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A case of Recovery of a Medieval Vaulting Technique in the 19th Century: Lassaulx's Vaults in the Church of Treis

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In 1829, the "Journal für die Baukunst", edited in Berlin by Crelle, published an essay with the title "Description of the procedure in the making of light vaults over churches and similar spaces", where, referring to observations made on medieval buildings, a method of building vaults without centering is described.

The author of this essay, Johann Claudius von Lassaulx (1781-1848), was a Royal Prussian building inspector at Koblenz (which in that time belonged to the Rhine province within the kingdom of Prussia). As an architect he built numerous public buildings in that area, including several large parish churches in the medieval style. He was strongly engaged in research, restoration and maintenance of medieval architecture, as well as a promoter of neo-medieval architecture both in his projects and in his writings. In 1846 and 1847 he returned to the subject of vaults in lectures and articles.

The essay in question has been brought to attention by Fitchen (1961, 175ff.). A closer look to Lassaulx' own vault constructions referred to in the essay may offer a more detailed understanding of his vaulting method and provides an opportunity to discuss the relevance of this publication and its position within the development of building technology in the 19th century.

The building we analyze, the first major project where Lassaulx put his method of vaulting into practice, is the Parish Church of St. John at Treis, on the Mosel river, built from 1824 to 1831.

1 Contents of the essay

Lassaulx starts his essay declaring that, to his personal conviction, building churches in the medieval styles (gothic and "pre-gothic", i.e. "pointed arch style" as well as "round arch style"), is "not only the most suitable and dignified, but even the cheapest". To build churches in that style is closely linked to vault construction: whenever possible, he says, they should have vaults built of stone. Moreover, "light and wide spanned vaults belong, without doubt, to the most daring and sensible human inventions". They have high formal qualities and resist to fire and decay. Therefore, Lassaulx says, he sought for a long time for a proper vault construction method. Knowing that in Vienna large domes were being constructed almost completely free-handed and that in the vicinity flat ovens and fireplaces were being built using only some weak rods, he had been already for some time trying to imagine how large church vaults could be constructed with similar means.

In the technical literature, there was no indication about how this could be done - "nothing referring to the point in question", apart from the well-known manners of tracing arches, says Lassaulx.

The solution could be found in observations made on medieval vaults. Lassaulx says that he understood the principle of free-handed vaulting through the observations he made on the vaults of St. Laurence's Church in Ahrweiler. Seen from their extrados, these vaults appeared so irregular in their curvature that it was impossible to imagine that they could have been built on a formwork. And as in some portions the plaster was broken, their structure could be studied in detail.

Lassaulx incorporated the conclusions he had drawn from these observations first in some experiments with thin slabs of pumice conglomerate, and then put it into practice in his church projects.

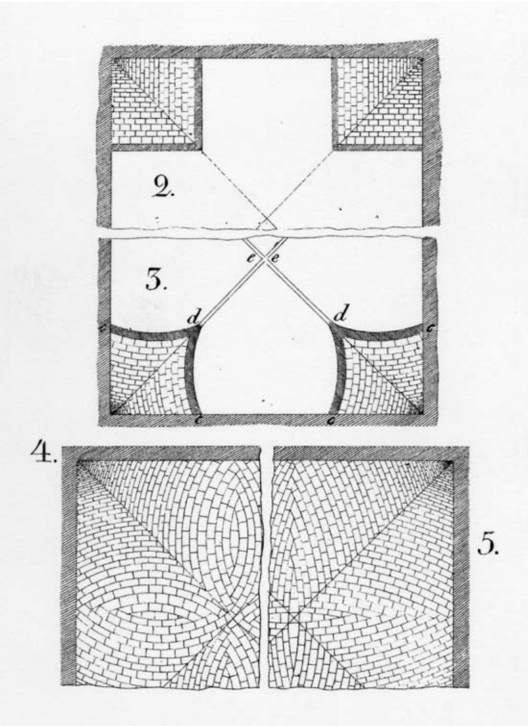

Figure 1

Illustrations from Lassaulx's essay (1829). Above: groin vault with straight and bowed courses. Below, vaulting pattern with horizontal (l.) and tilted (r.) courses.

Lassaulx formulates with great clarity the principle of the technique of free-handed vaulting he had explored: the individual courses form arches that are stable as soon as they are completed, offering a stable base onto which the next course can be laid. "The whole secret" is that the individual courses of the caps of the pointed vault, which are usually horizontal, are curved to the outside, each of them forming an arch or, as Lassaulx says, "a small vault in itself" as soon as it has some abutments on its ends. The bed joints of pointed groin vaults are not too much inclined, since the caps are quite steep; therefore the slipping of the masonry units can be prevented, and it is not difficult to lay the blocks to a self-supporting, completely stable course as soon as the arch is closed, and then to lay the next course on it. The abutments of the arches formed by the single courses are the vault's ribs or the centering arches set up in the groins. The thrust from the arched courses is neutralized by the confining caps, as long as the courses of the entire bay are brought up together - the procedure is not basically different from erecting circular domes, which can obviously be built with circular self-supporting courses.

