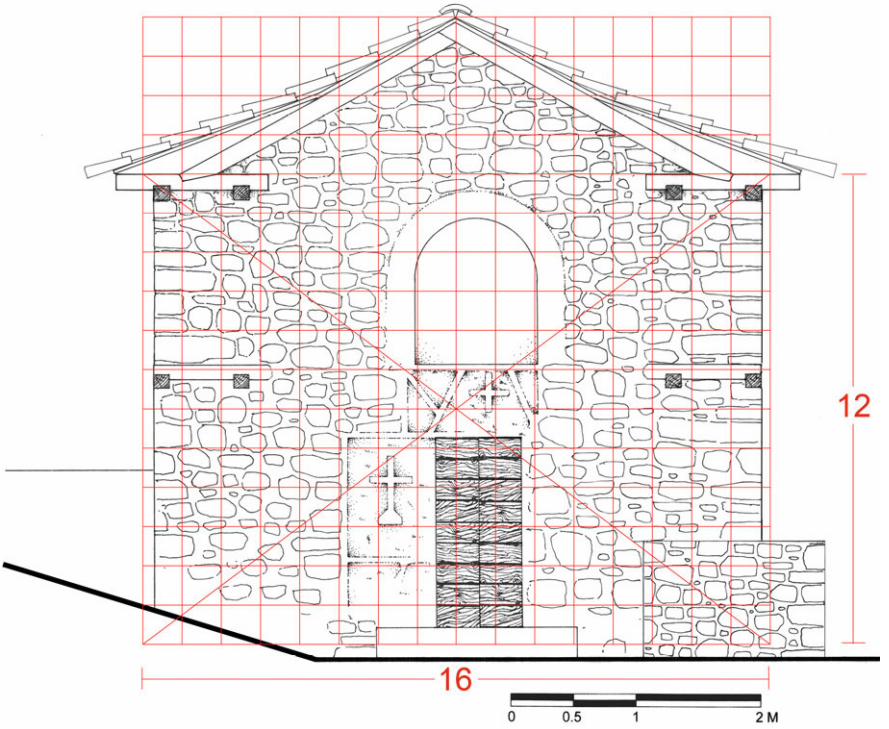

Fig. 4. St. Nikolaos in Vevi. Western façade (Byzantine feet grid)

As far as the construction of the church is concerned, the analysis of its structural elements also leads to interesting findings. The wall thickness is 70 to 75 cm, equal to approximately 3 Byzantine spithamai of 23.4 cm or 1 Ottoman arşin of 72.1 cm (sixteenth century). The wooden ties are placed at a height of approximately 1 Byzantine orgyia of 210.8 cm, while there is a second pair of wooden ties placed at the roof level, at a height of 12 Byzantine feet (375 cm) from the floor (fig. 5). The use of visible wooden ties is typical in small Byzantine and post-Byzantine single-nave churches.

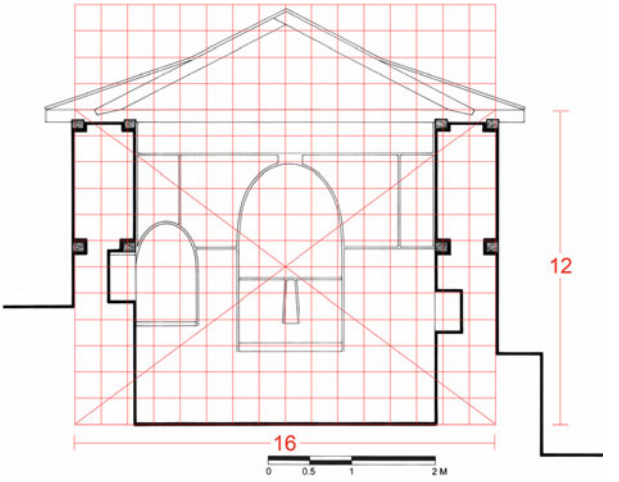

Fig. 5. St. Nikolaos in Vevi. Section (Byzantine feet grid)

The trusses follow a certain module and are placed at approximately 93 cm (3 feet of 4 spithamai) intervals. This standardisation, in combination with the particular internal dimensions of the plan, lead to the conclusion that in St. Nikolaos in Vevi, the original roof must have been composed by nine trusses with a height of 125 cm. This hypothesis is confirmed by the coincidence of these trusses with the zones of the internal paintings on the northern wall. The construction is aided by the use of two circles with radius 12 feet and two triangles 12-16-20 (fig. 6).

