Early Iron Roofs in Belgian Churches (1845–60)

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Abstract. This paper sets out to assess the early age of iron roof construction in Belgian churches and its evolution through an in-depth analysis of a selection of cases situated in Belgium, an early-industrialised country with a fast-developing iron industry. The study is based on fieldwork, archive and literature study of three early iron trusses in churches in Brussels, Antwerp and Ghent. By providing renewed insight into the early use of iron and the evolution of the construction principles in churches, this study intends to encourage researchers, architects or heritage assessors to consider the roof construction of churches with greater care.

Keywords: Iron · Church construction · Roof construction · 19th century Belgium

1 Introduction

The adaptive reuse of churches is nowadays gaining more and more importance in Europe, but is often based on incomplete heritage value assessment methodologies. It is even truer when it comes to roof structures probably because they are hidden above the vaults. Many studies about timber roof trusses in churches prior to the 19th century have already been carried out in Europe [1–4]. Yet, when it comes to the early use of iron in churches, publications exist on a few iconic examples as the 1813–16 churches built in Liverpool with entirely cast-iron internal structures [5], the iron dome of St. Isaac Cathedral built 1838–41 [6], the roof trusses of the Cathedral of Chartres built 1840–45 by engineer Émile Martin and locksmith Théophile Mignon [7], and the St. Clotilde's church (1846–57) in Paris. Except in the Netherlands, [8] general studies of the construction history of 19th-century church roofs are lacking. In Belgium, recent inventories of 19th-century religious buildings in the three regions (Flanders, Wallonia and Brussels Capital Region) [9–12] paid little attention to the materials and techniques applied to their construction. The technologies – traditional or novel – that were used to

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build church roofs in this period have not yet been documented. When and how did the transition from timber to iron as a primary material for roof construction occur in churches? To what extent were the shape and connections in these iron trusses influenced by traditional timber carpentry and by the emerging iron technology? Who were the actors who introduced the new material in these structures and who designed the trusses?

This study is based on in-depth on-site investigations, archive and literature study of three early iron trusses identified in Belgian churches. Firstly, the transition from traditional timber to iron trusses is addressed with the analysis of the truss of the St. Joseph's church (c. 1845) built in Brussels by Tilman François Suys (1783–1861). Secondly, the improvement in the use of iron through a new truss morphology is illustrated with the truss of the St. George's church (1849–50) built in Antwerp by the son of Suys: Léon-Pierre Suys (1823–87). Finally, the last section considers the optimisation of iron trusses through the use of the rational Wiegmann-Polonceau configuration implemented in St. Anne's church (1859–60) situated in Ghent and designed by Louis Roelandt (1786–1864).

2 Intellectual Interest in the Use of Iron in Young Belgium

After Belgium gained its independence in 1830, King Leopold I wanted to preserve, study and promote the national past of Belgium as well as to enliven the intellectual life of the young country and stimulate scientific research. For the first aim, he created museums, archival institutions and, in 1835, the Royal Commission for Monuments, which advised and approved restoration and new projects for churches and other public buildings. For the second purpose, in 1845, the king decided to create the class of Fine-Arts (*classe des Beaux-Arts*) in the *Académie Royale de Belgique* in addition to the already existing classes of letters and sciences. From its very early days, this new class attached great importance to the construction of churches and to the use of new technologies from the industrial age. This is demonstrated by the 1846 question on architecture issued by the *Académie Royale de Belgique*, which asked the contestants to discuss the construction of churches according to the specific Belgian climate, resources and the technological progress, emphasizing in particular the influence of the flourishing iron industry [13]. The commission in charge of the evaluation of the submitted works, composed of L. Roelandts, Pierre-Bruno Bourla (1783–1866, architect) and Corneille-Pierre Bock (1804–70, historian and antiquarian), assigned a "honorable mention" to two dissertations [14]. The first dissertation, published in 1847 under the title *Mémoire sur l'architecture des églises,* was written by lieutenant-colonel Charles-Armand Demanet (1808–68). He pleads for material innovation: cast-iron columns, walls in concrete instead of stone (as applied in England), wrought-iron sheets for roofing (as applied in Russia and Poland), and chemically fireproofed timber. He clearly links the following parameters: the slope of the roof, the covering material, the material of the trusses, and the construction of the vaults. Talking about the latter, he advocates the use of iron ribs for the construction of lightweight brick vaults. When it comes to roof trusses, he pleads for the use of wrought iron because of its great fire resistance and its relatively low cost [15]. The second dissertation, written by architect

Henri-Désiré-Louis Van Overstaeten (1818–49), was published in 1850 after his death by his father-in-law: L. Roelandt. Although little is written about the use of iron, a long paragraph of the book is dedicated to the St. Mary's church, that he had designed and whose construction had just started in Schaerbeek, a booming suburb of Brussels. Here, when talking about the dome, he justifies the use of iron as a possibility to reduce the amount of structural material leading to significant cost savings (this dome was finally built much later using riveted steel elements) [16]. In 1847, as a proof of the interest in church construction, a new but very similar question was published by the class of Fine-Arts. The new commission composed of T.F. Suys, Henri Partoes (1790–1873, architect) and Antoine Schayes (1808–59, historian and antiquarian) received two dissertations. However, the commission decided not to award a prize as the two dissertations were considered not to have sufficient merit [17].

