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Geometric Construction in Church Architecture in the Late Gothic Era: The Reformed Church of Nyírbátor

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SUMMARY

The topic of geometry in Gothic architecture has been popular for centuries. A general theory is that the master builders utilised grids to design a building. The most common forms of these hypothetical grids are based on the principles of "ad triangulum" and "ad quadratum". Relatively few architectural drawings have survived from the Gothic era, and those that still exist rarely describe the construction processes in detail. However, modern surveying techniques, such as 3D point clouds created through laser scanning, now allow us to examine the precise geometry of structures, including their irregularities, with high accuracy. We take sections of these clouds in different planes to analyse the applicability of geometric construction methods.

In our study we analyse the Reformed Church of Nyírbátor, a great example of late Medieval church architecture in Hungary. We investigate the potential construction systems used in this building and compare them to each other, highlighting their similarities and differences. Additionally, we offer plausible explanations for the irregularities. The objective of this research is to ascertain the extent to which geometric structures were employed in the Gothic period and the manner in which they manifested within a building.

KEYWORDS

Gothic architecture, Gothic construction methods, laser scanning, geometry, geometric construction

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1. INTRODUCTION

Geometric construction in Gothic architecture has been a popular topic of interest, prompting extensive research over the centuries. In order to discover feasible construction methods, however, a highly accurate survey of the researched building – documenting all flaws and imperfections – is needed. This paper demonstrates an example for the potential of terrestrial laser scanning (TLS) as a contemporary non-invasive method to investigate possible construction processes.

Our study aims to recreate the probable geometric construction process of the ground plan and vertical dimensions of the Reformed Church of Nyírbátor, a large-scale hall church in Eastern Hungary. The church is a magnificent representative of Hungarian late Gothic architecture with its intricate window tracery and ribbed net vault. Its larger structures and smaller details have mostly remained in their Gothic form to this day, making the building a good example for our study.

Our goal is to determine the potential construction method of the church both horizontally and vertically by studying the ground plan and sections, respectively. Recreating this method can grant us insight into the designing process of the church in question and provide the possibility of comparison to other similarly shaped buildings. We propose that understanding the geometric construction of a building, either in part or in its entirety, may allow us to better understand the historical era and that new data acquired by laser-scanning may settle ongoing debates or at least serve as a new point of view for further research. In general, identifying commonly used construction methods may also help us date buildings with limited historical resources or possibly link them to other structures built using the same principles, perhaps by the same workshops.

1.1. Building description and history

The Reformed Church of Nyírbátor was originally dedicated to Saint George. It is an aisle-less type church, consisting of a single nave, and the choir is not separated from the nave by a triumphal arch *(Fig. 1)*. A tower connects to this space from the west, a sacristy from the north, and a small entrance hall built in the 18th century[1] on the south. On the western side of the nave is a small gallery built at the same time as most of the church. The east end of the church is the choir with an octagonal apse. The space is lit by large Gothic windows with detailed tracery. The space is covered by a ribbed net vault. In the interior the vault is supported by narrow demi-columns along the southern and northern wall, following a seemingly regular distribution in accordance with the pattern of the vault ribs. The two easternmost pairs of demi-columns are not running all the way down to the ground but are supported by corbels at around half of the height,[2] which was probably due to the position of the stalls.[3] On the outside, the longitudinal walls are also

1 Entz–Szalontai, 1959. 52.

2 Therefore, these demi-columns are not shown on the ground plan of the point cloud.

3 The stalls of Nyírbátor dated to 1511 are among the greatest known masterpieces of early Renaissance carpentry, now exhibited partly in the Báthori István Museum of Nyírbátor, partly in the Hungarian National Museum in Budapest. It is still debated, however, if they were originally prepared for this church or only transported later, to replace earlier fixtures. Simon 2009. 151–153; Papp 2005. 37.

Figure 1. Interior photos of the Reformed Church of Nyírbátor

strengthened by massive buttresses. The positions of these, however, are significantly different on the northern and southern side. On the southern wall the distribution is rather regular and mostly corresponds to the demi-columns of the vault inside, with the position of the westernmost buttress exceeding the length of the nave and attached to the southern wall of the tower. On the northern wall the distribution looks quite random. The distances between the neighboring buttresses are all different, the pair closest to the sacristy is significantly closer, while the others are further from each other than those on the southern wall. The one on the north-western corner is placed in a 45-degree angle to the walls, the second buttress from the west also clearly diverges from a perpendicular direction.

The exact date of the founding of the church is unclear. Géza Entz[4] and László Császár[5] both suggest that works on the building started in the 1480s. A painted inscription on the wall – no longer visible, described by Leffler[6] – was transcribed to a decorated board that is hung in the nave, above the southern entrance that claims the following:

"The founding stone of this building was placed in 1484; its completion was in 1511. The damages caused by the 1834 earthquake were repaired in 1837, then again repairs were made, and new chairs were placed in 1867." The inscription itself [translated from the Hungarian original to English by the authors] was from the late 19th century, the source and authenticity of the data are unknown.