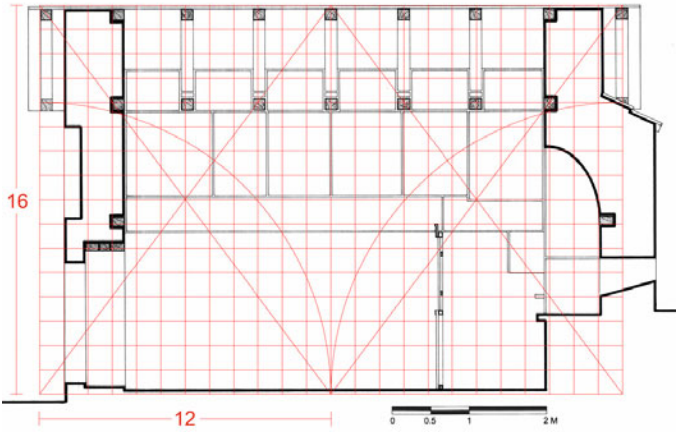

Fig. 6. St. Nikolaos in Vevi. Longitudinal section (Byzantine feet grid)

4.2 Ypapanti in Laimos (fifteenth c.)

The church of Ypapanti in Laimos (Rombi), during its first phase (fifteenth century) [Moutsopoulos 2003: 122], had a plan with similar external dimensions (7.35 x 4.95 m or 24 x 16 feet) to Ag. Nikolaos in Vevi. The tracing of the perimeter is probably based on the use of two consecutive 12-16-20 triangles. The intersection of the diagonals and the triangular tracing coincides with the beginning of the different level of the bema (fig. 7). It is also interesting to note that in another church, that of St. George in Kallithea [Moutsopoulos 2003: 133], the dimensions of the rectangular plan are similar. The external dimensions are 7.45 x 5.00 m or 24 x 16 Byzantine feet, while the internal dimensions are 5.60 x 3.50 m or 24 x 15 Byzantine spithamai. The church of Prophet Elias in Achlada [Moutsopoulos 2003: 188] has also the same plan dimensions (7.50 x 5.00 m or 24 x 16 Byzantine feet), despite the fact that it was built during the seventeenth century.

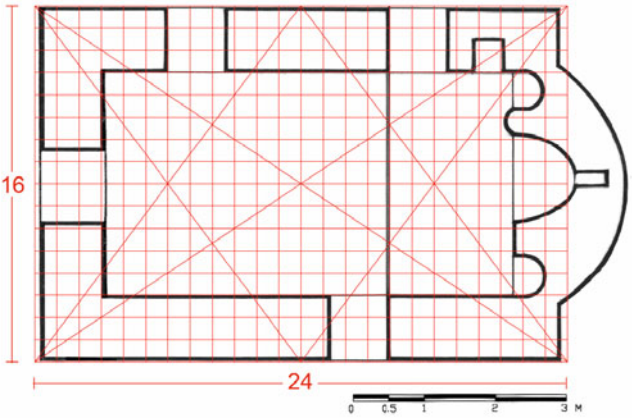

Fig. 7. Ypapanti in Laimos. Plan (Byzantine feet grid)

4.3 St. Nikolaos in Platy (1591)

The church of St. Nikolaos in Platy (Styrkovo) dates back to 1591 [Moutsopoulos 2003: 110-111] and has a plan similar to the above-mentioned churches, except that in this case, the proportions of the plan are 4:3; the external dimensions are equal to 6.20 x 4.70 m (20 x 15 Byzantine feet) and the apse protrudes by 1.00 m (3 feet).

The tracing of the plan is probably based on the use of the 3-4-5 right-angled triangle (multiplied by a factor of 5 to produce a triangle measuring 15-20-25) (fig. 8). The mean internal dimensions of the church are 4.70 x 3.25 m (20 x 14 Byzantine spithamai) (fig. 10).

The form of the church, which is characterised by the simplicity of its facades, is not very different from the form of the rest of the churches that belong to the same building type. The church has a symmetrical western façade with the entrance placed in its centre and a blind arch with traces of the image of the patron saint above it, while the roof forms a pediment. Nevertheless, the difference in the heights is very interesting, because the height of the western façade up to the roof level is in St. Nikolaos in Platy equal to 2.80 m (9 Byzantine feet), whereas in St. Nikolaos in Vevi it is equal to 12 Byzantine feet. The design of the façade is aided by the use of two circles with a radius of 9 feet and two 9-12-16 triangles (fig. 9).

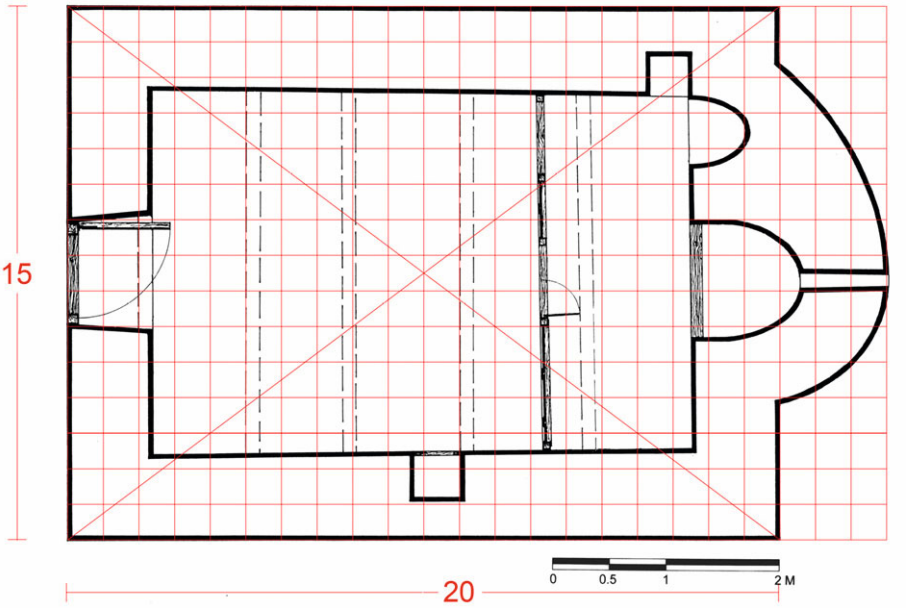

Fig. 8. St. Nikolaos in Platy. Plan (Byzantine feet grid)

