IRON AS CONSTRUCTION MATERIAL IN BUILDING CONSTRUCTION IN AUSTRIA IN THE SECOND HALF OF THE NINETEENTH CENTURY

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This present study deals principally with the material iron as an auxiliary building material, or, to put it more simply, those iron constructions which are not normally exposed to view. (1)
The late start made with the use of iron construction in building construction in Austria is best illustrated by a decree issued by the Court Chancellery in 1845, in which it is explicitly stated that there are no objections on the part of the surveyor's department to the use of iron arched girders, however, "every care must be taken in connection with gaining a preliminary conviction that those iron girders have the requisite load-bearing capacity". (2)
One of the earliest applications of iron girders in Austria is to be found in the extension to the swimming pool of the Sophienbad in Vienna which was begun in 1845 by the architects August Sicardsburg and Eduard von der Nüll. The ceiling (3) consisted of riveted box girders of approx. 32 mm thick iron sheet, with a curved lower flange and a polygonally-formed upper flange; the smallest cross section - for a clear span of no less than 17.7 m - was 263 x 2370 mm. It is also worth mentioning that the two architects also had iron vault girders incorporated into a side room, without calculating them - and immediately ran into difficulties. (4)
In 1856, during the construction of the offices for the First Danube Steamship Company in Vienna, the rolled I-girders were obtained from Belgium, because it was still not possible to produce them in Austria (5). In 1862, the iron works of the Klein family were the only ones in Austria producing such beams.(6) Significantly enough, it was one of the joint owners of that company, Albert von Klein, who had one of the first town mansions erected on the Ringstrasse, in the immediate vicinity of the opera, to the design of the architect Ludwig Förster, and here deliberately requested the use of iron pillars and girders as far as possible. (7)
Even in 1864, I-girders could only be supplied to special order by the majority of factories, so that the Austrian Engineers' and Architects' Association formed a committee of its own, which in 1865 drew up a list of ten sizes of I-girders, with heights ranging from 105 mm to 316 mm, which the steel mills were recommended to produce and stockpile. (8) Sixteen year later, in 1881, the position was somewhat different: there were 62 different rolled steel sections available on the Austrian market, and the afore-mentioned association now felt constrained to publish a recommendation for the reduction of the number of types. (9) The major iron construction companies of the period were already offering riveted girders as prefabrication components: for instance, a catalogue from the Ignaz Gridl company from 1883 contains such I-girders and bow girders in heights ranging from 158 to 1.111 mm. (10)
The majority of rolled girders were used in crown ceilings, that is shallow segment barrel vaulting constructed with bricks set between iron girders, which were given the nickname "Wiener Platzln" (Viennese biscuits) in Austria because they were so widely used in the capital. It was possible to construct these ceilings using simple templates, thus making them cheap, and initially they were used especially as fire-proof ceilings over cellars, ground floors and uppermost storeys - in keeping with building regulation requirements. Probably the first dwelling house in Vienna to have such ceilings on all floors was again - characteristically - a house for the afore-

mentioned industrialist, Albert von Klein, at Dr. Karl Lueger-Platz 2, built by the architect Karl Tietz between 1867 and 1869.(11)
However, the use of these ceilings was by no means restricted to tenement houses, in which, for obvious reasons, there had to be economies, they are also to be found in the majority of monumental constructions: thus, for instance, almost all the rooms in the Vienna City Hall, erected between 1872 and 1883 to the plans of the architect Friedrich Schmidt, have such ceilings. They were, however, only left bare in the rarest instances, for the most part they served as bearing constructions, from which the ceilings proper were suspended.
An obvious further development of this type of ceiling - influenced not least by the then widely held opinion that iron provided a great degree of fire safety - were the so-called calotte ceilings. In this system, section iron plates with concave indentation pointing upwards were riveted in between the iron girders. Hasenauer, for instance, had such ceilings constructed above the main staircases of the Natural History and Fine Arts Museums in Vienna. (12)
The "corrugated iron girder" represented an even simpler system which could be spanned from one impost to the next. The underlying principle of these sectional plates lay in the fact that the corrugations were higher than they were wide, resulting in a straight section between the peak and valley of the corrugation, something of considerable importance for the ability to bear loads. The afore-mentioned Gridl company, for instance, had an imperial charter on this construction system; admittedly, we no longer know the date of the original invention, the charter for an improved version was granted in 1875.(13)

