Vaults Without Buttresses: A Survey of Swiss Roodscreens

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Introduction

In the late Middle Ages, a new architectural motif prevailed: Vaults on very slender supports lacking a massive abutment.

The motif is well known to us from the Italian loggias south of the Alps, which became a ubiquitous part of cityscapes at the end of the 14th century. In the north, too, loggias were built on the Italian model, albeit more than 100 years later.

In fact, however, the same phenomenon has existed in the north for just as long, but in a different place: inside the churches, in the form of late Gothic rood screens. This refers primarily to the so-called "hall rood screens" [1], i.e. those that form a spatial structure in the form of rows of masonry canopies. According to J. Jung, they would be called "bridges" [2].

Even if rood screens and Italian loggias have little in common in terms of architectural history, they are very close in terms of construction history.

A new research project at the Institute of Construction History and Preservation at ETH Zurich will address the phenomenon of such filigree and delicate articulated vaults - *vaults without buttresses*. The aim is to look at and analyse the Italian loggia and the late Gothic hall rood screen as a comparable phenomenon in terms of construction history. Special interest will be given to the vaulting techniques as well as the extensive use of wrought-iron tie rods. The project itself is still in preparation. In the course of this, however, initial surveys (including 3D laser scans) have already taken place. In the following, three late medieval rood screens from Switzerland will be presented: the rood screens in the *Leonhardskirche* in Basel (1455/60, enlarged at the end of the 15th century) [3], in the parish church (Stadtkirche) of Aarau (before 1479) [4] and in the parish church (*Stadtkirche*) in Burgdorf, which was built in 1511 - 1512 and relocated to the east side of the nave in 1867 – 1868 [5].

The architectural history of the rood screen has been well researched, most recently in the works of M. Schmelzer [6] and J. Jung [7]. However, it is astonishing that they were not yet analysed from the perspective of construction history. The delicate appearance of the rood screen is, however, primarily due to its construction. The architecture of slender supports creates a filigree and yet spatially effective construct. Since the rood screens which have been examined have a massive vault, the construction challenge should not be underestimated for, despite their small size, the horizontal forces which were generated could not be resolved by massive abutments which would have run counter to the desired impression of the rood screen. In contrast to the majority of the loggias, the rood screen also lacks a superimposed load.

For this reason, iron tie rods were used extensively. Tie rods are a ubiquitous phenomenon in Italian vaults. Their use in medieval and early modern construction has recently been the subject of research [8]. North of the Alps, iron was also used on a large scale, for example as tie rods in the walls of Gothic cathedrals [9]. Visible tie rods in vaults were obviously avoided. In the case of slender rood screens, however, tie rods couldn´t be hidden efficiently in the masonry. So far, the use of iron in the context of rood screens has not been discussed. The future research project should provide new insights here.

The structural demands of the rood screen and thus its relevance to construction history can be well illustrated by the following examples.