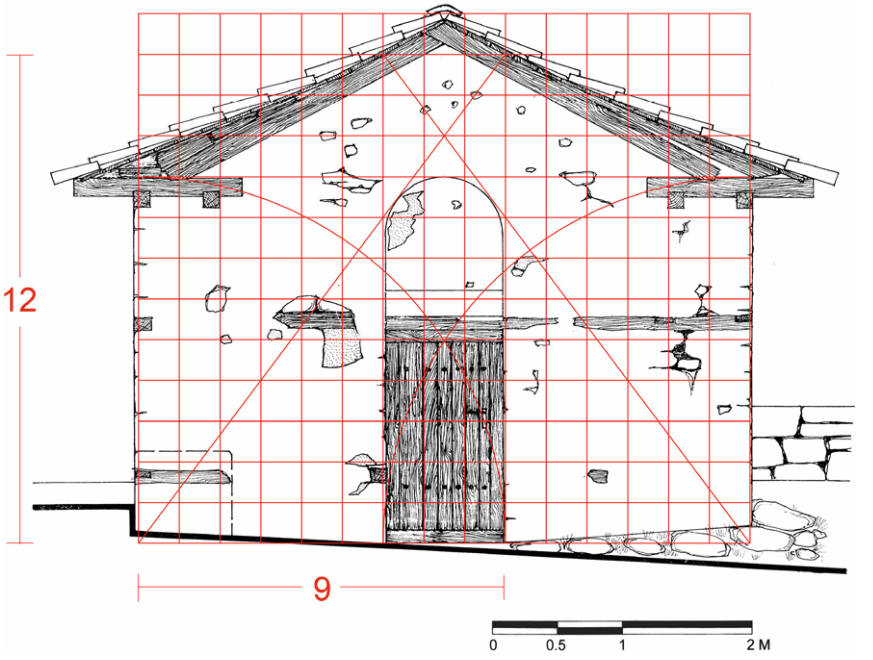

Fig. 9. St. Nikolaos in Platy. Western façade (Byzantine feet grid)

In St. Nikolaos in Platy, there exists an ingenious structural roof system of truss without posts inside, while on the outside there aren't any tie beams, and the principal rafters are supported on parts of horizontal beams, which rest in turn on the protruding wooden ties. The truss, which is repeatedly used, thus consists of the tie beam that protrudes from the side walls, the two principal rafters that are supported on the middle of the walls and two long wooden chamfers, which change the roof slope at its middle and form, together with the tie beam, the roof eaves *(astreha)*. The trusses are supported on the perimetric wooden ties on both sides of the wall. The trusses follow a certain module and are placed at approximately 93 cm (3 feet of 4 spithamai) intervals (fig. 10). In this way, there are four trusses in the interior, two in the inner side of the walls and two in the exterior (fig. 11).

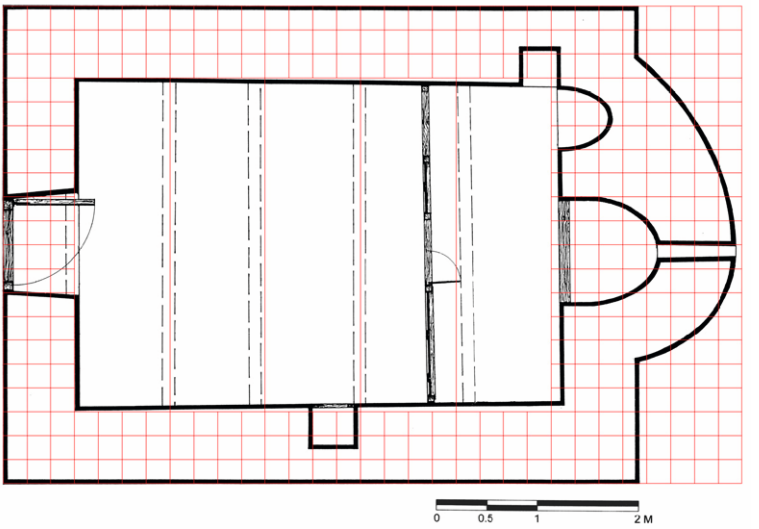

Fig. 10. St. Nikolaos in Platy. Plan (Byzantine spithamai grid)