4 Entz 1994. 1.
5 Császár 1987–1988. 153.
6 Leffler 1915. 262.

The benefactor of the church was the Ecsed branch of the Báthori family. The question of which member of the family was the actual founder of the building is also debated: either István, or his nephew András,[7] according to Szilárd Papp.[8] Béla Leffler suggests that the original works started under the supervision of István, and after his death in 1493 were carried on by András, who made some changes in the building.[9]

Incorporated into the frame of the southern entrance in the entrance hall are three lines of text – though partially faded now, but still readable –, which support that András was the one that had the church finished. It claims that the church was built in honor of the Virgin Mary and Saint George by András Báthori at his own expense.

Géza Entz and Barnabás Szalontai[10] claim that the building must have been mostly completed by 1488 and the details carved in Renaissance style were made as per the order of András, after the death of István. They suppose that the Báthori crest on a relief that has the year 1488 carved into it was placed in its current position secondarily.

Béla Leffler and Margit B. Gyűrky – in contrast to the previous hypothesis – suggest that the church was unfinished due to the death of István,[11] pointing out that his grave was first temporarily placed in the nearby Minorite church, which had already been completed at that point.

The church – despite the seemingly homogeneous look at first glance – was indeed not built upon a completely uniform plan. The irregularities – the odd placement of the buttresses on the northern side and the strange composition of the west end, for example – were already noticed by Béla Leffler in 1915, however, only a few other authors mention it in the following decades. He proposes two likely versions of events: the works either started at the western entrance or at the choir. However, he noted that the western wall and tower seem older than the southern wall, based on their details. He mentions the remains of a circular wall – which we could not find more information on – by the tower that supposedly belonged to the destroyed castle of the Báthori family. He suggests that the irregularities of the church might be explained if more ruins were to be excavated.[12]

Szilárd Papp also mentions the inconsistencies. He concludes that the visible signs point to a change – or perhaps multiple changes – of concept midway through the building construction. He states that without any archeological proof, the exact order of the building construction cannot be reconstructed with certainty, however, he finds it likely that the southern wall was built first, and the changes were first made when the builders worked somewhere along the apse walls.[13]

A small-scale archeological examination was carried out in 2009, led by Zoltán Simon, during which only the exterior of the structure was available for inspection.[14] The plaster was removed in the vicinity of a few notable points to determine whether the joining walls were built separately. The results of this exploration led Simon to conclude that the church had at least three

7 To clarify, István Báthori here refers to the judge royal and voivode of Transylvania, born in 1430, and his nephew, András Báthori, Master of the treasury, who died in 1534.
8 Papp 2005. 67–68.
9 Leffler 1915. 263.
10 Entz–Szalontai 1959. 40.
11 Leffler 1915. 263. B. Gyűrky 1943. 11.
12 Leffler 1915. 267.
13 Papp 2005. 69–72.
14 Simon 2009.

distinct building periods with some parts dating back to as early as the late 13th century. He suggests that the first church shared its southern wall with the current church and stretched along the second and third bays of the nave counting from the west. The second church, built around the end of the 14th and beginning of the 15th century, was presumably an extension of the first, its northern wall now embedded in the same structure of the current building. This church also had a sacristy in its north-eastern corner – this explains the odd placement of the fourth and fifth buttresses of the northern wall. With no other separation found along the rest of the walls, Simon presumes that the rest of the church was built in one stage resulting in the current layout. He suggested a dating for this somewhat later than generally accepted in the earlier literature. He concluded that the construction was commissioned by András Báthori, started at around 1500 and ended the latest by 1517, the wedding date of the benefactor.[15] It needs to be noted, however, that the archeologists had to limit their work to a handful of small portions of wall surfaces on the exterior, and with the scaffold available they could only reach up to about 4.5 m.

The net vault of the church is another topic that is often discussed. Most researchers, for example the aforementioned Béla Leffler and Margit B. Gyűrky believed previously that the vault is a barrel vault, and the ribs merely serve as decoration. As the vault in Nyírbátor is quite high up, and the pattern of the ribs is dense, it is challenging to identify the overall shape correctly just by eye. In a recent paper, however, Eszter Jobbik and János Krähling showed that the structure is a real net vault, which they prove by the same survey method we use, the geometrical analysis of a laser-scanned point cloud. On this accurate point cloud, they could ascertain the exact shape of the ribs and webbing, concluding the building method of the vault.[16]

2. METHODOLOGY

Few examples of drawn plans of Gothic buildings have survived to this day, however a substantial collection of these has been published by Johann Josef Böker.[17] Those that were preserved are typically perfected, and rarely provide insight into the construction steps. However, detailed designs might not have always been put on paper, in fact some large-scale carvings found in some churches suggest that elements were sometimes drawn on site. The tracing floor in York Minster and Wells Cathedral,[18] drawings on the wall of the Cathedral of St. Elizabeth in Košice,[19] or on the tower wall of Liebfrauenkirche in Trier[20] are some examples of this practice.