The problem of suspended ceilings mentioned above was often solved by means of so-called "agraffe constructions". They came - just like the word "agrafe", meaning "hook" or "clasp" - directly from France, and were also known as "Vaux Constructions" from the name of a Parisian locksmith. The principle of these constructions is best shown by a study paper, unfortunately neither dated nor signed, from the former Polytechnical Institute in Vienna; (14) flat-iron bars, arranged in a clasp-like pattern between a bearing system of appropriately dimensioned iron sections, form a net which is bricked over with hollow bricks. A plan for the construction of the Natural History Museum in Vienna in 1874 shows such a suspended ceiling. (15) Much more complicated - and for the observer almost incredible - there are agraffe constructions over the entrance halls of both the Natural History Museum and the Fine Arts Museum in Vienna. Optically, the cupola, with its ground plan span of 15.76 m, appears to be supported on the massive butress on the one and, and by a stone ring in the middle on the other, through which it is possible to see the cupola above.
As a matter of fact, however, the bearing ceiling consists of truss-like corbels arranged in circular pattern, from which the vaulting is suspended by means of agraffe constructions. (16)
The so-called "Parisian grids" represent a similar construction element: a sort of small iron bridge construction from which wide spanning, straight trusses could be suspended. This system also came directly to Austria from France; evidence for this is to be found in various papers in the first volumes of the Allgemeine Bauzeitung reporting on these "strange constructions", (17) with which in Paris the whole ground floor area of buildings was opened up for shops and cafés facing out onto the newly-created boulevards. -

One of these reports from 1849 is by a then relatively unknown Viennese locksmith by the name of Ignaz Gridl. However, about twenty-five years later, the in the meantime well-established Ignaz Gridl company was using quite similar constructions, such as, for instance, for the trusses in the parliament building. (18)
The "Parisian grids" used in this construction consist of flat iron bars laid on their edge; in principle, they are made up of one straight lower chord and one curved upper chord. Depending on the width of the lower chord, two or three such iron pairs are joined together by further flat iron bars to form construction cages, which are faced with bricks and then given a plaster finish. Flat iron lugs are mounted at the ends of the lower chords to anchor the cages in the brickwork. The spans in this example are 2.98 or 3.44 m respectively. The dimensions of the iron bars are about 15 x 75 mm; the baskets are 40 or 45 cm respectively in height.
Many apparently conventionally built, solid-brick buildings had considerable parts of their bearing systems built using these individual iron construction elements, of which it is only possible to give a few examples here. An example of this is the former Court Theatre scenery depository which was erected between 1874 and 1877 by the architects Karl Hasenauer and Gottfried Semper: from its external appearance, the building, with its Renaissance forms, is completely in keeping with the traditional concept of a building of the eighteen-seventies. The ground floor is faced in plaster imitation stone block construction, the first and second storeys with brickwork, the third storey has slender pillars between which there are large window openings. - In fact, however, of the bearing parts, only the external walls and one central wall are built of bricks.
Without wishing to go into more detail about the ground plan, (19) which ingeniously overcame the problems of a difficult site, the actual bearing system was formed of cast-iron pillars. These pillars, arranged in a grid patter, are set directly on top of each other in all four storeys, separated only by connecting pieces which are of the same height as the ceiling construction. The diameter of the pillars is 26 cm, the height from floor to floor 6.00 or 6.32 m.
The ceiling construction is inserted in between the pillars in the connecting pieces and is made up of riveted beams, between which there are wooden beams, which, for their part, are supported against one another by cross links. In the painters' room there is a metal calotte ceiling which is borne on a frame, itself constructed of iron sections. Here, the individual metal sheets are riveted to the girders of the roof construction and covered with a layer of concrete. - The polygonal transverse wall dividing the building into two large sections for fire-fighting purposes, with its wide door openings, is also constructed around cast-iron pillars.
Iron roof frames should, of course, also be mentioned in connection with the large bearing constructions, not generally visible, which are to be found in almost all monumental structures of the Historicism period.
As is generally known, the first cast-iron roof frame constructions were erected in Vienna shortly before the middle of the nineteenth century: as the most important example, one should mention the cast iron roof trusses over the winter swimming school in the Dianabad swimming pool, constructed from 1841 to 1843 to the plans of Ludwig Förster and Karl Etzel. (20) The important thing about that structure was that it displayed the roof trussing without any covering as a conscious part of the interior architecture - an idea which was undoubtedly new in Vienna. The creator of this idea was indisputedly Ludwig Förster who had been publishing the first German language