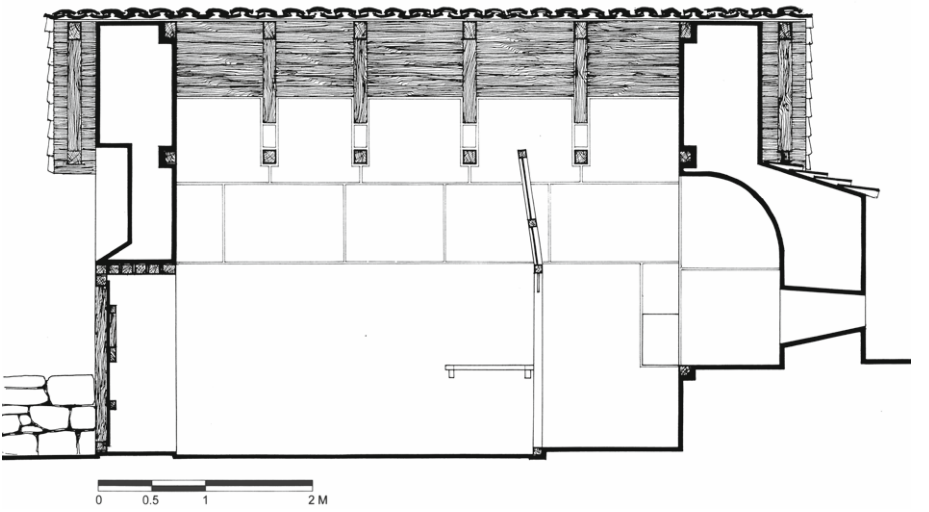

Fig. 11. St. Nikolaos in Platy. Longitudinal section

4.4 St. Athanasios in Kallithea (nineteenth c.)

The church of St. Athanasios is situated on a hill, to the northwest of the village Kallithea (Roudari) in the Prespa Lakes area [Moutsopoulos 2003: 128-129]. It is a small single-nave church with a wooden roof and an inverted L-shaped portico on its western and northern side. It was probably built during the nineteenth century. Two distinct constructional phases can be discerned: first, the nave was built and to this, an outer narthex was added, forming a portico in the southern side of the church.

The external dimensions of the main church are 910x560 cm (12x7.4 arşin). Its constructional tracing is most probably based on the golden section (fig. 12). This hypothesis provides an explanation for the fact that the width of the church is not a rational, but an irrational number [24/(√5+1)]. It is also interesting to note the circular rosette with two overlapping five-pointed stars (symbols closely linked to the golden section and the Pythagorean philosophy), on the centre *(omfalos)* of the initial wooden roof of the main church (fig. 13).

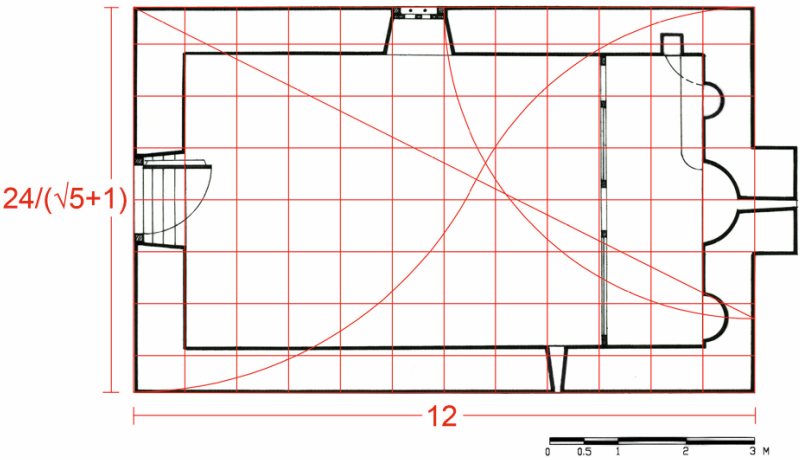

Fig. 12. St. Athanasios in Kallithea. Plan (Arşin grid). Redrawn from a plan by Achilleas Stoios

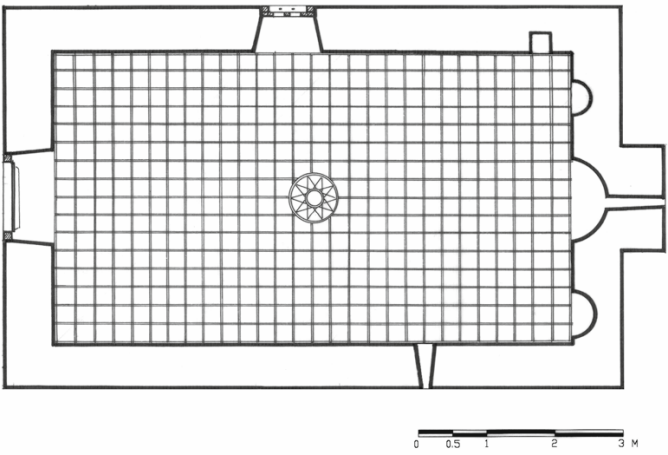

Fig. 13. St. Athanasios in Kallithea. Reflected ceiling plan

4.5 St. Georgios in Agathoto (1869)

The church of St. Georgios is situated in the abandoned village of Agathoto (Tyrnovo), in the Prespa Lakes area, near the Greek-Albanian border [Moutsopoulos 2003: 114-116]. It is a small single-nave church with a wooden roof and an inverted L-shaped portico on its western and northern side, which dates to 1869, according to the stone engraving over the western entrance (fig. 14). On the eastern façade there is a second stone engraving with a cross and a six-pointed geometrical rose (fig. 15). The church was most probably built in one phase.