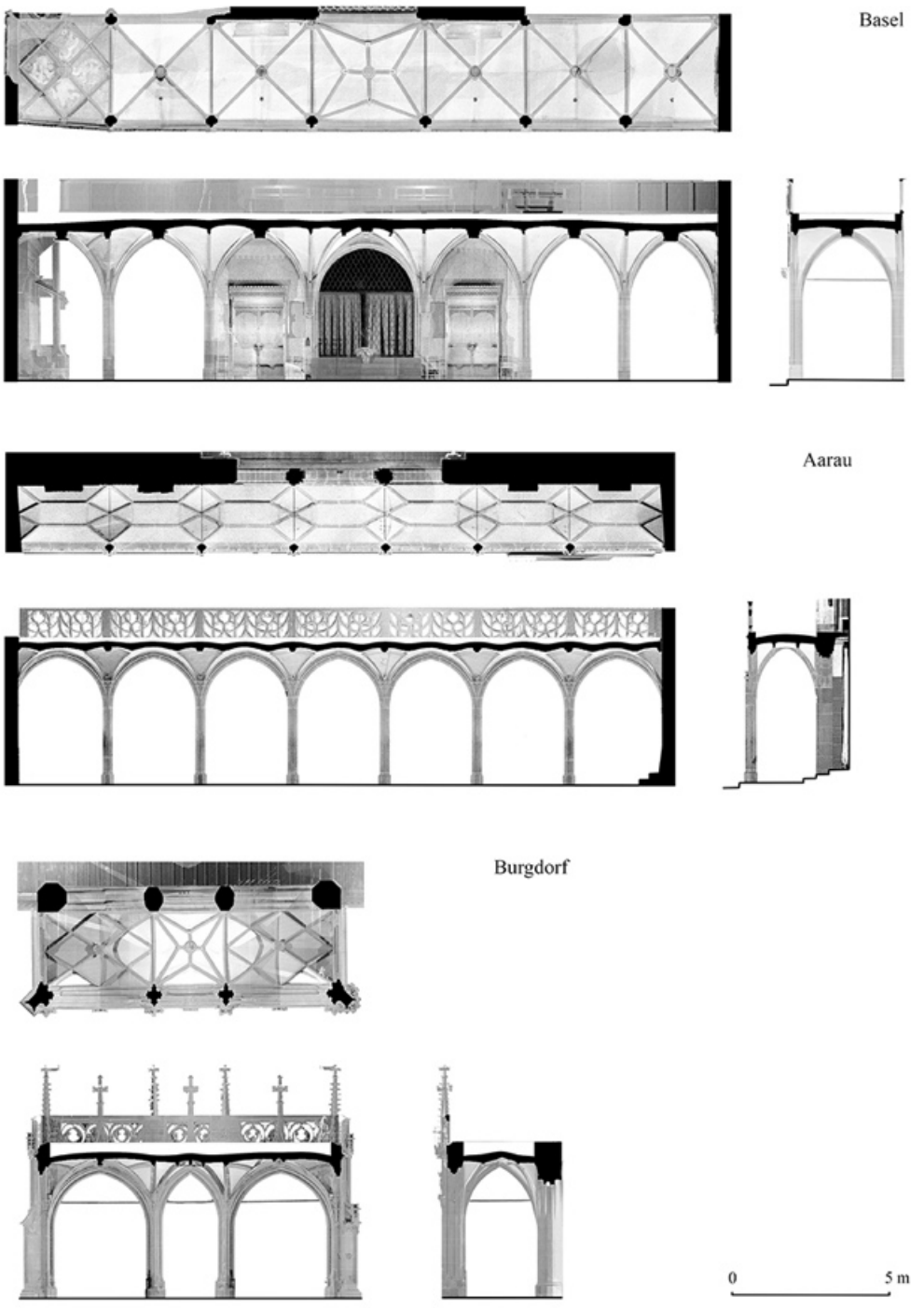

Fig. 1. Plans from the point clouds of the surveyed rood-screens. Drawings: Xijie Ma

Leonhard church in Basel

The rood screen in the Leonhard church *(Leonhardskirche)* in Basel was built between 1455 and 1460. (Fig. 1, Basel) In the course of a transformation of the church from 1489 onwards, the old basilica was demolished and the present hall church built (master builder Hans Niesenberger, Hans Nußdorfer). The rood screen, however, was taken over from the previous building. It was adapted to the wider new hall church in 1496 by extending it by one bay at each side [10]. After the Reformation in 1529, the rood screen remained in the church – not like the most rood screens in catholic churches, which were removed in the 16th century due to the reorganisations after the council of Trent [11].

The middle five bays represent the first construction phase of the rood screen. The central bay with a simple star-shaped rib vault is adjoined by two further square bays with ribbed vaults. (Fig. 2) The northern bay is irregular due to the connection to the new outer wall, its ribs form a rhomboid pattern. The front of the rood screen opens to the nave with wide-span pointed arches (2.80 m each, central arch 3.20 m).