If groin vaults are not pointed, but rather described by intersecting cylinders (like in "old", i.e. Romanesque churches), the horizontal courses would form flat arches and therefore would be difficult to construct.

In medieval vaults of this kind, Lassaulx says, one can often observe that the courses, instead of being horizontal, are tilted, rising from the diagonal groin to the wall with an angle of up to 45° with respect to the springing line. The reason to do so, according to Lassaulx, might have been to concentrate the pressure of the vault on the groins. Another reason would be that in this way the curvature of the courses increases. In fact even a barrel vault could be built in this way, "since all courses would then form tilted sections of a cylinder, thus consist in single elliptical arches" (p.321). This pattern is usually called "dovetail-pattern" (Gilly 1805; etc.); Lassaulx does not use this term.

Lassaulx mentions two auxiliary means for building vaults that have become well-known; however, in the essay he dedicates only a few lines to each of them, and he explicitly attributes them to the case of constructing semispherical domes.

One method is the stone-weighted rope device, well known through Fitchen (1961), which Lassaulx mentions to be used in Vienna: in the upper portions of a spherical dome, the bed joints get strongly tilted, and therefore the masonry units have to be prevented from sliding by pressing them to the bed of mortar. This can be done by means of a rope fixed on the extrados of the vault and weighted with a stone, and that will be moved to hold the next unit. Except for spherical domes, only very low cross vaults could need the use of this device (p.319).

The other auxiliary device is the trammel - a pole rotating from the center of the sphere that helps to control the form of the dome if built without centering.

As advantages of free-handed vaulting, Lassaulx mentions that besides the cost-savings for the formwork, vaults can be built thinner and lighter in this manner: In very thin vaults, he says, the movements of the formwork that damage the rising vault can hardly be avoided, the immediate removal of the formwork from the fresh vault is dangerous, and the delay of its removal may cause cracks due to the shrinkage of the mortar.

In the essay, there are only two references to technical literature. One is Rondelet's "Art de Bâtir" (the 5th edition, published 1812-14),[1] namely a passage from the 3rd Volume, that confirms Lassaulx's opinion that vaults may produce only little or even no horizontal thrust at all.

The other is Philibert de L'Orme; Lassaulx refers to an edition from Rouen of 1648.[2] The long passages cited directly in French are brought first to give confirmation to Lassaulx' hypothesis about the date of invention of the free-handed vaulting method, based on observations made by him on the Cathedral of Cologne. There, Lassaulx says, the earlier vaults are straight, and only the later ones are domed, so that he assumes the invention to have been taken place during the 15th century, which he believes to fit well with the fact that De L'Orme calls the pointed vault "modern". Secondly, it serves to introduce the nomenclature of the single ribs (croisées, liernes, tiercerons, formerets etc.) of a vault.

The buildings referred to at the end of the essay, in which Lassaulx put in practice his vaulting technique, are the churches in Valwig - a small church in "round arch style" -, in Kobern - the choir has a spherical vault where the trammel was first introduced - and in Treis.

2 Description of the church

The new Parish Church at Treis (1824-1831) is beyond doubt the most prominent of the three churches mentioned. It was one of the very first churches in gothic style in modern age in Germany - it was built in the same years as Schinkel's Friedrichwerder Church at Berlin, and was brought to attention by several publications.

The general layout is that of a hall church with three aisles and five bays covered with pointed cross-ribbed vaults, a polygonal choir, a tower in the center of the façade with a tall wooden spire, and a compact exterior appearance which is structured only by the attached buttress piers.

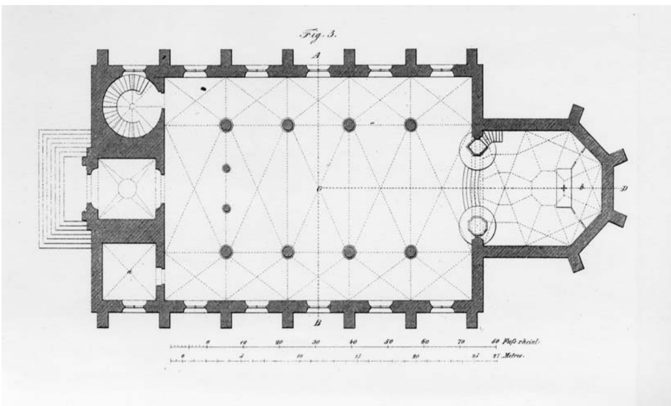

Figure 2

Plan of St. John's church in Treis, as published by Lassaulx 1836

The width of the central aisle is 10,36 m, that of the lateral aisles 3,92 m, and the length of the bays is 5,34 m. The vaults of the central nave rise 6,98 m over their springing. The vaults have transversal, longitudinal and diagonal worked sandstone ribs of the same profile. The caps are plastered; they are built of blocks of pumice conglomerate, with a thickness of about 20 cm including the plasters.

