Iron constructions for factory buildings in Berlin in the nineteenth and early twentieth century

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Paradoxically iron constructions which were decisive for the development of Berliner metal and metal tool industries were seldomly and only gradually applied from 1837 through 1870 for the erection of shops and factories, at that often in combination with wooden elements of construction. (The oldest industrial building of Germany, the foundry assembly hall built by C. G. Langhans (1825), is not in Berlin). The first cast and wrought iron weight carrying structure for utilitarian buildings in Berlin was constructed for the storehouse of the Schickler’sche Zuckersiederei (1835) by F. Hesse, after having visited England, and the first inner iron skeleton construction was erected by L. Persius and L. Dannenberger on the Mühlendammbrücke (1844–48).

Essential for the use of iron constructions was the challenge of fire protection. The conflagrations of 1831 and 1838 which destroyed the Factory of Cockerill and the Dammühlen, and the fire which ravaged the opera (1843) gradually set off more and more the use of the new building material iron in the Berliner construction engineering. As early as 1831 fireproof iron roofings were built for steam boiler shops. All the same iron constructions had been built abroad much before that, for instance structural systems for mills and storehouses in England. Also market halls were erected with iron elements. But for economical reasons the building material iron was only used for Berliner shops and factories by the 40’s.

The late works of the architect K. F. Schinkel, such as the Bauakademie (1831–35) and the Packhofspeicher (1835) served partly as model for the emerging Berliner industrial architecture. Both buildings have been cited in the literature of the history of architecture as landmarks of construction. They were looked upon as anticipation of serial building as well as forerunners of modern skeleton and frame constructions (Ausstellungskatalog 1981).

K. F. Schinkel had experienced impulses from English factories which he had investigated during his study trip to England 1826 (Riemann 1986). The English stripped down, utilitarian architecture of warehouses and docks were though not taken into account by Schinkels followers, although a new critical point of architecture and construction had been achieved with the Albert-Docks in Liverpool (1841–50). The early English iron constructions influenced the construction of industrial architecture and railway station buildings in Berlin though also by first hand information (Frühauf 1991).

In the following a selection of iron construction elements, columns, roof constructions and floor structural systems are going to be displayed, to illustrate the specific development in Berlin.

Columns

The slender iron cast columns gradually got carried out in Berlin since the 40’s, partly because the unbreakable wooden counterparts in warehouses and factories needed a diameter of 0.50 cm. Normally the
large supporting capitals carried two beams as joist (for instance: industrial courts at Bethanien-Damm 59, Leuschner Damm 9, Waldemarstraße 27). The architect L. Hesse proposed for the above cited fire-proof storehouse building also cast iron hollow columns for all the four stories, following English models. The beams and joists were performed though in wood. The stories rested on three rows of columns with a diameter of 18.3 cm, 15.7 cm and 13 cm, the wall thickness being 1.3 cm. The lower columns had to carry a compressive stress of approx. 1600 kg, having a weight of approx. 260 kg each. (fig. 1).

Chronologically the columns of Hesses' storehouse building were followed up by shops and factories for A. Borsig (1837–40, 1844 and 1861) in Berlin, however only for groundfloor assembly halls. The master carpenter G. Schamweber designed cast iron columns for the saw tooth roof hall of the carpet weaving mill Preatorius & Protzen at the Engelrufer (1854). These columns had at the height of the transmission roller flat fixed cast plates which served as basis for the brackets. (fig. 2) Likewise the smithy shop of F. A. Egells at the Chausseestraße 2 was erected with hollow cast iron columns (1851), following experiments in the assembly shop where iron supports with a height of over 5.76 m had been built and the construction of a two storied administration building was breadthwise bridged over by a row of columns.

In the years 1844–48 the Royal Mills at the Mühlendamm were erected with an inner iron skeleton construction. Hollow columns with a diameter of approx. 36.5 cm up to 20 cm were used from the ground to the floor carrying in the transverse and longitudinal direction fish belly shaped railway metals above the capitals (Rothe 1849).

Leaving aside the cast iron columns of the saw tooth roof hall of W. Borchert at the Kochstraße 30

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Figure 1
Storehouse for the Schickler'sche Zuckersiederei. 1835, details of the construction

Figure 2
Carpet weaving mill, 1857, saw tooth roof
built in 1866, the most outstanding constructions with iron columns before 1880 that should be mentioned were the low buildings of the Royal Artillerie shops at Spandau and the railway shops of the Royal Eastern Railway.