In our study we test possible geometric construction methods on the Reformed Church of Nyírbátor. We begin by comparing fundamental dimensions to identify correlations and possibly determine the measurement units used. The Medieval era used a wider range of measurement units than we are used to today. The existence of a system in a certain area, however, did not necessarily mean that it was used in building construction.[21] Gothic construction is generally believed to have utilised grid patterns based on the principles of *ad triangulum* and *ad quad-*

15 Simon 2009. 151–153.
16 Jobbik–Krähling 2023.
17 Böker 2005.
18 Harvey 1997.
19 Marosi 1969.
20 Helten 2011.
21 Hoppe 1994. 6.

ratum, known since antiquity and used in the Medieval era. These methods are referred to in the debate of the Cathedral of Milan – described for example by Ceriani–Schofield[22] – and were also used by Villard de Honnecourt.[23] A 60° grid pattern – based on triangulation and drawn by construction circles – was mainly used in churches with hexagonal apses,[24] while a 90° grid was likely more prevalent in structures with octagonal ones. Our analysis involves testing various iterations of these grid patterns to identify the most probable method regarding the current church.

To validate a possible construction system, an internal logic – a concept described and emphasised by Robert Bork[25] – must be found within the building: the same method is supposed to align to either multiple features of the ground plan of the same time period or to the vertical measurements of a space or both. This is vital, since small differences from the construction method caused by irregularities during the building construction are expected, and thus multiple approaches might yield similar results. However, if a system is found to be applicable to multiple aspects of a building, it is more likely that the theory is correct.

Analysing buildings – especially larger in size and with the irregularities present in Medieval structures – is challenging without an accurate, true-to-form survey. Therefore, we opt to use a form of contemporary method for our studies: terrestrial laser scanning. We used a Leica BLK360 G1 scanner, which has a nominal accuracy of 6 mm at a 10 m distance – far surpassing the precision of Medieval builders. We set up the scanner at multiple positions in and around the church. The data gathered this way was then processed with Leica 360 Cyclone Register to generate 3D point clouds. These point clouds were analysed in Graphisoft Archicad *(Fig. 2).*

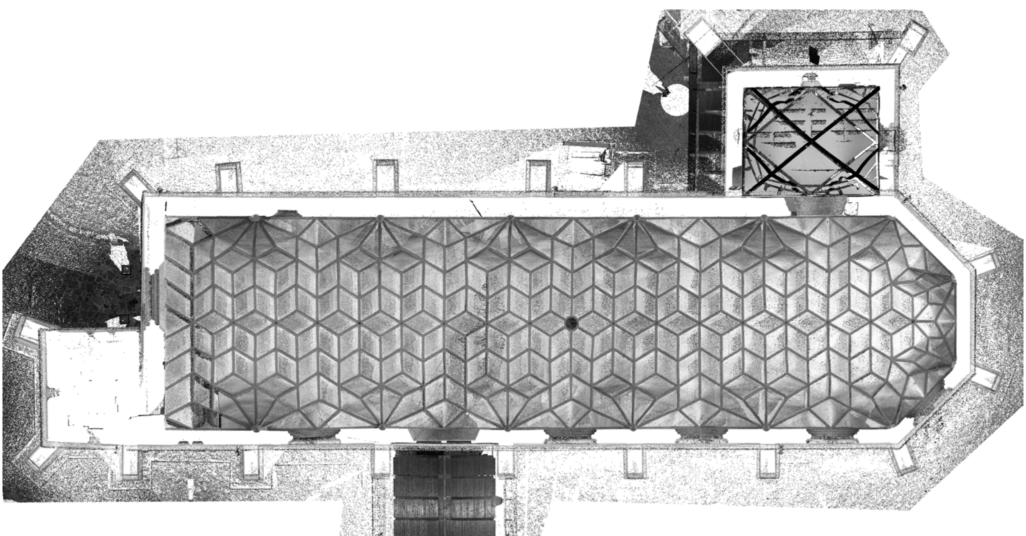

Figure 2. The full ground plan of the point cloud made of the Reformed Church of Nyírbátor

[22] Ceriani–Schofield 2016.
[23] Barnes 2009, folio 20.
[24] Budaházi–Halmos 2024.
[25] Bork 2011.

For the analysis, thin sections of the point clouds were cropped, close to the floor, where the imperfections deriving from the vertical inaccuracies of walls is minimal, and where the architects' and builders' intentions are possibly the clearest. It is worth mentioning that the church was hit by an earthquake in 1834, and though not damaged crucially, the walls slightly shifted. Therefore, a strengthening concrete wreath was built by the plans of Károly Möller between 1931–1934.[26]

3. RESULTS

Our initial focus during the analysis of the Reformed Church of Nyírbátor was to find the most probable method through which the draft of the building was designed. A draft could have existed as a small-scale drawing that was used to lay out the general design principles of the ground plan and to serve as a guide to the full-scale construction. In the case of Nyírbátor no original drawings were found, but it is not unreasonable to think that drafts were used in some form. In full scale some shortcuts and approximations might have been made to account for the scope of the building and make it easier to draw the full-size outline of the walls.

We investigated multiple feasible construction methods on the ground plan of the church. The only reasonable match was a quadrature-based 90° grid. The exact construction method that aligned to the notable points and corners of the building on its ground plan was a technique suggested by Werner Müller.[27] He offers an approximate construction of the apse octagon that could have been used by medieval masters, by dividing the width of the apse by 10 units and marking out the corners with a 3–4–3 ratio *(Fig. 3)*.