The cylindrical columns of the arcade, their bases and capitals, the profiles of the ribs as well as aspects of the entire layout, were apparently modeled after the late-medieval church in Ahrweiler where Lassaulx claimed to have understood the art of vaulting.

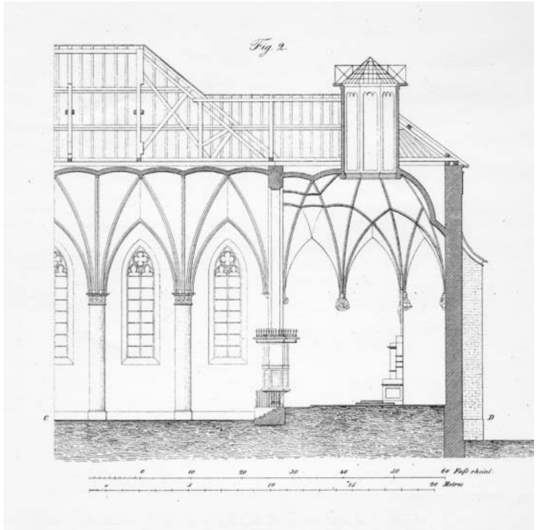

Figure 4

Longitudinal section of the church (Lassaulx 1836)

Figure 3

The vaults of the central nave.

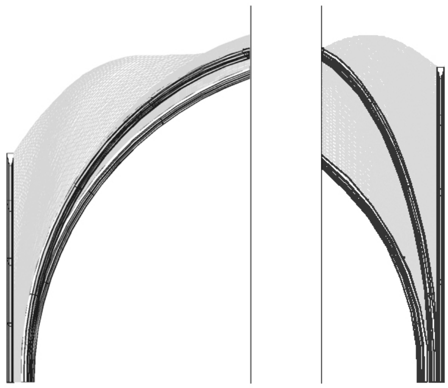

Figure 5

Transversal and longitudinal section of one bay of the vault in the central nave, as measured (CAD: Ye Zhang)

3 Analysis of the masonry pattern of the vaults

In 2001, the vaults of this church could be examined more closely. Before the painting of the intrados was renewed, the courses of the masonry were visible as a result of moisture marks that formed dark lines on the aged plaster.

In some caps, the lines of the bed joints have been measured with a digital tachymeter, as far as they were clearly visible. Along the visible lines, points were tracked with the laser and their three-dimensional position was measured; the resulting point clouds were then examined with a software tool for geometric reverse engineering ("Surfacer", now called "Ideas freeform modeler") in order to describe their geometrical properties. Apart from the geometry of the ribs and the vault on its whole, information about the masonry pattern of the vault, especially the geometry and the position in space of the courses could be obtained. The measurements and their interpretation regard only the bed joints of the courses on the intrados.

Observing the caps, one can see immediately that the pattern of the courses is far from being uniform throughout the vaults: different caps may present different meshes.

In some caps we can find a regular pattern of courses from the springing line to the top; in many others, though, some sudden changes in the direction of the bed joints are visible - above a certain course the following courses are tilted in a different direction, adjusting with triangular blocks cut *ad hoc*. These discontinuities can occur several times within the same cap. Since the vaults were intended to be plastered and their fabric therefore was not intended to remain visible, such irregularities were not disturbing their appearance. For us, however, a closer look to these discontinuities may be interesting, since we may consider them corrections in the growing masonry of the vault. Hence, understanding the motivation behind these irregularities might lead to the recognition of some construction principles.

The vaults are strongly domed: all caps present a significant double curvature. Their surface, however, is not spherical. The ridge line, in fact, is not circular, but describes a characteristic curve with non-uniform curvature (Figure 5). This proves that for the construction of these vaults the trammel (rotating pole device) was certainly not used.