building periodical (21) since 1836, had made numerous study tours and knew the comparable English examples.
The transition from cast-iron to wrought-iron construction took place in Vienna, by the way, in general between 1850 and 1860. The so-called Bank and Stock Exchange building, built by Heinrich Ferstel from 1856 to 1859, already had iron roof frames over the clerestories in the passage area and the covered inner courtyards, but still in part resting on cast-iron corbels encased in zinc sheet. (22)
Something which is characteristic for the transition from cast-iron construction is the difference in material between the design and the execution stages, something which can be observed repeatedly.
The plan submitted in 1860 by Theophil Hansen for the construction of the Protestant School still shows cast-iron construction over the courtyard (23); the project was carried out in 1862 using wrought-iron French trusses. There is a draft design for the Stock exchange building by the government architect Paul Sprenger, dated April 15th 1851, which also shows a massive cast-iron roof frame. (24) In the course of the construction of the Stock Exchange which, however, took place much later, from 1871 to 1877, under the architect Theophil Hansen, a wrought-iron roof frame was included, on the other hand, as a matter of course.
A decisive point in the development of iron roof frames comes with the roof over the main nave of the Votivkirche in Vienna which was constructed in 1865/66. There is a plan still in existence from the Althütten Engineering Works (25), the execution of which would certainly not have been possible for statical reasons.
Apparently at the same time, or perhaps a little earlier, a design had been obtained from the English company Ordish & Le Feuvre (26), which envisaged a cast-iron construction with simple tension bracing. The interesting point here is that the contract was not, it is true, awarded to England, the principle employed in the bracing is, however, clearly to be found again in the structure erected in 1870, to the designs of the engineer Eduard Leyser and produced by the G. Sigl Engineering Works. (27)
Of the many iron roof frames constructed in Vienna, we would here at the moment just mention the cupola structure of the church of Our Lady of Fictories (Maria vom Siege), constructed between 1867 and 1875 by the architect Friedrich Schmidt. The cupola is among the most impressive iron constructions from the Historicism period in Vienna. It has an icositetrahedral ground plan, with a support width of about 19 m. (28)
A few years after the completion of the church, Friedrich Schmidt once again had occasion to deal very intensively with the problem of iron roof frames in the construction of the City Hall in Vienna. Working in close cooperation with the companies involved in the building, the architect developed seventeen different constructions for this building alone which were executed in 1878/79. The darft and construction plans still in existence (29) here provide an excellent insight into the practical planning procedure: the architect first developed a construction system, in accordance with his own ideas, which was then revised by the company carrying out the work, in this case once again, the Ignaz Gridl company. Firstly, a larger scale system sketch was prepared, with the help of which the statical checks were made, and then the detailed drawings were produced.
The statical checks on such, in part, extremely complicated rodwork were conducted, by the way, almost exclusively using graphic methods, introduced, as is generally known, by Carl Culmann, and which had also spread rapidly in Austria with the publication of his main work "Graphical Statics" in 1866. (30)