Also the famous factories of L. Loewe at the Hollmannstraße 32 (1870–1882), just like the grinding department and the assembly hall at the Huttenstraße 17–20 (1896–98), were erected with iron columns. In the same way the seven stories of the Ermeler-Tobacco factory at the Breitenstraße 11 (1877–78) rested on rows of cast iron columns with a diameter of 15 cm up to 42 cm.

Cast iron columns were used for shops and assembly halls up to the 90’s, for instance at the Kappler’sche factory for mill building at the Prinzenallee 75–76 (1890), at the industrial court at the Adalbertstraße 70 (1898), at the dyeworks Schwendy at the Köpenicker Straße 7a (1894), and even at the mounting shops Schäfer & Walcker at the Lindenstraße 18–19.

Riveted and screwed wrought iron columns were in use in Berlin for industrial architecture only after 1890. The supports were assembled to I, L, and E profiles which were held together by cross-shaped or diagonal flat irons. In this manner the assembly shops of C. Flohr, at the Chausseestraße 28, and of L. Schwartzkopff at the Chausseestraße 20, both machine shops of L. Loewe (1895 and 1897) at the Huttenstraße 17, and at the Wiebstraße which were torn down in 1994, showed these latticed columns. Also the foundry of A. Borsig at Berlin-Tegel (1896–97), just like the boiler plant at the same place (1896–98), and the locomotive hall (1900) were erected with latticed columns. (fig. 3) The AEG machine factory at the Feldstraße- and Ackerstraße (1896–98), the AEG turbine hall at the Berlichingenstraße (1908), and the AEG machine shops at the Brunnenstraße 107a were furnished with steel columns, often with a rectangular cross section. (fig. 4).

In the early phase of industrialization (1808–40) it was possible to find out the reaction, the bending
moment as well as lateral loading and shearing forces of weight-carrying structures analytically and partly relying on the parallelogram of forces. The tabular data for strength tests of different materials and their best cross section allowed every academically or practically trained master builder or master craftsman to define the dimensions for roof structures and floor constructions, iron columns and masonry walls.

In the 60’s it was possible to determine the cross section of iron girders by calculating the second moment and the section moment. Stress transfer of the beam support and frame work truss which was often used for industrial buildings could be estimated by the Ritter’sche method and following the rules of «graphical statics» by C. Culmann.

For the first time static stability had to be proven according to public announcement from August, 2nd 1864. Paragraph 14 of the announcement asked for «all iron cast construction elements to be in such dimensions as to guarantee under continuous stress an absolute stability of 2,5 kg/pc 2 mm2 and a relative stability of 5 kg/per 2 mm 2, and for wrought iron a stability of 7 kg/per 2 mm 2». The static calculations and the guarantee for iron constructions were furnished by the contracting firms for iron constructions.

**ROOF STRUCTURES**

According to commentaries of L. Klasens the architect L. Hesse also designed the first saddleback roof with the building material of wrought iron in Prussia for the already above mentioned storehouse (Klasen 1876). The construction of the roof resembled a wooden construction with double-posts-roof, however did not take into calculation loads due to wind and snow. The placing of the bowstring girder, rafters and struts to elevate the arch trust followed the French wrought iron constructions, foremost the market hall of Magdalena in Paris (Allgemeine Bauzeitung 1838).

The roof construction of the machine shop of A. Borsig at the Chausseestraße (1844) also followed the model of the triple roof of the Magdalena market hall. For the span of 16,75 m a triangular system with rafters and beams measuring 22,5 cm × 15 cm was chosen. The iron elements were cast iron rafter heads and supporting purlins, wrought iron diagonal members and round tension rods which were secured by eye bolts.

The of recent rediscovered drawings disclose that A. Borsig did not carry out plain iron constructions at his first machine shops at the Chausseestraße (1837–44). Borsig’s craft masters A. Pardow and A. Karchow built 1844 a noticable framework construction of an English three-dimensional purlin with lifted horizontal tiebacks, following the models of roof system of the machine shop of the London-Birmingham-Railway (1836) and the Hungerford market hall in Manchester (Allgemeine Bauzeitung 1838).