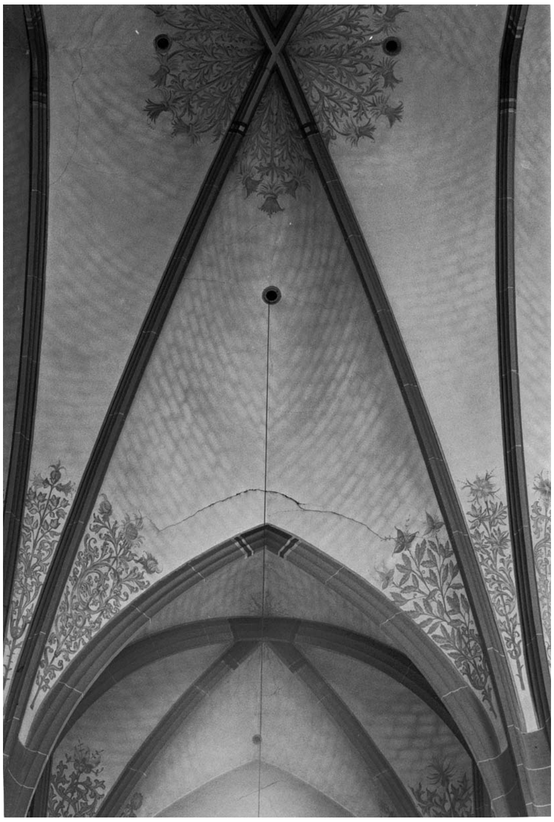

Figure 6

Detail of the vaults; the courses are visible. Note the changes in the bond pattern in the left portion.

There is no continuity of the masonry from one cap to another, but every cap is built independently. Behind the ribs the courses are not continuing, rather their fabric is interrupted. This is not visible, but can be deduced by the fact that the bed joints of two neighboring caps are neither continuing in position, nor in direction, nor are they lying in the same or parallel planes. Such an interruption of the masonry bond between the caps is significantly different from the description of the laying of the courses as it is proposed in the technical literature, especially the dove-tailed pattern (Ungewitter 1859-1864).

The advantage of such discontinuity is that the individual caps, to a certain extent, can be built independently from one another - in that case, however, some care must be given to avoid that the growing domed masonry panel would push the centering arches to the sides, causing the collapse of the vault. In fact, Lassaulx writes that in such a case the centering arches must be laterally supported. According to the building records, an accident of this kind actually seems to have happened at Treis, after the masons disobeyed the architect's instructions and had attempted to complete a part of a bay on their own account (Schwieger 1968, 41).

According to the results of measuring, the curves formed by the visible lines of the bed joints are very close to circular arches - in spite of the rather irregular appearance of the cap seen from the extrados. However, the radii of these circular courses vary from one course to another, and throughout the same caps there are strong differences. Therefore, one can exclude the use of any kind of sliding template, like the "cherche movible" mentioned by Viollet-le-Duc (1844 ff., and in the "Dictionnaire").

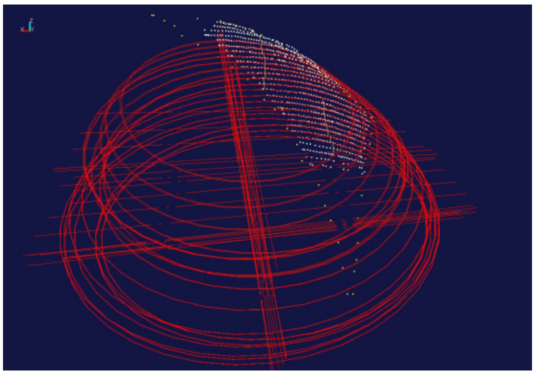

Figure 7

Enclosing circles of the single point clouds, showing the circularity of the bed joints in one portion of the vault (2nd from left in Figure 6); the curvature is varying throughout the vault.

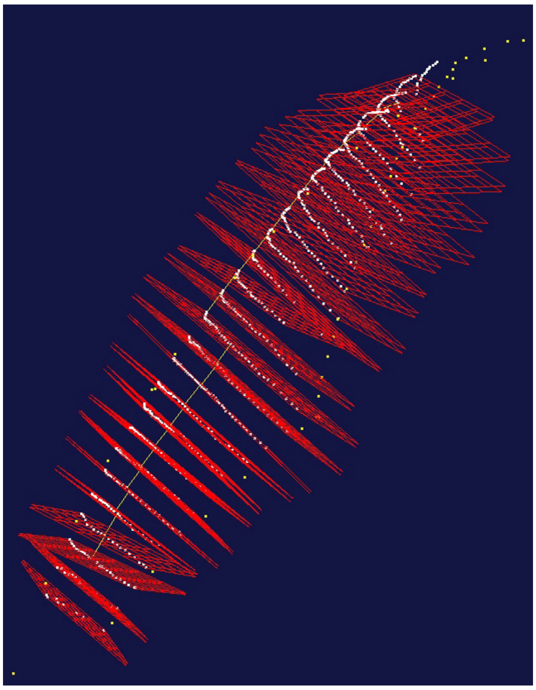

Figure 8

Enclosing planes of the single point clouds showing the parallel planes of the bed joints in Figure 7

Further, we observe that the bed joints are approximately lying in planes. These planes are tilted to the inside of the vault; in most cases they are parallel. This parallelism of the bed joints' planes is surprising considering that the technical literature throughout the second half of 19th century - namely Ungewitter and the manuals based on him – describes the planes containing the bed joints as being radial, all passing through the center of curvature of the vault.