The octagonal pillars have a diameter of only 36 cm. The transverse arches are not profiled more strongly than the cross ribs. The rood screen is 4.63 m high, measured from floor to key stone. The slender columns have a cross-section of 0.1 m^2 and are 2.33 m high, measured from floor to rein. This corresponds to a slenderness ratio of 25.9 [12]. The thickness of the vault could not be measured because the rood screen is covered with a floor. Since the other vaults of the church were made of brick, it is assumed that this material was also used for the rood screen, which would require a vault thickness, referring to other Swiss examples, of about 12.5 cm [13]. A plan showing the contour lines of the vault was generated from the measurements. This shows a slight rising of the vault caps to their middle axis, which could indicate freehand vaulting [14].

Fig. 2. Basel, Leonhard church, rood screen. Photo: author.

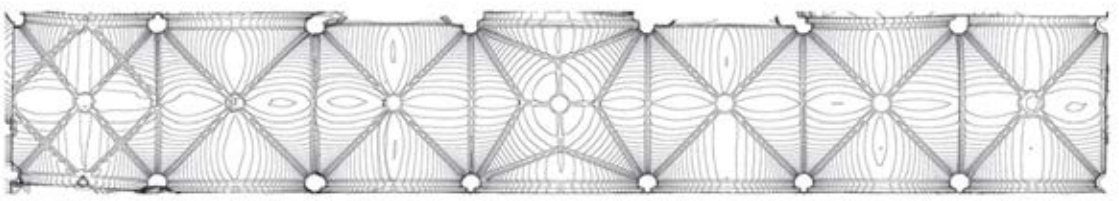

Fig. 3. Basel, Leonhard church, contour lines of the vaults of the rood screen. Drawing: Xijie Ma.

The second and fourth bays have a solid slender back wall. The adjoining bays merely rest on the filigree supports. In the middle bay, a door opens at the back, taking up almost its entire width. The outer walls of the church serve as lateral abutments.

The high structural demands of the rood screen become clear when taking a closer look at the proportions in one bay. A column has a cross-section of 0.10 m^2, the referring vault has a surface area of 10.70 m^2 / 4 = 2.675 m^2 per quarter bay (projected on the ground). This corresponds to a ratio of 1: 26,75 (for simplification and for better comparability with the other rood screens, the cross-section is calculated with only one support and the area of a quarter bay).

The horizontal thrust is compensated by iron tie-rods. These have an average cross-section of 2.8 × 5 cm in the older parts of the rood screen, and a cross-section of 1.6 × 5.5 cm in the outer and thus younger bays. There are only transverse tie-rods which are anchored efficiently into the masonry just above the rein. A survey of the cloister of nearby Basel Cathedral, finished 1492 [15] (Fig. 4) suggests that in comparable contemporary buildings, tie rods were also attached in the longitudinal direction (perhaps as a reaction to the earthquake in Basel in 1356) and later removed - possibly due to the aesthetic concerns already mentioned above. There is no evidence of this in the rood screen of the Leonhard Church. The installation of tie rods in the longitudinal direction would indeed have been necessary if there had been no lateral abutments, e.g. to avoid a progressive collapse [16].

Fig. 4. Basel, cloister (Kleiner Kreuzgang) next to the Basel Minster. Photo: author.

Parish Church in Aarau

The parish church *(Stadtkirche)* in Aarau was rebuilt between 1471 and 1479 (master builder Sebastian Gisel) as a three-nave basilica with a flat ceiling. The rood screen (Fig. 1, Aarau) was completed together with the church. Here, too, the Reformation (1529) prevented it from being demolished. Its late medieval substance has been completely preserved. (Fig. 5) Minor changes were made in 1880 with the opening of two new doors next to the original gate to the presbytery. A new balustrade was contructed and finials on the front were added in 1939 [17]. Until 1818, the church's late Baroque organ was situated on top of the slender rood screen [18].

Fig. 5. Aarau, rood screen. Photo: author.