In 1844 the roof of the Borsig locomotive hall at the Thorstraße was erected with a slightly improved English triangular rafter system without purlins. To cope with the span of 18,78 m the English models of triangular roof systems which were introduced for the railway station halls and passengers waiting rooms of the London-Birmingham-Railroad (1836) were followed. The roof framing was put together by two flat iron guide rails (7,62 cm × 1,27 cm), rafters filled with wooden battens, cast iron struts with T-shaped cross sections, vertical suspension rods as well as tiebacks which coped with the shear strength of the rafters (Mislin 2002). (fig. 5).

This construction system was not only used for market halls and railway stations in England. In the
50's the roof of a foundry of the Austrian Lloyd in Trieste was built in a similar way as the Borsig's roof with a rafter system. Through to the 70's this English triangular rafter system was mentioned in the manuals for building constructions of E. Brandt and L. Klasen (Allgemeine Bauzeitung 1857; Brandt 1871).

The Borsig machine shops at the ChausseestraBe being mainly roofed with wooden carpenter roof structures and only very rarely with combined hanging trusses made of iron and wood, the resurrected Royal mills at the Mühlendamm displayed with the skeleton construction a total innovation which remained unrivaled for a long time. The unusual roof structure was sloping from both sides to the middle of the building. The rafters of the pent roof and the joints were T-shaped rails, whereas the beams were constructed with cross-shaped cast iron profiles. The drawings for the Royal Mills belonged to the property of the Prussian Fiscal Department, being drawn up by the Hofbaurat L. Persius and the mill builder Dannenberg (Wiebe 1861). (fig. 6).

The latticed girder which was put to use in the late 40's in bridge art, was introduced to rising structures with great delay. The roof structure of the market hall at the Rue du Chateau d' Eau (1857–58) was designed prior to a construction of the saw tooth roof for the Artillerie shops at Berlin-Spandau for which the rural masterbuilder Beyer had succeeded in calculating for a latticed girder in transverse direction (1868) (Wiebe 1859). (fig. 7).

A. Borsig executed a number of interesting roof constructions for his shops in the years 1848–58 which were inspired by the bridge constructions in
commission. The roof system of the 15,12 m spanned joinery was built by the masonry and carpenter masters A. Pardow and H. Müller built as rafter roof construction with suspended double pitch-roof and tiebacks, suspended and diagonal rods of round bar-steel. Nearly at the same time with the erection of the railway station Hamburger Bahnhof (1847–49) A. Borsig built his new rolling mill in Berlin-Moabit. The roof system of the rolling mill was put together by latticed girders with tiebacks which spanned over a width of 15,20 m and 21,50 m. Because of the great arch trust the butments were supported by the massiv external masonry wall which was ornamented by the architect J. H. Strack like a fortress so that the roof construction was hidden. This constructural inconsistency was overcome by the latticed girder roof system of the hammer mill hall (1852–54) with a complete barrel vault roof which most probably is unique in the history of industrial building architecture, performed as one-room construction without intermediate columns and spanning a total of 21,20 m (Mislin 1993).

In this context special mention should be made of the barrel vault roof designed by the A. Borsig shops
for the Dortmunder Bergbau- und Hüttengesellschaft and for the muck and rolling mill in Wärtzilda/Finnland (1853–56). Amazingly the firmly fixed framework latticed girder with walled in tiebacks beneath the floor and spans for the roof frame of 2.10 m, 23.25 m and 24.80 m, and lantern towers were built before W. Barlow succeeded in erecting the St. Pancras station in London (Wiebe 1859). (fig. 8).

1856–57 the master craftsmen A. Pardow and O. Sauerteig built a Polonceau truss covering the tender shop of A. Borsig at the Thorstraße 48–53, composed of a series of united triangles (Mislin 2002). The iron vertical elements called for a static calculation of the roof structure which was carried out by the master craftsmen. Remarkable for the history of constructions is the fact that up to this date the statistic calculating engineer J. Weisbach had not calculated Polonceau trusses in the second edition of his manual «Statics of solid bodies» (1850–51). (fig. 9).

However the first Polonceau truss of the Berliner industrial buildings most probably was built 1851 for the smithy of F. A. Egells at the Chausseestraße 3, spanning 12.60 m. 1856–58 also the machine shop of A. Borsig at the Chausseestraße 1 made use of three Polonceau trusses with spans of 11.83 m, 18.37 and 10.50 m, the construction combining wood, cast and wrought iron.