At Treis these planes are parallel, less or more tilted to the inside. Only at the discontinuities mentioned above their direction sometimes changes drastically. However, in masonry with curved bed joints it is reasonable (and automatic) that the planes are parallel. Otherwise, if the planes were to form an angle, the thickness of the joint would not be uniform; rather they would vary according to the local distance from the axis (e.g. the center of curvature in case the planes would be radial). Such variations in the thickness of the joint would be questionable, not only with regard to the working process and the stability of the masonry fabric, but would also cause problems with the geometrical control of the rising structure. Therefore, the radial disposition of the pattern as proposed by Ungewitter and others appears more difficult and less practical.

As already mentioned, by diagonally tilting the planes of the courses, like in the dovetail pattern, it is easier in most cases to obtain curved (and therefore self-supporting) courses. In cylindrical caps, such tilted courses will be curved without giving a double curvature to the cap.

When building the vaults at Treis, Lassaulx abstained from this option. As mentioned, he gave a strong double curvature to the caps and apparently endeavored to begin and end the courses approximately in the same height above the springing. In some cases the courses seem to have resulted tilting towards the diagonal ribs, perhaps because these are longer than the longitudinal and transverse ribs, and were then corrected, continuing with courses running parallel to the springing line. Some of the large caps in transversal direction to the nave have courses that are slightly tilted towards the longitudinal ribs, contrary to the scheme of the dovetail pattern. In most cases, however, and especially in the higher portions of the caps, the bed joints begin and end in about the same height above the springing, but their planes are tilted to the inside, so that in elevation the bed joints appear as curves.

Figure 9

Extrados of the vault. The "horizontal" courses are visible, as also the form of the slope of the vault.

At the ridge, the courses of the neighboring caps meet each other and are bound together in a herringbone manner. There is no re-entrant groin; except for a small portion at the vicinity of the longitudinal or transverse ribs, the surface of the vault at the ridge is continuously curved.

At the locations where corrections of the masonry pattern were observed, the changes to the inclination of the bed joints' planes appear to be of minor importance and altogether not systematic: in some cases the planes change direction, in some cases the inclination increases significantly. Hence, these corrections probably were not aimed to reduce the inclination of the beds.

The major alterations in these corrections regard the curvature of the courses, and they are definitely systematical. In those caps that have been measured and that present these corrections, the radii of curvature of the courses are drastically reduced above the locations where their direction changes. In some cases, even such corrections that are hardly visible to the eye lead to a considerable reduction of the radius of curvature.

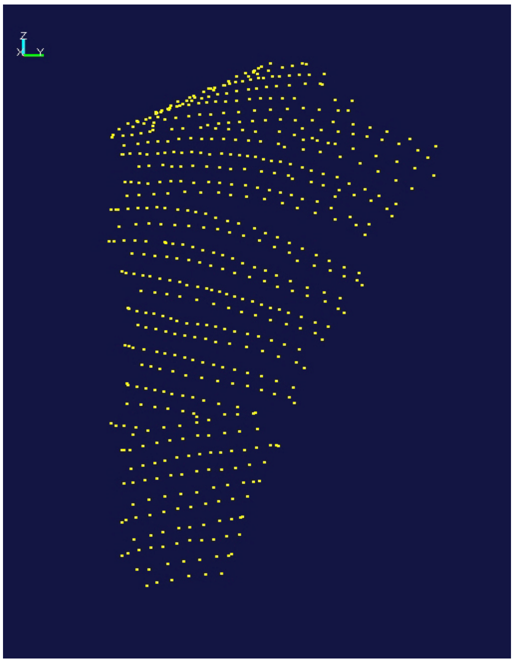

Figure 10

The courses of the left cap, Figure 6, as point clouds, in elevation.

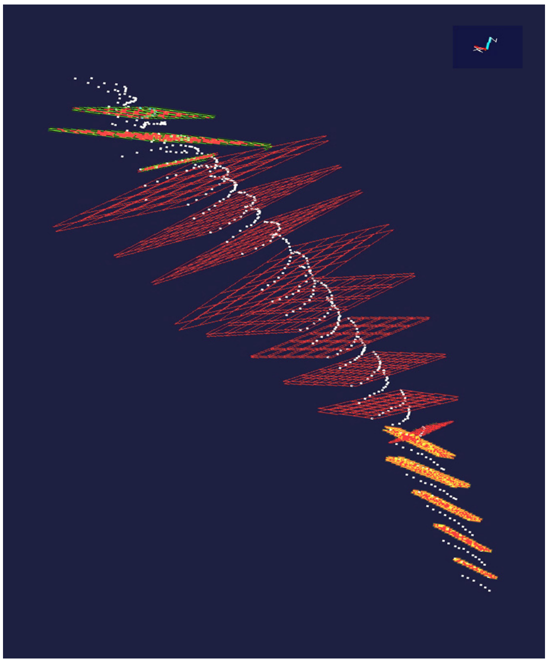

Figure 11

The bed joints' planes of the same portion. Note the changes in the directions of the planes.