The rood screen uses the east wall of the church as back abutment. Below the quire arch, it is opened to the presbytery by three arches (only the central pointed arch being from the original building period, see above). The rood screen opens towards the nave with seven (almost round-shaped) arcades, each with a clearance of 2.66 m between the columns. Only the southern bay is somewhat wider (2.78 m) due to the irregular ground plan of the nave.

The dimensions of the rectangular bays are 2.17 × 2.96 m each. Thus, an area of 6.42 m^2 is vaulted per bay. The vaults have an almost round-arched cross-section, i.e. they are flatter than those in Basel. The ribs are figured as an elongated net without transversal arches. In Aarau, too, it was not possible to determine the thickness of the vault. However, it is assumed that here, too, vaulting was done with the common brick format of about 12.5 cm thickness. The contour lines of the vault show no superelevation of the caps, but very shallow apexes. The small dimensions of the vault do not allow a definite statement, but it can be assumed that vaulting was carried out on a formwork.

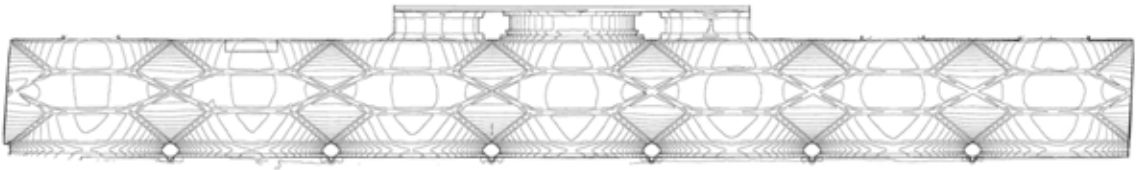

Fig. 6. Aarau, contour lines of the vault of the rood screen. Drawing: Xijie Ma.

The supports of the vaults are particularly filigree. Being 2.60 m high (measured from floor to rein), they have a diameter of only 29 cm, which corresponds to a slenderness ratio of 35.9. A column cross-section of 0.07 m^2 refers to a vaulted area per quarter bay of 6.42 m^2 / 4 = 1.605 m^2 (ratio 1:23).

Here too, transversal wrought-iron tie rods are attached just above the rein of the vault. These have a cross-section of 2.1 3×.8 cm. There is no evidence of tie-rods in the longitudinal direction.

Parish church in Burgdorf near Bern

A new church was built in the town of Burgdorf in the canton of Bern between 1471 and 1490. The building is designed as a three-nave basilica with flat ceilings in the nave and a vaulted choir. In 1511 – 1512, a three-bay rood screen (Fig. 1, Burgdorf) was erected in the eastern part of the nave, directly in front of the quire arch. As in the examples discussed before, the rood screen probably owes its survival to the Reformation, which found no further use for the presbytery behind it. Between 1867 and 1868, the interior of the church was redesigned, and the rood screen was moved to the west between the first pair of free pillars of the nave. It was rotated by 180° for the new installation. The remaining open space between the back of the rood screen and the east wall of the tower was covered with a wooden gallery, whose splendid prospectus was to become the late medieval rood screen [19].

The rood screen has an irregular bay sequence. The central arcade opens with a clearence of 1.76 m, the wider side arcades with a clearence of 2.96 m to the nave. The rood screen is open on all sides. The nave-side arches are strongly profiled, while the transversal arches are only slightly more profiled than the ribs. The vault is supported by six pillars. The outer piers, formerly on the east side and now on the west side, were once connected to the eastern wall of the church and are now connected to the western pair of pillars. The arcades of the small sides were each partly renewed so that they could be connected directly to the pier. The rich tracery of the front, consisting of interlocking ogee arches, pinnacles and finials, and the rich profiles of the arches results in an unusually elaborate decoration, which can otherwise only be found on a few preserved rood screens, cf. e.g. Breisach, Tübingen or Halberstadt [20].

The unusual rhythm of the bays can be traced back to the crucifix altar that once stood in the central narrow bay, the rear arcade of which was closed with a wooden grille [21]. The wider arcades were open on all sides and thus offered an unusually generous view into the presbytery.