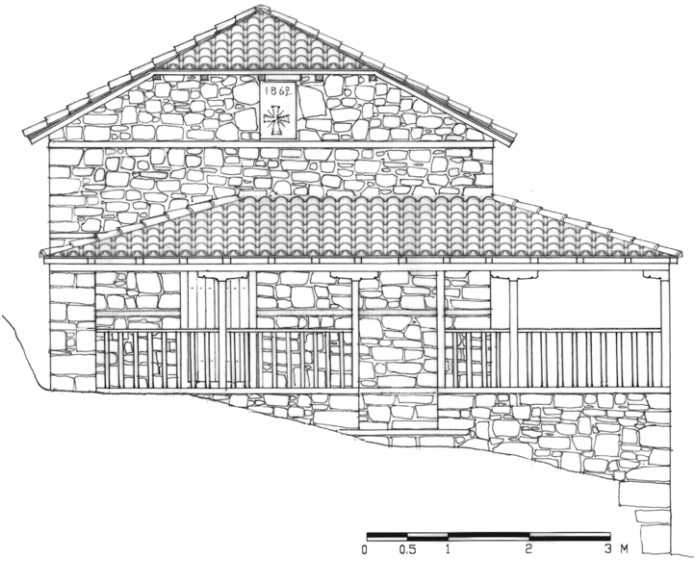

Fig. 14. St. Georgios in Agathoto. Western façade. Redrawn from an elevation by Achilleas Stoios

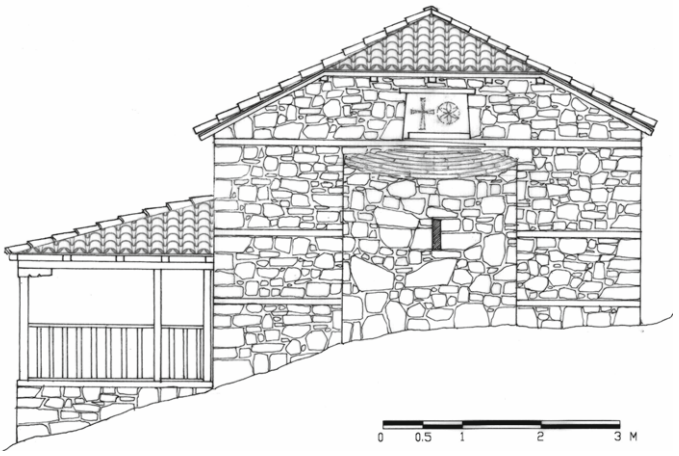

Fig. 15. St. Georgios in Agathoto. Eastern façade. Redrawn from an elevation by Achilleas Stoios

The external dimensions of the church together with the outer narthex are approximately 1212x758 cm (16x10 arşin), while the main church has dimensions 985x530 cm (13x7 arşin). The constructional tracing of the church perimeter including

the portico, is based on two circles with a radius of 10 arşin (vesica pisces) and two 6-8-10 right-angled triangles (fig. 16). The triangles help to trace the western entrance, while the division of the length into 6 and 10 arşin coincides with the interior partition of the place set apart for women. The main space of the church is traced with the use of a circle with a 7-arşin radius.

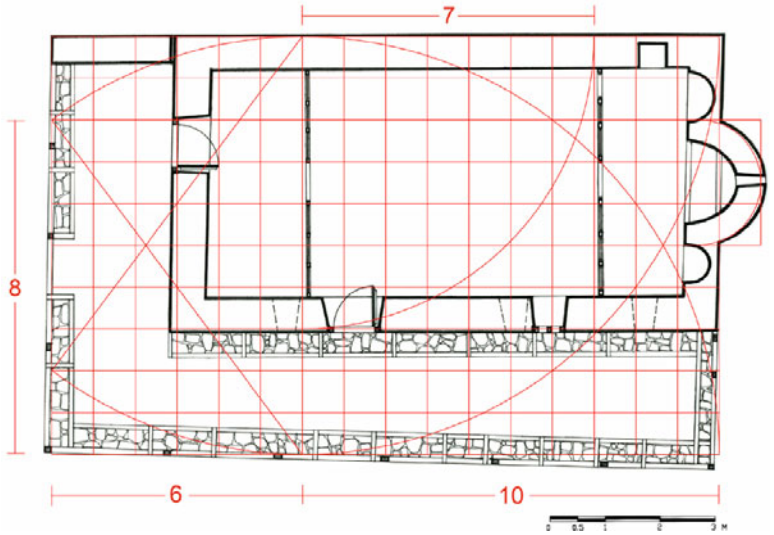

Fig. 16. St. Georgios in Agathoto. Plan (Arşin grid). Redrawn from a plan by Achilleas Stoios