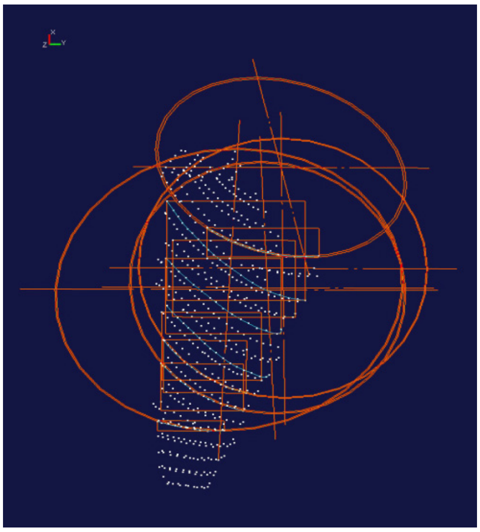

Figure 12

The bed joints' curvatures of the same portion, showing considerable reductions of curvature after the corrections in the bond pattern.

Therefore, Lassaulx's effort seems to have been oriented towards organizing the courses in such a manner, as to creating the radius of curvature as small as possible, without affecting the geometry of the vault. This is very consistent with Lassaulx's essay, since the basic principle of free-handed vaulting depends on the arch-like curvature of the courses.

The general strategy, as it emerges from these observations, seems to have been to raise the caps in their lower part (starting from the corbelling spandrel) along the ribs, gradually inclining them towards the inside, but then, in the upper half, to proceed straight ahead, giving a uniform inclination to the cap over a greater portion. The resulting form of this upper portion is that of an upright cylinder inclined towards the inside of the vault - the courses are thus bowing more and more to the outside of the ribs, and their arches are closed to a third of circle or more. The direction only changes at the top, where the courses are meeting those of the neighboring cap and therefore become shorter. The inclination of the vault's surface strongly decreases and the vault is closed; in this area, the bond becomes rather irregular, and the bed joints neither form circular arches nor planes.

4 Lassaulx's choice of the vaulting pattern

Within the examples of medieval vaults in Lassaulx's geographic vicinity (Rhineland, northern Germany, the Netherlands) either dove-tail patterns or patterns with courses running parallel to the springing line may be encountered. In the latter type, at the top of the domed caps, the bed joints form a characteristic lens-like figure.

When the dovetail pattern is implemented, the doming of the caps can be reduced, and within a course to be built, the individual masonry unit is not only laying on the bed joint, but is also being pressed to the preceding one because of the inclination of the course, which can be helpful for free-handed vaulting. Another advantage is the continuation of the bond over the diagonal rib, avoiding a joint at the groin which would weaken the structure.

As we have seen, Lassaulx well knew the dovetail pattern but chose not to use it. Perhaps he did not consider the continuity of the pattern as an advantage, since from the beginning the neighboring caps have to be built up together over the diagonal rib. Further, the courses of the four corners, due to their inclination, meet rather early at the ridge of the confining arches. This demands a rather tight coordination during the construction of an entire bay, which could have caused some difficulties to the construction process especially in vaults with greater dimensions.

Another reason for Lassaulx not using the dovetail pattern might have been his opinion of how the bond pattern of a vault influences the distribution of the loads and the resulting thrust. It is quite obvious from the respective passage of the essay that Lassaulx probably believed that a vault with horizontal courses would produce less horizontal thrust than one built with the dovetail pattern.

Another type of vaulting pattern, which Lassaulx probably knew, has its courses only slightly tilted towards the center, as described by Willis (1842, 8) as typical for English vaults. It presents an intermediate solution to those patterns already mentioned. Lassaulx's drawing of a vault with tilted courses is much more similar to this typology than that of the current dovetail pattern.

5 The lack of technical information

In his essay, Lassaulx states that he could neither find masons capable to build vaults without centering, nor was there any information available in the technical literature. The first statement regarding the masons obviously can hardly be verified today, with respect to what geographical area this might have been true. The second, however, can be interpreted on the basis of a comparative study of the technical literature available to him.

D'Espie's book describing timbrel vaulting, for instance, was well-known in Germany. A German translation circulated since 1760, and it is cited in many of the technical literature of Lassaulx' time. However, it was hardly considered useful because of the need of gypsum mortar, which was expensive and problematic for the local climate. To Lassaulx, this technique must have seemed of no interest since, apart of the vault typology associated with it (and shown in the tables) being far from "medieval" or "gothic", he is strictly orientated to copying medieval architecture in his area, where only half-stone vaults and no examples of timbrel vaults are found.

In Rondelet's treatise (widely known in Germany already prior to its translation), free-handed vaulting is not mentioned at all - even the D'Espie vaults are described to be built on centering.