It is obvious that all these architects, engineers and industrialists, who promoted iron because of its durability, safety, aesthetic possibilities and relatively low cost were acting together and engaged in passionate debates about the use of new materials from the industrial age. It is therefore not surprising that the same actors were at the root of the development of iron as a roof-construction material in Belgian churches.

3 Early Iron Roofs in Churches: Three Belgian Case Studies

3.1 Transition to Iron Trusses: St. Joseph's Church in Brussels (1842–49)

As far as we know today, full-iron trusses appeared for the first time in Belgian church construction with the roof of the Renaissance-Revival St. Joseph's church (see Fig. 1), erected in Brussels in 1842–49 during the first urban extension of the capital. The new *Quartier Léopold* was a neoclassic grid plan neighbourhood for the elite, developed by a private company, the *Société civile pour l'agrandissement et l'embellissement de Bruxelles*. Architect T.F. Suys, already in charge of the urban planning of this new district, was contracted to design this church by Ferdinand de Meeûs (1798–1861), the principal shareholder in the company (who was also shareholder of the *Société générale*, which owned metalwork industries that he wanted to develop and promote). It is thus possible that iron was selected for reasons relating to the backgrounds of the stakeholders. Ferdinand de Meeûs was a progressive man: later, in 1855, he commissioned architect Raymond Carlier (1805–92) to design the first full-iron church in Belgium, near his castle in Argenteuil (inaugurated in 1862, this remarkable building was demolished in 1941) [18].

The trusses (see Fig. 2) that cover the three naves of St. Joseph's church were constructed circa 1845 using wrought iron for all the bars and the nodes of the trusses, as well as the purlins. Only the common rafters are in timber. The trusses of the main nave have a span of 10 m. They are composed of two curved principal rafters, a tie-beam to prevent these elements from spreading apart, a kingpost and two struts supporting the principal rafters off the kingpost. The trusses are braced longitudinally by means of two members that link the kingpost to the ridge purlin. All the trusses' members are flat rolled bars with a rectangular section varying from 50×20 to 70×25 mm. They are connected using square-headed bolts. One exception is the

Fig. 1. St. Joseph's interior (1842–49). Photo: R. Wibaut

iron-wedge assembly (inherited from timber connections), which is used to connect the curved rafters to the roof purlins (see Fig. 3). One explanation for the use of such a connection could be that wedges, which are easier to assemble, were used for the final in-situ assembly, while bolted connections were used for preassembly of trusses at ground level, prior to installation at roof level.

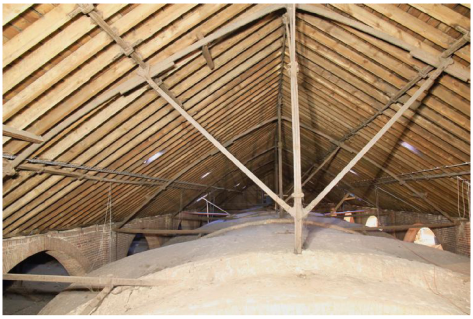

Fig. 2. St. Joseph's wrought-iron trusses (c. 1845). Photo: I. Wouters

As already mentioned for the wedges, this first application of (wrought) iron in the construction of roof trusses in Belgian churches clearly illustrates the influence of traditional timber carpentry on early iron roof trusses. An interesting feature that illustrates this transition are the assembly marks hammered and carved into the wrought-iron elements. This derives from the practice of carpenters, who marked all the unique hand-made timber elements in order to facilitate assembly at ground level followed by dismantling and reassembly in their final position at roof level. In the roof of St. Joseph's, as the different members were manufactured in wrought iron, the ends of each element were adjusted by hand in order to be sure that the elements of the trusses would fit together. The overall geometry of the trusses also appears as a transposition into wrought iron of a traditional timber kingpost truss typology. This typology, which is not suited to the use of iron, was progressively abandoned in favour of other dispositions more adapted to the properties of that material.