4.6 St. Dimitrios in Moschohori (1871)

The settlement Moschohori (Vambeli) is situated near the Greek-Albanian border, at a distance of fifty kilometres from the town of Florina. St. Dimitrios is a large church, pertaining to the type of the three-aisled basilica, which was built, according to the stone lintel of the entrance, on 1871 [Moutsopoulos 2003: 310]. Its roof has sustained serious damage, which resulted in its collapse on 1965, leading in turn to the destruction of the church's interior. The church had a raised place set apart for women (*gynaikonitis*), located in its western part. The quality of the stonework and the joint-fillings leads to the conclusion that the church was built by an important company of builders (*esnafi*), probably coming from the villages of Voio or those of Epirus. The openings have stone frames and stone arches on their upper part. On the western façade, there existed a stone cross at the upper part, and on the entrance a portico, supported by stone pillars. On the eastern façade, there existed a circular rose window with a twelve-pointed star and two stone cypress trees on its sides, on the pediment over the apse. All these stone parts have fallen in the interior of the church, along with many of the wooden columns that supported the roof and formed the aisles. In the interior of the church, an important part of the mortars and finishes are saved, while the zones of the mezzanine and the raised part for women can also be discerned.

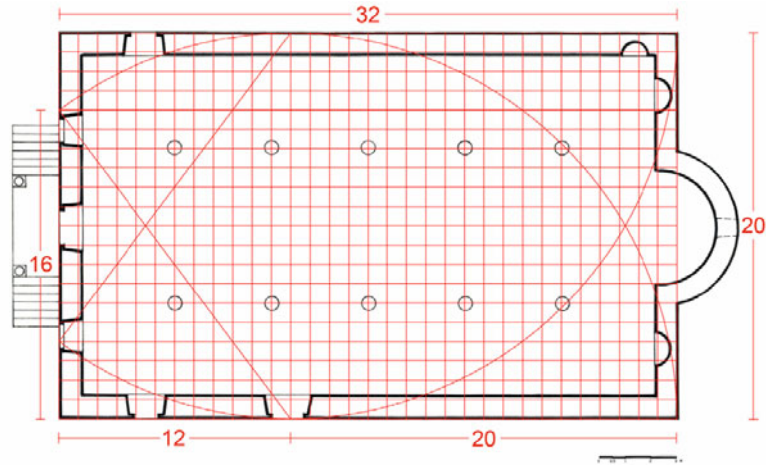

Fig. 17. St. Dimitrios in Moschohori. Plan (Arşin grid)

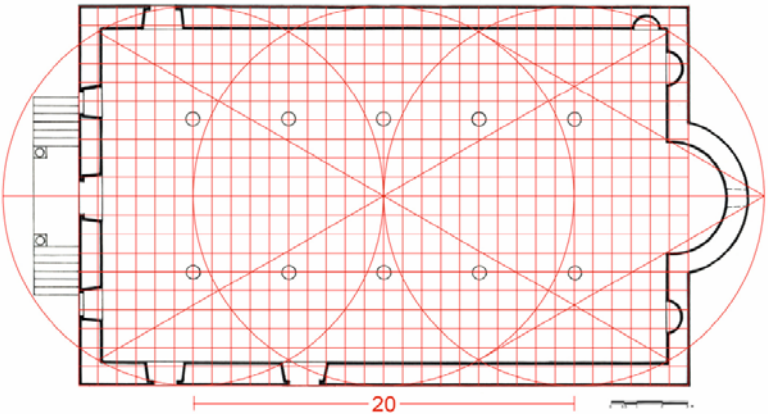

Fig. 18. St. Dimitrios in Moschohori. Plan (Arşin grid)

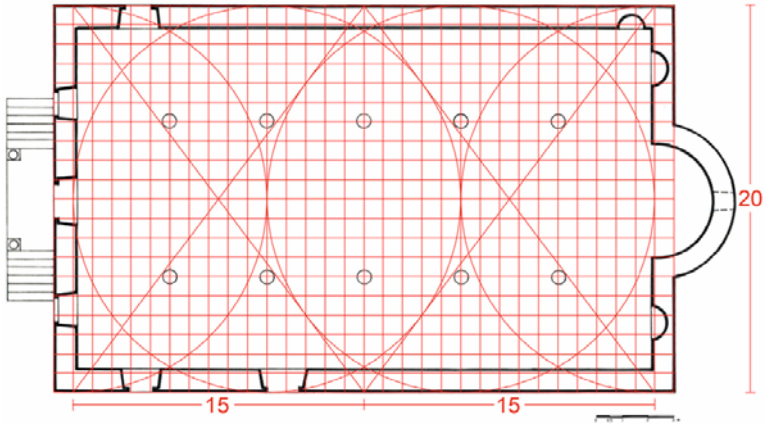

Fig. 19. St. Dimitrios in Moschohori. Plan (Arşin grid)

The plan of the church has external dimensions of approximately 2390x1494 cm (32x20 arşin), while the tracing of the external perimeter is probably based on the use of two circles with a radius of 20 arşin (vesica pisces) and two 12-16-20 right-angled triangles (fig. 17). The centre of one of the circles coincides with the middle of the main, southern entrance, while in the eastern part the circles define the points of the genesis of the apse recess. The tracing of the walls is most probably based on the use of three circles with a radius of 10 arşin (ad triangulum),[5] because their section defines the internal side of the walls (fig. 18). The triangle that is formed in the eastern part also defines the recess. At the same time, two consecutive 15-20-25 triangles and circles with a diameter of 20 arşin define characteristic points of the plan, as the columns and the internal perimeter (fig. 19).