Even more interesting than the examples quoted up to now are those buildings, or parts of buildings, in which whole steel skeleton constructions were carefully concealed behind plaster and stucco work. Here we would mention the former auditoria of the Vienna Opera House and Burgtheater. The ceilings of the dress circles and the boxes in the opera house were in agraffe construction, resting on solid cast-iron pillars. (31) The pillars were rectangular in section, measuring 53 x 158 mm. Every pillar had a head plate and a base plate incorporated as part of the casting, measuring 316 x 210 mm. It was possible to bolt both the iron girders of the ceiling construction and the base plate of the next gallery pillar up into a specially formed head piece. The pillars were partially concealed in the corridor walls, and partially in the partitions between the boxes. It was certainly not possible to see in the auditorium that it was for the most part made up of iron constructions.
The auditorium in the Burgtheater was constructed in a very similar fashion. (32) However, here the ceilings were formed by a close network of I-girders with corrugated iron girders in between; box girders of 145 x 283 mm cross section, made of wrought-iron and rolled-iron sections, were used as supports.
One construction which appears especially curious to the modern observer was erected about 1910 in the first storey of the central part of the Neue Hofburg. (33) The room involved has a cruciform ground plan, over the crossing is a higher calotte-form cupola, apparently resting on pillars and pilasters, while over the side arms of the room there is a semicircular barrel vaulting. In fact, the whole load-bearing system is made of iron, the vaulting is formed in agraffe constructions, and the bearing supports of the cupola also consist of riveted iron sections. The whole iron frame was covered and decorated with an elaborate stucco decor, with bases and capitals for the pillars. Nowadays, the corresponding parts of the iron construction are bare in the roof area, so that there can be no doubt about the realisation of the detailed plans which are still in existence.
The examples quoted, which have been taken from a comprehensive research project (34) and could be added to at will, do permit some generally valid conclusions - at least as far as Austria is concerned:

1. Iron became an accepted building material, also actually used in practice in building construction, at a relatively late date, namely not until the second half of the nineteenth century.
2. The introduction of iron in building construction was not dependent on the development of statics and material mechanics, but much more on the economic and building organisational advantages which the "new" building material had over traditional materials.
3. Iron constructions developed in the second half of the nineteenth century for the most part independently of the architectural appearance; the historicising building forms were just put on over the technical structure, much as one might put on a shirt.

Notes

1. The most important Austrian iron buildings from the second half of the nineteenth century have already been presented at the last symposium in Bad Ems. Cf.: R. Wagner-Rieger, Eisenarchitektur im Wiener Historismus, in: ICOMOS (ed.), Eisenarchitektur. Die Rolle des Eisens in der ersten Hälfte des 19. Jahrhunderts, Bad Ems 1979, Vincentz-Verlag, Hannover 1979, pp. 126-131.