Fig. 3. Wedge assembly. Photo: I. Wouters

3.2 Improvement of Iron Trusses: St. George's Church in Antwerp (1847–53)

St. George's church (see Fig. 4) was erected in Antwerp from 1847 to 1853 in the Gothic-Revival style. Although architect F.J. Stoop won the competition launched by the church fabric for the erection of a new church, his plans were never realized due to a last-minute extension of the land available for use. The extended church was finally designed by T.F. Suys and its realisation was entrusted to his son, L.P. Suys [19]. However, due to dissent between the latter and the church fabric, he was dismissed in 1853 before the completion of the tower and finishing of the interior, later assigned to architect François-Heliodore Leclef (1811–78). The St. George's church is divided into three naves. They are all covered by iron trusses for which the realisation, by Ch. Marcellis' *Atelier de Construction*, straddles the years 1849 and 1850 [19].

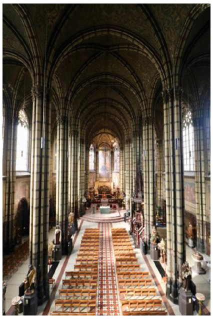

Fig. 4. St. George's interior (1847–53). Photo: R. Wibaut

The trusses of the middle nave (see Fig. 5) cover a span of 9 m and are each composed of two trussed wrought-iron beams made with ties connecting the ends of a round-profiled wrought-iron compression strut to each end of the principal rafter. The compression struts situated at mid-span and perpendicular to the principal rafters stiffen and strengthen the rafters in bending. The outward thrust of the two trussed beams on the walls is carried by a rectangular, rolled wrought-iron tie rod between the two lowest parts of the truss. This tie rod is supported by three vertical ties, one hanging from each trussed rafter and one hanging from the ridge connection. The trusses are longitudinally braced by making some trussed beams out of each purlin lying from one truss to another. Wrought iron was used for all the truss members and assemblies except the connections between the raked struts and the purlins. Here the wrought-iron compression strut is screwed into a cast iron connection element, which is connected to the purlins and the rafters using hexagonal-headed bolts, as used in all the other connections (see Fig. 6).

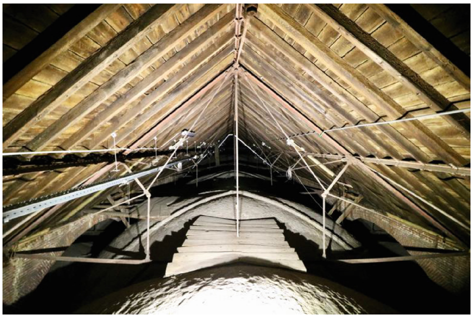

Fig. 5. St. George's wrought-iron trusses (1849–50). Photo: R. Wibaut

Fig. 6. Screwed connection. Photo: R. Wibaut

This second application of iron in the roof construction of Belgian churches shows an evolution in the overall form of the trusses. Rather than a form influenced by traditional timber construction, a new type of truss is used whose form and dimensions are better adapted to the properties of iron. The shape of the applied sections also evolved: both principal rafters and purlins are constructed in wrought-iron T-Sections (60 × 70 mm). Nevertheless, some characteristics remain influenced by timber trusses, such as the presence of a king-post and rectangular, rolled tie-beam (whose section is the same as used at St. Joseph's: approximately 20 × 70 mm), which could have been replaced by a horizontal tie linking the two trussed beams together, as used in typical Wiegmann-Polonceau trusses. Hence, although they do not have the Wiegmann-Polonceau form, the trusses at St George's already show a first step toward the implementation of this more rational configuration.

3.3 Optimisation of Iron Trusses: St. Anne's Church in Ghent (1853–62)

St. Anne's church (see Fig. 7) was erected in Ghent from 1853 to 1862 in the Rundbogenstil. The church was designed by L. Roelandt, at that time city architect of Ghent. However, L. Roelandt resigned in 1854 following dissent with the church fabric regarding the stability of the foundations and was replaced by the architect Jacques Van Hoecke (1802–62), who completed the works respecting Roelandt's design but in a more sober way [20]. Between 1835 and 1850, Roelandt presented several designs with hidden timber or cast-iron trusses [21]. He even proposed a project with a visible cast-iron structure [22] reminding the exceptional cast iron interiors built by foundry John Cragg in Liverpool in the 1810s [5]. However, after discussing these different projects, the church fabric finally opted, in 1851, for an innovative single-nave church comprising a large, column-free room. To cover such a large nave, it was decided to use Wiegmann-Polonceau trusses (see Fig. 8). In 1858, the contractor Charles-Louis Carels was appointed to construct the roof of the church. He had to assemble all the trusses after the completion of the vaults, before September 1859 [23]. It is important to note that in the two previously addressed churches, the roof trusses were positioned before the construction of the vaults had begun, which was common practice since the Middle Ages.