Starting out this way, we also divided the width of the choir by 10, which gave us our base unit, X. X is 1.14m, which roughly equals 4 feet – as mentioned before, measurement units were not universal, many systems used a variation of a foot, which tended to be close to 30 cm. The plausibility of this method is strongly supported by the fact that the wall thickness also seems to

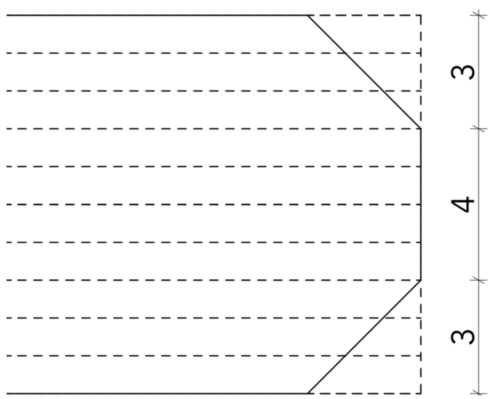

Figure 3. The ratio defining the apse octagon suggested by Werner Müller (Müller 1990. 82)

[26] Grynaeus et al. 2014.
[27] Müller 1990. 82.

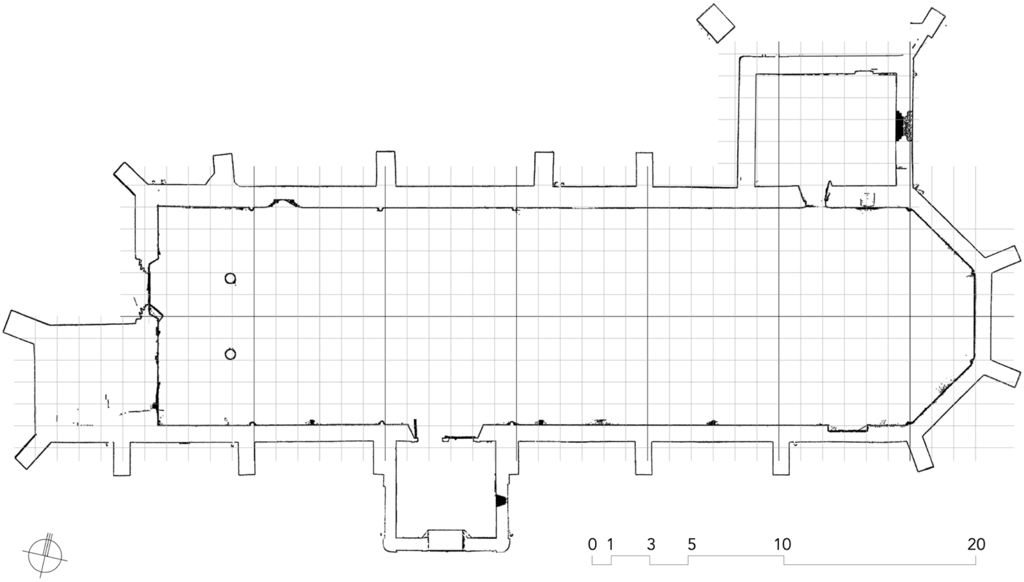

Figure 4. 90° grid on the ground plan of Nyírbátor

correlate to the grid system: on the northern side at the base the wall is roughly 1X (4 feet) thick, while the rest of the walls are 3/4X (3 feet) thick. We then created a grid based on this measurement. As shown in *Fig. 4,* it fits on the southern side of the building, including the tower on the west, excluding the entrance hall by the southern entrance, which was a later addition to the building. The corners of the apse align to this system as well, as does the sacristy in the most part. Looking from the east, the apse polygon is 3X long and going westward from here the inner demi-columns are placed every 6X, while the positions of the buttresses outside roughly correspond to the same rhythm. The internal face of the western wall of the tower is 3X from the axis of the nearest buttress of the nave.

The same grid put on the sections *(Fig. 5)* suggests that the construction system was carried over to the vertical elements: the maximum height of the vault is 16X – the position of the sills of the southern entrance and the sacristy door suggest that the floor level of the church has not been significantly altered since the construction. On the right (southern side) we can also see that the height of the wall plinth is 1X. The inner elevation of the southern wall *(Fig. 6)* demonstrates that the height of the vault arches by the wall – or formerets – is determined by the same system as well, this is 15X measured from the floor. The consoles, demi-column capitals and vault imposts also align to the grid system: the lowest of these elements are placed 4X high from the floor, the rest are 6X, then 8X, finally the imposts are 10X high.

The buttresses of the northern wall do not align to this construction method, as seen in *Fig. 4*. As concluded by Zoltán Simon,[28] their placement was determined by a previous stage of the church. The thickness of the wall and buttresses is also larger here.

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28 Simon 2009.