2. Decree from the Court Chancellery of the 23.6.1845, Zl.15.895 and the government ordinance of the 9.7.1854, Zl. 40.175.
3. Vienna, Department of plans and documents (Plan- und Schriftenkammer), No. EZ. 1089/III, detailed plan, signed "van der Nüll et Sicardsburg", "Peter Gerl, Building Engineer" and "Franz Morawetz", stamped the 13th August 1845.
4. Vienna, Department of plans and documents, No. EZ. 1089/III, sheets 6/1-2, decision of the city authorities dated the 17th August 1846.
5. M. Schimmelbusch,Ueber die Anwendung des Eisens zum Hochbau, in: Zeitschrift des österreichischen Ingenieur- und Architektenverbandes, Vol. 16, Vienna 1864, pp. 44-66.
6. L. Förster, Wohnhaus des Herrn Albert von Klein in Wien, in: Allgemeine Bauzeitung, Vol. 27, Vienna 1862, p. 241.
7. L. Förster, Wohnhäuser in Wien, Ecke der Ringstrasse zum Ausgang der Kärntnerstrasse links, in: Allgemeine Bauzeitung, Vol.27, Vienna 1862, pp. 27-29.
8. A. Bochkoltz, P. Fink, C. Gabriel, E. Leyser, J. Winterhalder, Bericht des Comité's zur Feststellung von Typen für gewalzte Eisenträger und deren Anwendung im Baufache an den Verwaltungsrath des österreichischen Ingenieur- und Architektenvereins, in: Zeitschrift des österreichischen Ingenieur- und Architektenvereines, Vol. 17, Vienna 1865, pp.14-17.
9. G. Rebhann, J.E. Dörfel, J. Buberl et al., Bericht des Vereins-Comité's zur Aufstellung neuer Typen für gewalzte Träger und einige andere Walzeisensorten, in: Zeitschrift des österreichischen Ingenieur- und Architektenvereines, Vol. 34, Vienna 1882,pp.7-11.
10. J. Gridl, Tabellen zur Berechnung der Tragfähigkeit und des Gewichtes von gewalzten und genieteten Trägern, Eisenbahnschienen, gußeisernen Säulen etc. 1st edition, Vienna 1883.
11. Vienna, Department of plans and documents, No. EZ. 1472/I.
12. Vienna, Archive of the Gebäudeverwaltung des Kunsthistorischen und des Naturhistorischen Museums, plan No. 11, dated 12.12.1877, signed Ig. Gridl.
13. Vienna, Austria Patent Office, Charter No. 25/26, granted on the 16.I.1875.
14. Vienna, Archive for Building at the Institute for Construction for Construction Engineers at the Technical University Vienna, No. A III/27/467.
15. Vienna, ibid. Note 10, Plan No. 674, dated 17.7.1874, signed Ig. Gridl.
16. Vienna, ibid. Note 10, Plan No. 1382, dated 30.11.1878, not signed.
17. Anonymous, Eigenthümliche Konstrukzionen an Gebäuden in Paris, in: Allgemeine Bauzeitung, Vol. 2, Vienna 1837, pp. 311-313,321 ff., 334-336, 337-341, 345-347, 353-360. Anonymous, Eisenconstructionen für Brücken, Träger, Dachstühle, Fenster, Thüren usw., in: Allgemeine Bauzeitung, Vol. 29, Vienna 1864, pp.393-396,sheets 688-691. (I.) Gridl, Eisenkonstrukzionen an der Passage Jouffroy zu Paris, in: Allgemeine Bauzeitung, Vol. 14, Vienna 1849, p.5, sheet 235.
18. Vienna, Archive of the Gebäudeverwaltung Parlament, No.226, not dated, not signed.
19. Vienna, Archive of the Gebäudeverwaltung des Öterreichischen Bundestheaterverbandes, Plan No. 136, dated 20.1.1876, signed Ig. Gridl, and 9.3.1876, "seen Hasenauer".
20. K. Etzel, Das Dianabad in Wien, in: Allgemeine Bauzeitung, Vol.8, Vienna 1843, pp. 115-121, sheets DX-DXIV.
21. L. Förster (ed.), Allgemeine Bauzeitung, Vienna 1836 ff.
22. H. Ferstel, Der Bau des neuen Bank- und Börsengebäudes in Wien,in: Allgemeine Bauzeitung, Vol.25, Vienna 1860, pp.1-3,sheets 308-316.