The vaults in the outer bays are figured with rhomboid patterns. In the narrow inner bay, the ribs form a simple star. The contour lines suggest that vaulting was done partly freehand. (Fig. 8) The bays have dimensions of 3.80 × 3.60 m (lateral) and 2.30 × 3.60 m (central). According to sources, the wrought-iron tie rods with a cross-section of 2.5 × 5.5 cm were reused during the reconstruction [22]. However, the findings cast doubt on whether this also applies to their connection to the wall.

Fig. 7. Burgdorf, rood screen. Photo: author.

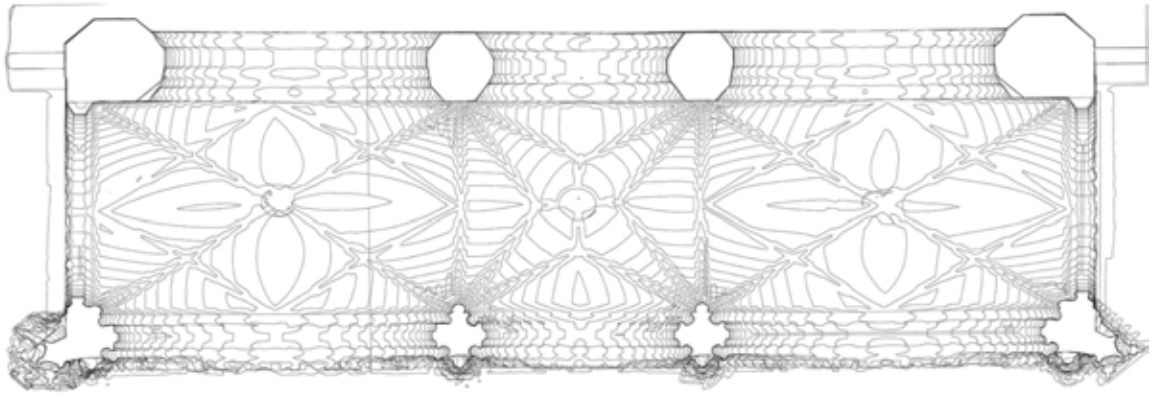

Fig. 8. Burgdorf, contour lines of the vault of the rood screen. Drawing: Xijie Ma.

Further research both on site and in the archives is required. However, it is certain that in the originally there were tie rods in both the transverse and longitudinal direction. This is necessary here, since on the small side - in contrast to the rood screens in Aarau and Basel - there was no abutment (e.g. the outer wall), and the rood screen was designed as a canopy open all around. The fact that the rear arcades manage without tie rods may be because the pillars of the church provided sufficient abutment, both in their original location and at the new site, thereby avoiding investment in expensive iron components

The pillars of the rood screen are, compared to the other rood screens, thicker. So, the ratio of column cross-section to vaulted area is not as ambitious as in the other rood screens. If we consider the more filigree central pillars, there is still a ratio of 0.20 m^2 to 3.4 m^2 (quarter bay) or 1:17. The slenderness ratio of the most slender pillars is 19.

Since the rood screen was relocated, it would first be necessary to reconstruct its original state. For this, the original components would have to be distinguished from the new components, which is partly possible by eye (Fig. 9), but partly can only be achieved with the help of archival documents and in-depth building archaeology. This is the task for an individual research campaign on this highly exciting object. For further research within the framework of the planned project, the rood screen is less suitable as it is no longer in situ. However, due to its importance in architectural history, it should not go unmentioned here. The relocation of rood screens was not uncommon in the 19th century, as the close example in Basel Minster shows [23].

Fig. 9. Burgdorf, connection of the rood screen to the western pillar of the nave. Photo: author.

The investigations outlined are only the beginning of a far-reaching research project, which will also be devoted to the material properties of the iron tie rods and their anchoring in the masonry by the aid of non-destructive testing methods. Further building archaeology will take each stone into account.

The aim of this article firstly is, however, to address the often-unmentioned constructional challenge of such filigree vaults - vaults without buttresses.