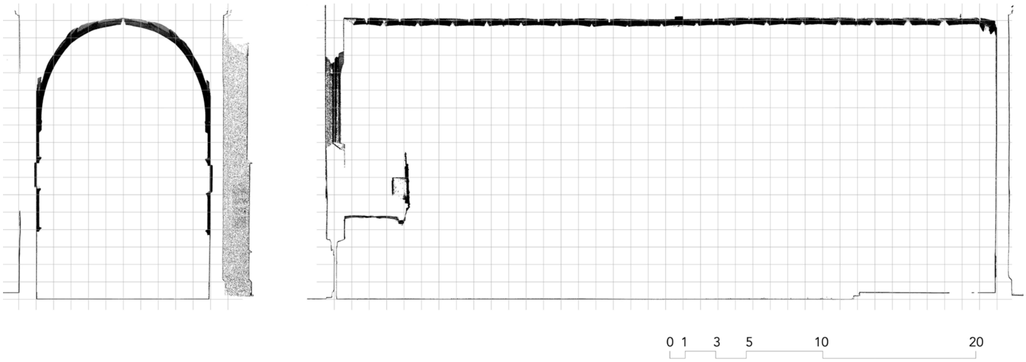

Figure 5. 90° grid on the sections of Nyírbátor

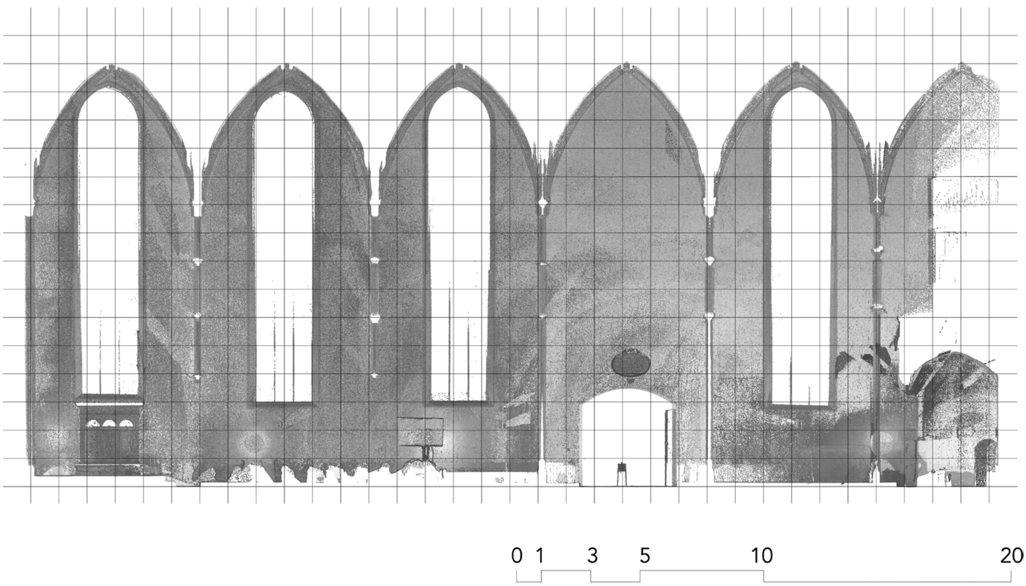

Figure 6. 90° grid on the inner elevation of the southern wall of Nyírbátor

4. DISCUSSION

4.1. Approximation in geometry

In the geometrical thinking of the medieval masters, the approximation of irrational numbers – the diagonal of a square, the height of an equilateral triangle – by the ratio of even numbers was acceptable if the necessary precision was required. These approximations were considered and used as equivalent in practice. The medieval method of constructing regular pentagons and heptagons[29] is a reference to this approach, and it certainly appeared in the construction of polygonal apses.

Approximation was also part of the possible design principle we presented previously: the nearly regular octagonal shape was drafted by a rectangular grid that defined most of the other parts of the structure. The grid fits on many aspects of the building, as our base unit X fits into the width of the church 10 times, and 42 times into the full length. Changing the base unit even by a small amount would result in a grid that fit the ground plan quite differently. Thus, to recreate a reasonably accurate construction system we started with the larger measurement of the choir width instead of trying to build a system on smaller measurements, such as wall thicknesses. We also measured the nave width in multiple places, then found the average value of these and the choir width. This average was then divided by 10 to get X. What suggests that a grid very similar to this one was probably used is that it fits notable points across the length of the church as well. The length of the vault bays – except for the westernmost one – correlates well with the system and so does partially the tower: the westernmost grid line fits well on the inner side of its wall.

The deviations of structures compared to regular polygons built with these approximations are still within the margin of error of common irregularities. Even larger discrepancies are hard to pinpoint on a complete building, which the masons of the era were probably aware of. Thus, the full-scale construction of the ground plan presumably did not completely follow this design principle, and instead the builders seemingly adapted and simplified some aspects of it to be viable on site. In fact, drawing the entire grid on the ground would not have been necessary to mark out the walls. The northern and southern walls already partially existed, thus the line of them could be lengthened, the length of the bays (6X) could then be marked out. The apse, however, required a slightly more complicated approach. Due to the relatively accurate manner in which the church was built, it is difficult to pinpoint the exact way this part of the building was drawn on site. On *Fig. 7* we present a handful of possible methods.