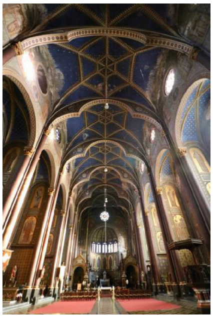

Fig. 7. St. Anne's interior (1853–62). Photo: R. Wibaut

As St. Anna's nave is 20 m wide (two times larger than the two previously addressed trusses), a double Wiegmann-Polonceau is applied. Such a combination allows to stiffen the long rafter. Hence, Roelandt opted for an optimal use of the different components. Because of their length (11 m), the principal rafters were made by riveting two rolled I-section wrought-iron beams end to end (see Fig. 9). This assembly was probably made in the workshop, unlike all other connections, which were made on the construction site (at ground level), using hexagonal-headed bolts.

Fig. 8. St. Anne's Wiegmann-Polonceau trusses (1859–60). Photo: R. Wibaut

Fig. 9. Riveted connection. Photo: R. Wibaut

As stated by Camille Polonceau in 1839, this configuration required the minimum quantity of materials, which resulted in a very light and cheap truss [24]. At that time, indeed, the cost of an iron structure was mainly determined by the amount of material, since labour costs were comparatively low. In this type of truss all the members are (in theory) loaded purely in tension or compression. Reflecting the different strengths of wrought and cast iron, Roelandt used traditional cast-iron cruciform sections, thickened towards their mid-length (optimal section to avoid buckling) for the struts and wrought-iron bars for the ties. The trusses at St. Anne's thus display a better understanding of the materials' different properties. From that time, the Wiegmann-Polonceau configuration was widely used in Belgian church roofs including those built during the second half of the 19th century (e.g. St. Catherine in Brussels, 1854–74; St. Amandus in Antwerp, 1869–74; St. Servais in Schaerbeek, 1871–76; Sacred Heart in Bruges, 1879–85). This type of trusses only ceased to be used at the very end of the 19th century, when steel began to be widely adopted by the Belgian construction industry.

4 International Network

Churches were not the first typology to introduce iron trusses. The *Théâtre Français* in 1788 and the *Salon carré du Louvre* in 1789 already had iron roof trusses. However, the real start of using iron trusses in Western Europe occurred simultaneously with the construction of the *Bourse de Paris* in 1823 and the *Marché de la Madeleine* in 1824 both using iron for fire-safety reasons [24]. These two buildings were respectively designed by Eloi Labarre (1764–1833) and Pierre-Alexandre Vignon (1763–1828), who were both professors at the *École des Beaux-Arts de Paris* at the time the Belgian architects Tilman François Suys (1783–1861) and Louis Roelandt (1786–1864) attended this school. It is therefore not surprising that iron was introduced into church designs after the 1838–39 Belgian industrial crisis, by those architects.

5 Conclusions

This paper sheds light on the roots of the design and construction of iron roof trusses in Belgium, by means of a systematic recording of several existing 19th-century church roofs. It gives an overview of the evolution that occurred in the design of iron trusses from timber-influenced iron trusses (at St. Joseph's, c.1845), via the use of a hybrid system (at St. George's, 1849–50) to the use of the more rational Wiegmann-Polonceau configuration (at St. Anne's, 1859–60).

Due to a lack of standard solutions available in mid-19th-century Belgium for the construction of iron roofs, a continuing search for suitable solutions and experimentation was necessary. In less than 15 years, indeed, the use of the material was progressively adapted from fully-wrought-iron trusses to composite (cast iron and wrought iron) trusses where the materials were chosen for their respective properties. The connections also give evidence of this rapid evolution. Although bolts and nuts were used for most of the connections in the three case studies, some specific assemblies are remarkable. Hence, at St. Joseph's wedge-connections inherited from carpentry are used, while at St. George's screw threads were introduced in the cast-iron connections. When it comes to St. Anne's, the principal rafters were connected with the hot riveting technique. The sections of the elements also evolved within these 15 years. At St. Joseph's, rectangular rolled-wrought-iron profiles were used for all the trusses' members, while a few years later with the construction of St. George's, round bar-iron (for both ties and struts) and rolled T-sections (for the rafters and the purlins) were used. At St. Anne's church, cruciform cast-iron sections were used to increase the buckling resistance of the struts and rolled I-sections were used for the rafters. Therefore, the period between 1845 and 1860 appears as a transition during which architects and contractors assimilated the characteristic properties of wrought and cast iron, learning from each other through experimentation and discussions.

Finally, it should be stressed that this paper provides new information to facilitate the structural and heritage assessment of historic iron roofs and is intended to encourage researchers, architects and heritage experts to consider carefully the construction of church roofs. Through understanding the evolution in the use of iron as roof construction material it is possible to identify the characteristics, strengths and weaknesses of these structures. In the near future, further on-site investigations will be undertaken to gain a more precise insight into the evolution of timber, iron and concrete roof constructions in Belgian churches from 1830 to 1940.

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