23. Vienna, Department of plans and documents, No. EZ. 794/IV.
24. Vienna, Archive of the Chamber of the Stock Exchange, no number, dated 15.4.1851, signed Sprenger.
25. Vienna, Parish archive of the Votivkirche, No. VI/7, dated 31.8.1866, signed Ad. Fischer, stamp "Fürstliche Colleredo-Mansfeld'sche Maschinenfabrik Althütten".
26. Vienna, Parish archive of the Votivkirche, No. VI/8, dated 20.4.1865, signed Carl R.v.Wehsely, stamp "Ordish & Le Feuvre, 18, Great George Street, Westminster".
27. Vienna, Parish archive of the Votivkirche, No. VI/11, signed Mayer, stamp Eduard Leyser.
28. (A.) K. (östlin), Kirche in Fünfhaus nächst Wien, in: Allgemeine Bauzeitung, Vol. 40, Vienna 1875, pp.59 ff. sheets 61-64.
29. Vienna, Department of plans and documents, archive in the attic.
30. C. Culmann, Die graphische Statik, Zürich 1866.
31. Vienna for Building (see note 14) Note 17, plan No. 277 c, not dated, not signed.
32. Vienna, Archive of the Gebäudeinspektion Burgtheater, Plan No. 1235, 1230, not dated, not signed.
33. Vienna, Archive of the Burghauptmannschaft, Haus-, Hof- und Staatsarchiv, at present in the Kriegsarchiv, No. K-476, Plan No. 452, dated 31.8.1910, stamp of the Max Wahlberg company.
34. M. Wehdorn, Die Bautechnik der Wiener Ringstrasse (Die Wiener Ringstrasse - Bild einer Epoche, Vol. XI), Wiesbaden 1979.

IRON ARCHITECTURE IN THE BOHEMIAN LANDS FROM THE MID-NINETEENTH CENTURY UNTIL ART NOUVEAU

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The Bohemian lands had already been to the forefront in iron production in central Europe for some centuries. Production in the modern period thus has a long tradition in the past. Already by the end of the first quarter of the nineteenth century, iron architecture was beginning to influence the appearance of our countryside. It was first represented by several chain suspension bridges. Their main planner, the engineer Friedrich Schnirch, built the first chain bridge over a side arm of the Morava close to the town of Strážnice in south-east Moravia in 1823-24. It was the earliest chain suspension bridge on the European continent, with a span of nearly 30 m.

Only one of these chain bridges has survived down to the present. It was built by Friedrich Schnirch to provide a bridge across the Vltava (Moldau) for the Tábor-Pisek road in 1847-48. The bridge was dismantled in 1960. The granite blocks and iron components were transported into the nearby valley of the Lužnice, where the bridge was reconstructed in 1975. It was classified as a historical monument and is used as the river crossing of a minor road in this picturesque landscape.

By the period shortly before the middle of the last century, iron architecture had developed within the framework of late, Gothicising Historicism. Direct English influence played a decisive role here.

In the Liechtensteins' castle at Lednice (Eisgrub) on the Moravian-Austrian border, the iron glasshouse or palmhouse was erected in 1843-45 to the design of the English architect P.H. Desvignes. The cast-iron construction was supplied by the Klein Brothers' Iron Works in Sobotín in northern Moravia.

An exact parallel to this is the iron orangery erected by the engineer Damian Devorecký, following English designs, in the Schwarzenbergs' south Bohemian castle of Hluboká.

By 1830, the technique of iron statue casting had been highly developed. The centre for this were the Salmische Eisenwerke foundry in Blansko to the north of Brno (Brünn), which was also called the "School of the Moravian Foundry Industry". Sculptures, monuments and reliefs were cast there with the greatest skill and to high artistic standards.

Already from the eighteen-twenties on, cast iron had made its breakthrough as a material for architectural details, mainly for staircases and railings in general. We could take as an example the stair handrail on the magnificent stairway in the town mansion No. 1023-II in the New Town in Prague, opposite the new railway station. The mansion was built by the architect J.O. Kranner in 1843-44 for Albert Klein, a member of the afore-mentioned iron-founding and railway-building family. The renowned Viennese architect, Ludwig von Förster, built a town mansion for the Klein brothers on the main square in Brno(Brünn). The building, which was erected in 1848, was at the same time intended to represent the products of the Kleins' iron foundries in Sobotín. Within the framework of the late-Classicistic façade composition, Förster employed very original and striking cast-iron architectural elements. On both sides of the frontage of the house, two two-storey high bay windows project out, each richtly decorated with figures and ornaments. Cast-iron details were also particularly developed for the windows and on the main cornice. In the case of the cast-iron components, the decorative function played a more important role than the structural one. The whole frontage of Förster's mansion was an interesting