Fig. 7a shows the grid which we presented as a possible design principle. This could have been partially drawn to mark out the corners of the apse. The same result could have been

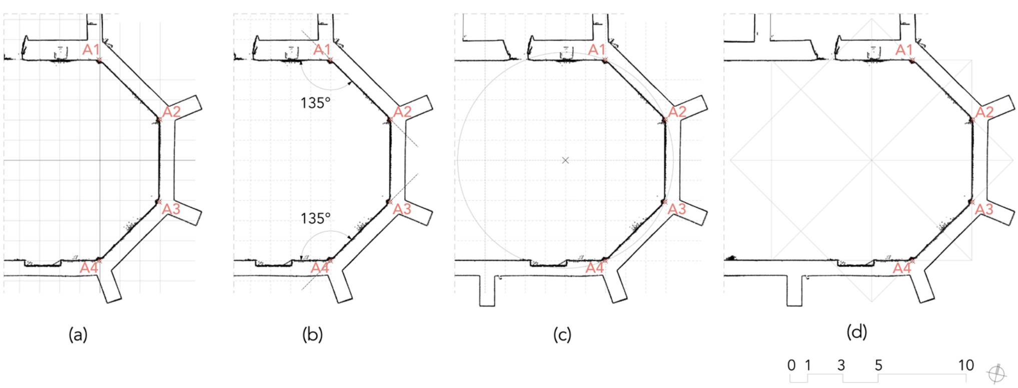

Figure 7. Possible full-scale construction methods of the apse polygon

29 Fehér et al. 2018.

achieved by determining the length of the apse to be 3X, or half of a bay, then measuring 135° from A1 and A4 to get the slanted walls (b). In (c) we propose that a circle might have been used to partially determine the corners – the centre of which is 2X, or 1/3 of a bay westward from A1 and A4. Its radius is defined by the distance of the centre and A1 or A4. Finally, in (d) we tested if a regular octagon could have been used to construct the shape. We compared these construction methods based on the deviation of the corners from them, whose results we compiled into a table *(Table 1).* It must be noted that in the apse there are demi-columns in the corners and thus on the ground plan we had to rely on the direction of the adjoining walls to determine their theoretical intersection.

The grid was fitted on the ground plan of the entire church, so even though the overall fit is good, none of the apse corners fit exactly. The circle was fitted on A1, A3 and A4 – marked with "*" – so the fit of A2 is the only uncertainty in theory, and the only deviation of significance here. This corner, too, however, fits quite well, with only a 1.5 cm deviation. The octagon was fitted to the width of the apse and the corresponding vertex to A1. Since the order of operations and the exact logic of the builders and architects of the church is not known, the construction methods were fitted to points on the ground plan chosen by us. Choosing different points might have yielded a somewhat different result, however, the importance lies in the order of magnitude of the deviation, rather than the exact number.

All these deviations from all three construction methods are relatively small considering the size of the building and the accuracy of the era. The lack of substantial differences between the analysed methods makes it impossible to decide which one of them is more likely to have been used.

Table 1. Deviation of apse corners from construction methods

Corner	Deviation [cm]		
	from grid	from circle	from regular octagon
A1	2.7	0.0*	0.0**
A2	4.0	1.5	6.9
A3	11.2	0.0*	2.6
A4	2.0	0.0*	2.8

4.2. Reflecting on the archeological findings

Although the 2009 excavation may have been restricted to a few areas, it still brought key information to light about the church. Counting from the west, between the 3rd and 5th buttresses of the southern wall stood the southern wall of the first church based on the separation of walls and buttresses here. The adjoining buttresses all seem to have been later additions. Between the 2nd and 4th buttresses of the northern wall was the northern wall of the nave of the second church. The 2nd buttress was originally a corner buttress, its original shape is still visible partially next to the current one. The 3rd buttress was built simultaneously with the wall, while there is separation in the wall just before the 4th one.[30]

On the point cloud the transition of one period to another is hardly visible on the walls. One of the only areas on the ground plan that can be deemed irregular is the north-west corner, where the first section of the northern wall joins the rest at a slight angle at the 2nd buttress. The other area of significance is the 3rd buttress on the southern side: its axis does not match the corresponding demi-column on the inside. Knowing, however, that behind it two walls of different periods meet, we can assume that it was placed in this way to support the joining.

We can assume that while tracing the layout of the enlarged church in the late Gothic period around 1500, the starting measurement of the construction was the width of the nave already given by the 2nd period church. Intending to build a plan with an octagonal apse of the same width as the nave, this length was divided into 10 parts to trace the apse polygon. The starting line to determine the length of the new construction was most probably the southeastern corner of the old nave, which was where we have the 5th buttress on the southern wall today. From here, 3x6 units (corresponding to the rhythm of the future vault) were measured towards both east and west to determine the place of the apse polygon and the western wall of the nave.

Regarding the thickness of the walls, this aspect differs on the two sides: the southern wall is 3 feet, the northern wall 4 feet thick, which is likely due to the remaining parts of the previous churches. The first church, as shown in *Fig. 8* was likely built in the 13th century and had 3 feet thick walls, while the second church, presumably built around the turn of the 14th and 15th centuries, had 4 feet (or 1X) thick walls. Even though the latter fits into the grid system well, the smaller thickness on the southern side was likely deemed enough by the builders to be structurally sound in the late Gothic period, thus they did not thicken the wall from the 13th century.