4.7 St. Georgios in Krystallopigi (1891)

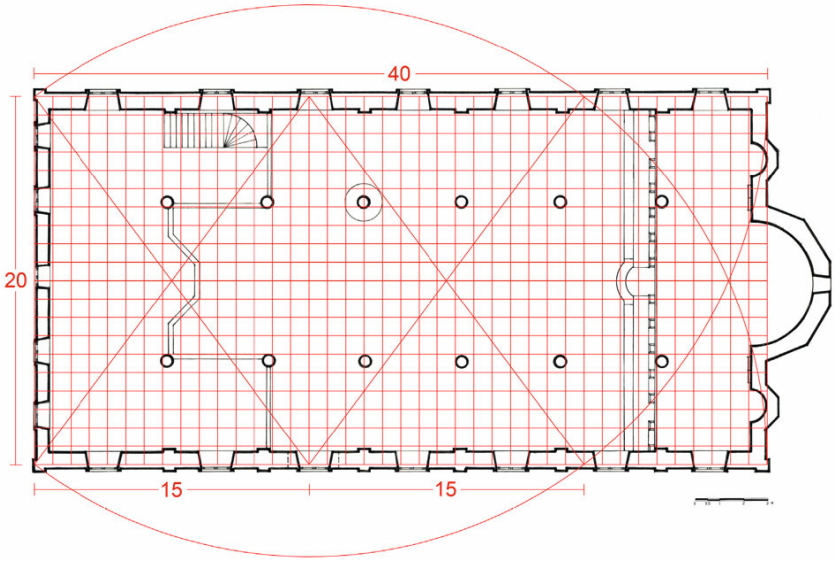

Fig. 20. St. Georgios in Krystallopigi. Plan (Arşin grid)

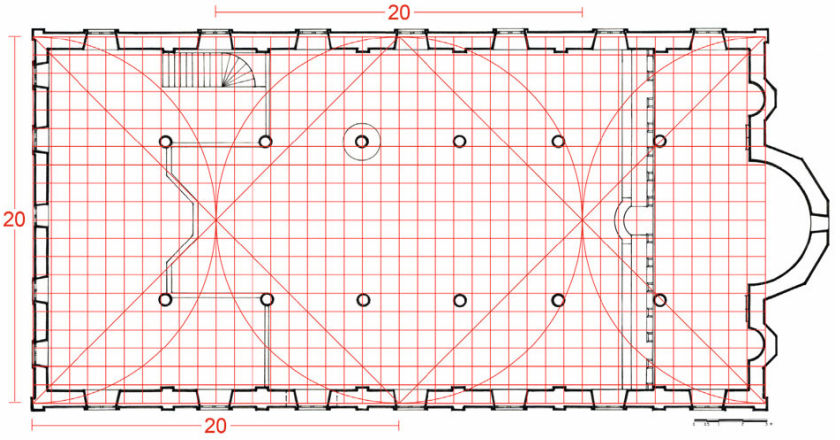

Fig. 21. St. Georgios in Krystallopigi. Plan (Arşin grid)

Krystallopigi (Smardesi) is situated near the Greek-Albanian border, at a distance of approximately fifty kilometres from the town of Florina. St. Georgios church is situated east of the existing settlement, in the place of the initial settlement that was destroyed during the Greek civil war.

It is a large three-aisled basilica with narthex [Moutsopoulos 2003: 309]. In the central axis of the western façade there is a bell-tower. On the same façade, there is a stone engraving with a pediment stating the date, 1891. The church has sustained many interventions on all its facades, which are evident from the different qualities of the stonework and it also has a more recent roof. The openings have stone neoclassical frames, whereas at the corners of the western façade is found a particular form of dressed corner stones, which is reminiscent of Renaissance prototypes. In the interior of the church, there still exists the raised level of the place set apart for women, which is reached by a staircase ar the northern part of the entrance.

The church plan has external dimensions of approximately 3005x1523 cm (40x20 arşin), while the tracing of the external perimeter is based on two circles with radius of 25 arşin and four 15-20-25 right-angled triangles (fig. 20). The centre of one of the circles coincides with the middle of the initial, main southern entrance, while in the eastern side the circles define the points of the genesis of the apse recess. The tracing of the walls and the upper storey is most probably based on the use of three circles (fig. 21) with a radius of 10 arşin (ad quadratum).[5]

5 Conclusions

In this paper, the application of metric proportions and tracing has been investigated in selected examples of post-Byzantine churches in northwestern Greece. This has made it possible to identify certain metric models and building types that were commonly applied, together with the triangles used in their tracing.