As much as we know about Lassaulx, he certainly was well informed and highly interested in technical literature. He knows, cites and applies Rondelet's treatise, and one has to imagine him as a bibliophile and well-read person. In his publications, he habitually gives extensive reference to the sources he used. Hence, we should consider seriously his statement on the lack of written instructions on free-handed vaulting.

One may be surprised, therefore, to find a statement in David Gilly's "Landbaukunst" that cross vaults (and only those) can be built without formwork when using the dovetail pattern, which is also illustrated by a drawing. The third edition of this manual appeared in 1805, it was generally used and circulated within building professionals. The author had a determinant role in the development of the Royal Prussian building authority, and Lassaulx was an official of this same authority. Also, the fact that Lassaulx had close contact to Schinkel makes it extremely unlikely that Lassaulx would not have known this manual, despite the fact that there is no evidence that he was aware of it. And even if one might assume that he ignored it, one should expect that Crelle, the editor of the Journal that published Lassaulx' essay (who probably knew Gilly personally), would have intervened.

A possibility worth considering may be, that Lassaulx in fact knew this manual, but does not mention it because he did not consider the information given in it useful, but would not be in position to refer to it in a critical manner.

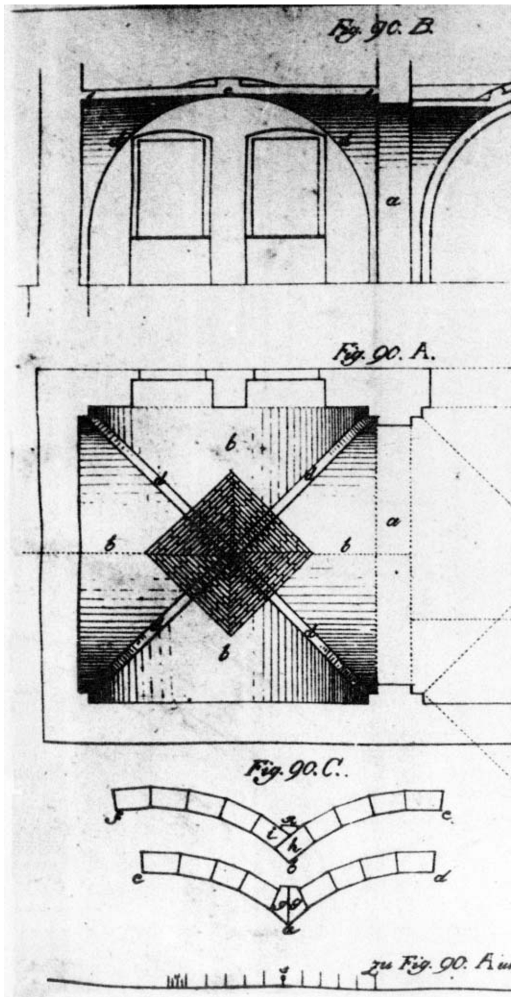

Figure 13

Plate in David Gilly, *Landbaukunst*, describing a cross-vault with dovetail pattern (Gilly 1805, fig. 90, detail).

As a matter of fact, Gilly only writes that "skilled masons" are needed to build a cross-vault without formwork, without providing any precise description of the procedure. In the drawing, the masonry pattern is represented only in the central part of the vault, where the bed joints form a square turned 45° with respect to the plan; the lower courses, as they depart from the springing, are not shown - neither in the plan, where they would appear curved, nor in the section. Gilly does not offer any precise description of the masonry pattern in drawing or in text, and therefore would not provide sufficient information to build vaults like the one in Treis.

What Lassaulx found lacking, and what he contributed to the technical literature, is in fact a precise technical description of a construction principle that allows its reproduction. In his essay, avoiding any consideration about the geometry of vaults (he would dedicate his lecture published in 1846 to that topic) he describes in a very concrete and clear manner the principle, and formulates guidelines of this type of construction. Such an instruction gives the architect the possibility to interfere in the construction process, and to link construction and architectural design.

6 The position of Lassaulx's essay in the technical literature

As far as can be said today, Lassaulx's essay met a rather broad attention. Beyond the distribution of the "Journal", translations of the essay were published in England and France. In England, it appeared in 1831 in the "Journal of the Royal Institute", reported by Whewell (who had added a text by Lassaulx to his "Architectural notes on German churches" in 1842); this translation was cited by Willis (1842). In France, it was published in 1833 in the "Journal du Génie Civil" (Lassaulx 1846, Schwieger 1986).