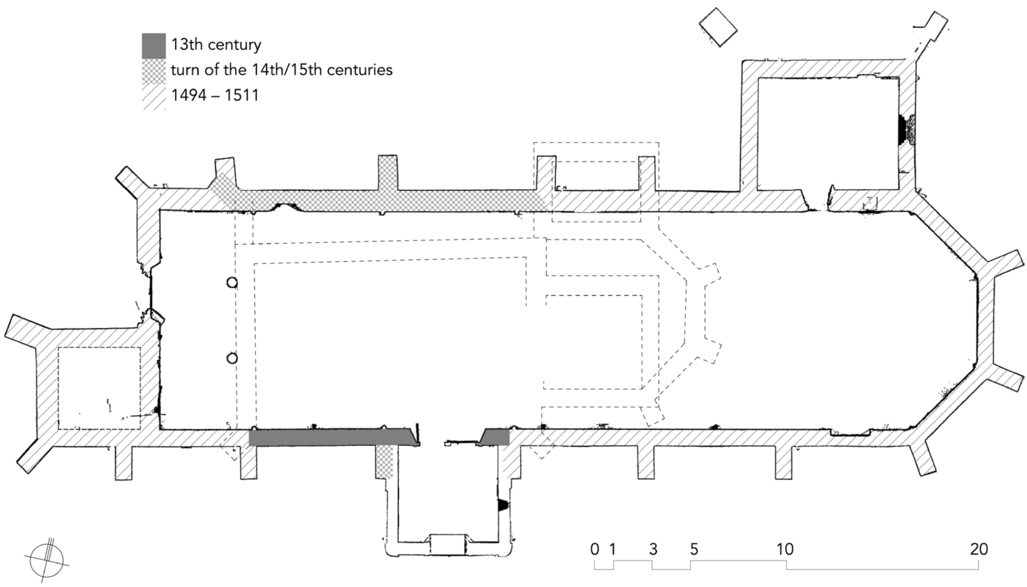

Figure 8. The Medieval building periods of the church and the possible layout of the previous churches based on the archeological findings (Simon 2009. 140) transferred to the ground plan from the point cloud

[30] Simon 2009. 138–139.

On the northern side the thickness of the wall (1X) of the second church was continued later along all of the northern wall in both directions, however, the method of joining differently angled walls to this one differs on the east and the west. In the east, the thickness changes to the smaller one right at the first corner, which is the northernmost corner of the apse. In the west, however, the same 4 feet thickness is carried over to the western wall. Based on the archeological analysis, the church is believed to have had at least three building periods. However, these contrasting approaches may suggest that the two sides were built with a somewhat different logic, perhaps in different stages of the construction. Supporting this hypothesis is that the north-western corner – and thus the western side of the nave – does not seem to have been defined by the 90° grid we suggested as the design principle of the church.

Consequently, we hypothesise that during the building process of the last Gothic period there might have been a change of concept mid-build at the southwestern corner of the tower. The archeological analysis does not mention any separation in this area, thus a completely separate building period is unlikely. At this junction we also found the joining of a thicker (western) and thinner (southern) wall – this change, just as before, might suggest a change in logic. The western wall of the nave and the northern and western walls of the tower seem to belong to the earlier concept, while the southern wall likely does so to the later one. The grid system proposed by us fits to the southern wall entirely, including the southwestern corner which may have served as a starting point for the construction method, if our hypothesis is true. As the vault must have been one of the last elements of the building to be completed, it is reasonable to assume that it belongs to the later period. The structure of the ribs and demi-columns conforms to the eastern side, and the length of the bays correlates with our proposed design principle. The westernmost bay, however, is shorter than the others, the junction of the vault and wall seems almost incidental. All these signs seem to indicate as well that the southern wall and the entire eastern side along with the vault might have been built later than the western wall.