 Whereas the struts of the Polonceau trusses remained through the 90’s fabricated of wood with a rectangular cross section of 21 cm × 21 cm, the compression columns were usually made of cast iron rails and the tie rods of round rod-steel. For the ironworks A. Borsig at Berlin-Moabit the first Polonceau truss, made of flat and angle iron was carried out (LAB Rep 226).
1866 the building master Bayer developed for the Artillerie shop at Spandau a saw tooth roof truss with beam support. Equally new was the triangular frame work with lantern which was executed for the hammer smithy of Schwartzkopff at the Ackerstraße 96 made of wood and iron rod diagonals, covering a span of 23.50 m. (fig. 7).

Beginning at the early 70's more and more iron constructions were put to use for all kinds of roof frammings. The cast iron roofs did not display transverse distribution which had been normally employed for the wooden systems shallow pitch roofs by using roof joists. All the more it became of importance to make use of tension elements in order to balance the rafter shear. By manufacturing triangulated systems the roof structures were ment to be non-sliding supporting structures.

Already in 1882 A. Vogt designed a machine shop for the L. Loewe Kreuzberg complex with an innovative iron construction. The garden court at the Alte Jacobstraße had already been built over by the machine shop, and the remaining side wings were left without free spaces. In closing up to these buildings with a western annex new constructive ideas were performed, such as roof and axial construction made of rolled bars, wrought and cast iron supporting elements and cast iron columns. The placing of the assembly hall between the already existing wings without windows resulted in a completely glazed roof pane. A grid of steel angles held panes of glasses measuring 75 cm × 75 cm. This roof-lighting system could compete with the later on erected halls at Moabit (1896–98), and the assembly halls of AEG, A. Borsig and Siemens & Halske, built in the years 1896–99 and 1908–10. (fig. 10).
Already in the 80’s frame work trusses, at times also parabolic girders or solid wall girders, were used for assembly halls; 1884 and 1888 the master craftsman P. Buchow built for the paint manufacturer Beringer a triangulated steel framed structure with T- and L-shaped iron diagonals, the short vertical members being in compression, the longer ones in tension, and a span of 16 m. Also the 16 m and 24 m wide spanned truss girders for the machine shop L. Schwartzkopf designed by C. Scharowsky were made of rolled iron section (1891), the first truss being a very unusual lantern and allowing for aeration. (fig. 11).

Similar lanterns were inserted into the roof pane of the framework built for the AEG machine shop, at the Brunnstraße 107a, by the master builder P. Tropp. In the same year Siemens & Halske had built an assembly hall on their land at Salzburger/Franklinstraße 27–29 with a saw tooth roof, the roof floor and the gallery floor being furnished with rolled iron section. For the machine hall of L. Loewe at the Wiebe-/Huttenstraße A. Vogt designed 1897 a bented steel framework with polygonal top boom (resp. 9,70 m and 10 m). (fig. 12) This fourfold-bented-buttress framework with vertical struts and steep rafter pitches under the skylights near the wall was in design and construction a real novelty of the Berliner hall buildings which was only topped by the frame system of the AEG assembly hall at the Huthenstraße (1911) (Mislin 2002). (fig. 13).

In 1896–98 the roofing work of the boiler-smithy and the foundry of A. Borsig at Tegel was carried out with a double-bented-buttress-truss, a kind of threefold Polonceau truss — spanning 18 m up to 19 m. Tall trussed girders with altered threefold Polonceau trusses were also used for 16 m wide halls in America (for instance Boyer Machine Co./Detroit). (fig. 14).

The state of the art for roof constructions before 1900 is demonstrated by the framework with upper flange and tieback at the foundry of A. Borsig at Berlin-Tegel, and by the triangular framework with rising diagonals for the machine shop of L. Sentker at the Müllerstraße 10 (1899) (span 20 m). The beginning of the century is characterized by the three-hinged-framed truss for the AEG turbine hall at Moabit.
Assembly hall L. Schwartzkopff, 1891

(1908) (span 25.10 m), and the AEG machine hall at the Hussitenstraße (1911), (span 31 m) (fig. 15).

Compared with the turbine hall the novelty was the consistent use of steel section instead of latticed girders and frameworks with small elements and tieback which had reduced the space of similar assembly halls before. The lighting effects of a glazed pane between the roof framing had been experienced before at the machine hall of L. Loewe (1882), the machine hall at the Brussels world exhibition (1910), and was further developed by K. Bernhard for the silk weaving mill Michels & Cie, at Nowawes (1912) (Bernhard 1914).