References

[1] M. Schmelzer, Der mittelalterliche Lettner im deutschsprachigen Raum. Typologie und Funktion. Petersberg: Imhof, 2004. pp. 64-118.
[2] Jung, The Gothic Screen. Cambridge: Cambridge University Press, 2012. pp. 45-70.
[3] F. Mauerer, Die Kunstdenkmäler des Kantons Basel-Stadt. Band IV: Die Kirchen, Klöster und Kapellen. Zweiter Teil: St. Katharina bis St. Niklaus, Basel: Birkhäuser, 1961. pp. 164-219.
[4] M. Stettler, Die Kunstdenkmäler des Kantons Aargau. Band I: Die Bezirke Aarau, Kulm, Zofingen, Basel: Birkhäuser, 1948. pp. 41-52.
[5] J. Schweizer, Die Kunstdenkmäler des Kantons Bern. Landband 1: Die Stadt Burgdorf, Basel: Birkhäuser 1985. pp. 186-234.
[6] M. Schmelzer, Der mittelalterliche Lettner im deutschsprachigen Raum, (Note 1).
[7] Jung, The Gothic Screen, (Note 2).
[8] M. L'Heritier, 'Le fer et le plomb dans la construction monumentale au Moyen Âge, de l´étude des sources écrites à l´analyse de la matière. Bilan de 20 ans de recherches et perspectives', Aedificare, vol. 6, 2019, pp. 79-121; R. Vecchiatini, 'Historical Use of Metal Tie-Rods in the Italian Territory: Treatises, Essays, and Manuals through Four Centuries of History', International Journal of Architectural Heritage, vol. 13, no. 3, 2019, pp. 451-471.
[9] M. L'Heritier, Le fer et le plomb, (Note 8), pp. 79-121.
[10] Mauerer, Die Kunstdenkmäler des Kantons Basel-Stadt, (Note 3) p. 214.
[11] M. von Engelberg, Renovatio Ecclesiae. Die „Barockisierung" mittelalterlicher Kirchen, Petersberg: Imhof, 2005. pp. 166-186.
[12] $\lambda = \sqrt{\frac{A}{I_{min}}} \times l_k$; λ= slenderness ratio; A = diameter of the column; Imin = axial area moment of inertia, here assumed approximately as a circle; lk = length of the column.
[13] M. Maissen, 'Gewölbebau der Spätgotik in Graubünden' (Ph.D. thesis, ETH Zurich, 2020), pp. 167 - 168.
[14] S. M. Holzer, Gerüste und Hilfskonstruktionen im historischen Baubetrieb. Berlin: Ernst & Sohn, 2021. p.147.
[15] H.-R. Meier, D. Schwinn Schürmann, M. Bernasconi, S. Hess, C. Jäggi, A. Nagel, F. Pajor, Die Kunstdenkmäler des Kantons Basel-Stadt. Band X: Das Basler Münster, Bern: Gesellschaft für Schweizerische Kunstgeschichte, 2019. pp. 397-402.
[16] S. M. Holzer, Statische Beurteilung historischer Tragwerke. Band 1: Mauerwerkskonstruktionen, Berlin: Ernst und Sohn, 2013. p.19.
[17] Stettler, Die Kunstdenkmäler des Kantons Aargau, (Note 4) pp. 46-47.
[18] S. Ehrismann, 'Die spannende Geschichte der Orgeln in der Stadtkirche Aarau', Aarauer Neujahrsblätter, vol. 86, 2012, pp. 42-50.
[19] Schweizer, Die Kunstdenkmäler des Kantons Bern, (Note 5) p. 194-196.
[20] M. Schmelzer, Der mittelalterliche Lettner im deutschsprachigen Raum, (Note 1) P. 74.
[21] Schweizer, Die Kunstdenkmäler des Kantons Bern, (Note 5) p. 211-212.
[22] ibid., p. 209.
[23] Meier, Schwinn Schürmann, Bernasconi, Hess, Jäggi, Nagel, Pajor, Das Basler Münster, (Note 15) p. 141.