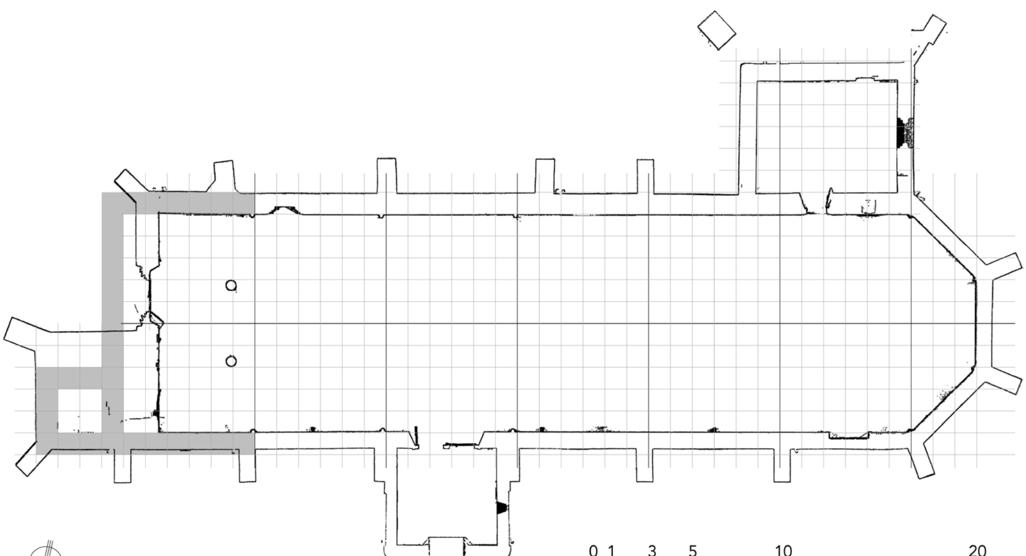

Figure 9. A possible theoretic reconstruction of an originally intended layout

On the other hand, the possibility of western parts being built later cannot be eliminated. If these walls were the last ones to be built, the placement of the tower is still odd; it shifts the main entrance to a strange position, creating an unusual and unbalanced western elevation. This is peculiar considering the overall accuracy of the building, the general attention to details in other aspects of it and the religious and political importance of the church. The size of the tower is also too large for it to be only used as a stair turret – was it perhaps intended at some point as a bell tower? A rather coherent layout of the plan *(Fig. 9)* can be drafted with the western wall of the nave and a smaller tower all aligned with the grid, also allowing the main entrance of the church to be placed in the axis of symmetry. This way the size of the bay – and thus the rib pattern of the vault – would be in accordance with the rest of the ground plan as well. In this case, too, the alteration of the plan was possibly made while building the western wall, thus assuming that this part could have been built in the final stage. If so, the question is still open: what was the reason behind the shortening of the nave while enlarging the tower?

Until a further in-depth archeological excavation, these hypotheses and questions cannot be satisfactorily answered. Larger areas would be needed for analysis on the northern and southern walls, in larger heights than the previous attempts to look for signs of separation. The western wall and the tower could also still reveal more with a new excavation.

5. CONCLUSIONS

In this study we examined the possible geometric construction methods of the Reformed Church of Nyírbátor. This church was chosen as a case study because of its relatively accurate geometry and contrasting irregularities caused by the likely reconsideration of the concept mid-build. We based our analysis on the exact geometry of the building, which we acquired through a laser-scanned point cloud.

Regarding the ground plan we found that for most of the building presumably a rectangular grid was used as a design principle. The approximation of irrational numbers with simple arithmetic ratios was a common method in the Gothic era to make construction processes easier. The church in Nyírbátor is a good example for this – the grid used on the rest of the ground plan also extended to the apse. The apse shaped as a seemingly regular octagon was also likely determined by the grid as a method of approximating the simple geometric shape. This same construction system is also detectable on the vertical sections of the church; therefore, we believe they were designed by the same line of logic.

We also found that while the grid might have been used as a design principle and a guide, the full-scale construction possibly did not include drawing the entire system on the ground. It is more likely that the principle was adapted to be suitable for easier work on a larger scale. This adaptation was presumably also used to mark the placement of the apse corners. We presented a handful of methods with which this might have been done. However, due to the relatively small deviation of the apse corners from their corresponding theoretical place given by each of the construction methods, it is impossible to decide for certain which method had actually been used.

Regarding the building periods, the 2009 excavations point to at least three of these. The supposed third period, however, sits on both sides of the first and second, it is not a continuous whole at the height it was examined. Thus, the western and eastern sides could just as well belong to two separate periods or rather separate phases of the same period. This hypothesis is supported by the different use of wall thicknesses and the placement of the western wall not aligning to the design principle. However, other reasoning, such as a change of concept mid-build might instead be the cause of the placement of the western wall and the odd position of the tower.

Many of our questions regarding the construction were answered through our analysis. Nevertheless, many more remain still. Non-invasive methods are a highly important part of research; however, some questions could only be answered by thorough archeological excavations. Although the excavation in 2009 brought to light invaluable details, further analysis would be required to discover the entire history of the building. All in all, in the case of Nyírbátor with the help of modern surveying techniques new correlations came to light, but the added value of further excavations could take the research further.

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Geometriai szerkesztés a késő gótikus templomépítészetben: A nyírbátori református templom

ÖSSZEFOGLALÓ

A gótikus építészetben a geometria alkalmazása évszázadok óta népszerű téma. Az általános vélekedés szerint az építőmesterek szerkesztőhálókat használtak az épületek tervezéséhez. Ezen elméleti rácsok leggyakoribb formái az „ad triangulum” és az „ad quadratum” elvén alapulnak. A gótikus korszakból viszonylag kevés építészeti rajz maradt fenn, azok, amelyek még léteznek, ritkán részletezik a szerkesztési folyamatokat. A kortárs felmérési technikák, például a lézerszkenneléssel létrehozott 3D pontfelhők ma már lehetővé teszik, hogy nagy pontossággal vizsgáljuk az építmények pontos geometriáját, beleértve a szabálytalanságokat is. Ezekből a felhőkből különböző síkokban metszeteket készítünk, hogy elemezzük a geometriai építési módszerek alkalmazhatóságát.

Tanulmányunkban a Nyírbátori Református Templomot elemezzük, mely a késő középkori magyarországi templomépítészet egyik nagyszerű példája. Megvizsgáljuk az épületen alkalmazott lehetséges építési rendszereket, és összehasonlítjuk őket egymással, kiemelve a hasonlóságokat és a különbségeket. Emellett lehetséges magyarázatokat kínálunk a szabálytalanságokra. A kutatás célja annak megállapítása, hogy a gótikában milyen mértékben alkalmaztak geometrikus szerkesztéseket, és ezek milyen módon nyilvánultak meg egy épületen belül.

KULCSSZAVAK

gótikus építészet, gótikus szerkesztési elvek, gótikus szerkesztőmódszerek, geometria, geometriai szerkesztés, lézerszkennelés