Apparently, its contents also found their way into the technical literature. In Wolfram's exhaustive "Complete Manual of the Entire Building Art" (1838) that is mainly depending on Gilly and Rondelet, the essay is cited and referred to. In the chapter about the building of the caps (Wolfram 1838 vol.III.2, p.85), the principle of arched, self-supporting courses is explicitly pointed out (with reference to Lassaulx), and the drawings illustrating that chapter (ibid. fig.198a+b) are clearly depending on those of his essay (fig.5+6). In order to obtain the necessary curvature of the courses, the dovetail pattern is recommended.

Where Viollet-le-Duc explains the building of groin vaults in his essay on construction, published in several parts in the first issues of the "Annales Archéologiques" (1844 ff.), apart from the use of a sliding template he mentions exactly the same principles as Lassaulx: "… chaque rang de meollons étant bandé, et formant un arc de l'arête diagonale au formeret, ou à l'arc-doubleau, pouvait être abandonné à lui-même sitôt que le dernier morceau était pose." (Annales Archéologiques 2.1845, p.148). He mentions Lassaulx only in 1847; from 1846, however, in the "Annales" great attention is given to Lassaulx by Didron and other authors, and there is evidence for close contact. The French translation of Lassaulx's essay had been published 1833, twelve years before, and he had come to the attention of the readers of the "Bulletin Monumental" just a few years before, in 1838 (in the following number, he was mentioned as coeditor) - therefore it seems interesting to suppose, though it cannot be proven, that Viollet-le-Duc's statement is depending from Lassaulx.

Breymann - probably the most successful manual in Germany, first published in 1849 and then republished in 7 editions, with two major revisions, up to 1903 - doesn't mention the essay. One can only find a reference to Lassaulx's later essay from 1846, where a summary of the 1829 essay is given in a long footnote. But he cites (and mentions) Wolfram, so it is certain that he knew the contents of Lassaulx's essay. Besides, Breymann also extensively cites Willis' article on the geometric construction of vaults (1842) - without mentioning its author - where he could find a reference to Lassaulx's essay (this also proves that Breymann is very selective in mentioning his sources). In fact, one can find a drawing showing the auxiliary devices mentioned by Lassaulx, the trammel and the hanging stone device (Breymann 1849 t.24, fig.1). As both are shown together, it is hardly believable that the source would be other than Lassaulx.

The principle of self-supporting courses is only implicitly mentioned, the text on (free-handed) building of the caps (p.68) is based mainly on Gilly. However, what is essential is that it appears at all. For the rest, Breymann gives a much more detailed graphical representation of the cross-vault built in dovetail pattern than Gilly: in the plan, all courses are drawn and their projection in the lower parts is carefully traced. To reproduce the construction method is therefore easier than following Gilly's description. A graphical representation of the courses in elevation, however, can only be found in the 4th edition revised by H. Lang, in 1868.

Ungewitter - his manual on gothic architecture appeared in several deliveries from 1859 to 1864, a revised and extended edition was published by Mohrmann in 1890 - doesn't mention Lassaulx. In the foreword, however, he mentions two building manuals: Gilly and Wolfram. As stated above, Wolfram's manual quotes the main points of Lassaulx's essay; thus Ungewitter inevitably was aware of them.

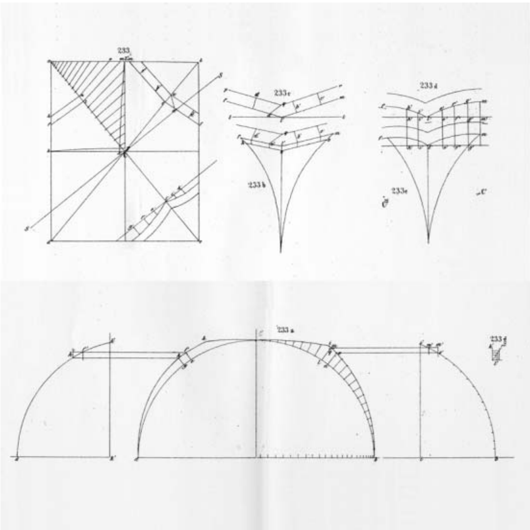

Figure 14

Ungewitter 1859-1864, t.8 (details). Geometric construction of the courses of a groin vault with dovetail pattern.

Here, a detailed and exact description of the geometrical disposition of the courses is supplied both in the text and the illustrations, describing the overall geometry of the severy, the position of the bed joint planes, and the curves of the courses themselves, referring to the principle of self-supporting courses. In contrast to Lassaulx, the dovetail pattern is preferred (as already in Wolfram 1838).

Such a precise description (leaving apart the question of its correctness) enables the architect to design all details of a vault, in general of a gothic construction, and to gain complete control of the working process. The close link between the properties of the materials and their working, and the design and the appearance of the entire building, finally becomes possible - as it had been clamed already by the neo-gothic avant-garde of the early 19th century and aimed to namely by Lassaulx.

Notes

1. The German translation of the 6th edition appeared only in 1833-36.
2. This is not the same edition David Gilly used and gave to the knowledge of the German public.

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