In the wider Florina area and in the Prespa Lakes region during the fifteenth century, the building type of single-nave church and the same plan (model 16x24 feet) is applied to more than one case (St. Nikolaos of Vevi, Ypapanti in Laimos) and can also be found in more recent examples (St. Georgios in Kallithea). During the sixteenth century, a different metric model (model 15x20 feet) is applied in some cases (St. Nikolaos in Platy), while the dominant building type remains the same.

The typological similarities of St. Nikolaos in Vevi with the fifteenth century churches, such as Ypapanti in Laimos, and with more recent monuments of the sixteenth century, such as St. Nikolaos in Platy, actually reveal the spreading and the prevalence of this certain building type, that of the single-nave church, in the wider area during the first centuries of Ottoman domination. From all the afore-mentioned data, it can be concluded that there existed a certain design model or prototype, which was followed in more than one instance [Mamaloukos 2003].

Later on, during the eighteenth and nineteenth centuries, the type of single-nave church with portico prevails (St. Athanasios in Kallithea and St. Georgios in Agathoto) and the metric models that are applied are different from the previous ones (model 12x7.4 arşin and model 16x10 arşin). During the nineteenth century were built basilicas that have plan dimensions 24 x 12 arşin and 24 x 16 arşin. Finally, at the end of the nineteenth century, the three-aisled basilica is the most common type (St. Dimitrios in Moschohori and St. Georgios in Krystallopigi) and the plans follow the models 32x20 arşin or 40x20 arşin. From the above, it can be seen that the size – as well as the plan ratio – is constantly changing and becoming larger. Thus the ratios go from 3:2 and 4:3

(fifteenth-sixteenth centuries), to 1.618:1 and 8:5 (eighteenth-nineteenth centuries), to 2:1 (end of the nineteenth century).

Another important finding is that the tracing of post-Byzantine churches of the fifteenth and sixteenth centuries, is based on the Byzantine foot and spithami, whereas in the majority of the other presented examples (eighteenth and nineteenth centuries), the Ottoman arşin is used. This rather important finding is explained by the fact that during the first centuries of Ottoman rule, the Christian master builders carried on the Byzantine building tradition, while the Balkan master builders of later centuries were occupied also in other important buildings as mosques and Ottoman baths (hamams).

Concerning the use of triangular tracing, it should be noted that during the whole post-Byzantine period, the basic triangle 3-4-5 and its transformations (multiplied by factors of 2, 3, 4 and 5) is used for the tracing of the perimeter. Nevertheless, changes in the building types and the dimensions of the plan resulted in significant changes in the use of orthogonal triangles. During the fifteenth century, two consecutive 3-4-5 right triangles are applied, whereas in the sixteenth century, the perimeter of the plan is traced with the use of one right triangle. In contrast, during the eighteenth and nineteenth centuries, the design and tracing are based not only on the 3-4-5 right triangles, but also on circles. The ad-triangulum[5] system is probably used in these churches. Last, but not least, in some examples (St. Athanasios in Kallithea), the tracing is based entirely on the golden section ($\sqrt{5}+1$: 2) and the resulting width of the plan equals an irrational number.

From the above, it can be seen that the choice of certain basic models/prototypes and triangles is directly linked to the application of the predominant building types during the different periods (small single-nave church, church with a portico and large three-aisled basilica) and largely affects the form and the proportions of the churches.

Further research should include a larger number of monuments from the wider Balkan area, including Byzantine churches of the twelfth, thirteenth and fourteenth centuries, pertaining to different types. In that way, the principles and the proportions of the Byzantine and Post-Byzantine monuments can be derived and similarities and differences between the various types noted.

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The author would like to thank Arch. Eng. Achilleas Stoios, for providing some of the original plans of post-Byzantine churches of the wider Prespa area, Prof. Stavros Mamaloukos (Dr. Arch. Eng.) for his valuable scientific advice concerning the design and construction of Byzantine and post-Byzantine churches, and also the 16th Ephorate of Byzantine Antiquities in Kastoria.

Notes

1. See also Jouven [1951: 25], for the principle "circle-square-triangle" by the Bauhutten building guild in Germany, according to Ghyka [1931].
2. This investigation departs from the approach described by Cerasi [1988] and Stoichkov [1977].
3. See also Choisy [1976: vol 1, 49-50] and Konstantinidis [1961: 112] concerning the construction of right angles with the application of the Pythagorean Theorem in the Egyptian and Indian architecture, respectively. The 3-4-5 right triangle is also called rope-stretcher's triangle or Egyptian triangle.
4. Cerasi [1988] cites [Berbenliev and Partasev 1963], as well as his personal communications with P. Berbenliev.
5. See also Jouven [1951: 23, 24], for the council concerning the construction and completion of the Milan Cathedral ad quadratum or ad triangulum (1391).

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