The arrangement of a main hall and subordinate halls for the assembly which had been first developed by K. Bernhard for Straßburg (19) and consecutively
The deliberate designing of the construction. Compared with American factories it proves that these principles of construction had already been implemented in the 90’s for iron and steel framed structures of machine shops (for instance Newport Ship Building, 1890, and Berlin Iron Bridge Co., 1891, with a facade of running fenestration, also around the corners).

**Floor Constructions**

The period of seventy to eighty years use of iron columns is closely connected with the introduction of fire-resistant floors, although columns exploded on fire. Despite the danger of fire at production sites and growing standards for industrial buildings wooden floors continued to be in use, and only few combined constructions of beams and iron girders were built.

Also the fire-proof cap vaults with bricks which were used at Schinkel’s Bauakademie already 1835, were not introduced for industrial architecture before 1850. We found a modest construction of cap vaults at the glassworks at the Salzufer 4, dating from 1864.
Only in the 80’s the cap vaults came more and more in use. Besides the typical inner construction of wooden beams with load bearing I-girders and hollow cast iron columns with capitals the spaces between the I-girders were filled up with flat brick cap vaults which were later on called Prussian cap vaults. The new paint mill of the Beringer factory at the Einsteinufer 65 (1889), the AEG works at the Ackerstraße 76 (1893–96) and the small engines shops by B. Behrens at the Voltastraße (1911–13) were furnished with Prussian cap vaults.

Beam floors across several columns which had been performed at the English docks and storehouses between 1800 and 1839 turned up in Berliner industrial architecture earliest at the storehouse by L. Hesse (1835), at Schinkel’s packing storehouse (1832–35), and also at the administration building of F. A. Egells (1847). Possibly these floors have been calculated in neglecting the moment determination by oversizing the load-carrying elements, simply placing beams across two columns, section by section and side by side (Hertwig 1941).

The new floors of the rebuilt Royal Mills at the Mühlenlamm by L. Persius (1848) represent a very singular construction. The beams of 3.76 up to 5.03 m length were shaped like a fish belly, in each section they paired two rails which were placed on the capitals of iron columns (Rothe 1849). (fig. 6).

Of equal interest is the construction of a gallery floor with iron girders at the drilling works of the Royal Artillerie shop at Spandau (1855), the joist beams having been replaced at the new building (1859) by wrought iron latticed girders (Wiebe 1859).

The static advantages of enforcing girders by a reverse hanging truss or a reinforced girder were known since the middle of the 30’s. R. Wiegmann improved the reinforced girder and introduced this construction together with the Polonceau truss about 1839–40 into the German speaking professional circles. The reinforced girder, usually a wooden beam, was placed on a cast iron column, the bottom being connected to the seating with two slanted tiebacks. This girder could only be performed in industrial buildings where no massiv loads had to be carried (LAB Rep 10–02).

For the smithy of F. A. Egells at the Chausseeestraße 3 a reverse hanging truss was built in 1850. For floors of smaller sheds and steam boiler shops of the Kühlein factory at the Salzufer 4 plain and double reverse hanging trusses were performed 1882, 1888 and 1893.

Corrugated metal floors combined with iron section girders were not only used for preliminary storage buildings but fixed with cement screed, even for multi-storied factories (for instance Kühlein, Salzufer 4, 1882).

In the 80’s the search for suitable solutions for fireproof floors was enforced to match the growing standards of fire protection between stories and an improved load support. The building magazines and manuals, amongst others the Deutsche Bauzeitung of the architects and engineers association and the later editions of G. A. Breymann construction manual of the 90’s, published a number of iron reinforced block floors which eventually were not carried out because of costs. In our research work we only found very few reinforced block floors in the drawing plans.

The combination between bricks and steel section girders for reinforced block floors which were to improve the tension strength often failed because of technical or structural defects. Reinforced concrete floors following the patent of Monier were more successful. This construction was improved in calculation and performance in the 90’s by M.
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Koenen. After having developed the ribbed floor (1894) which combined concrete ribs made of I-girders at a space of 25–30 cm with the concrete floor as a whole, he designed about 1895 the «Koenensche Voutenplatte» (vault rib) where the iron elements were placed in the middle of the plate and on top of the double T-flooring system. The final pieces are thus stressed like brackets whereas the centre piece is carried like fixed beams. Like this the ribs could be placed at intervals of approx. 2 m. Koenensche rib floors (joinery) and Koenensche Voutenplatten (machine tool shop) were performed for L. Loewe at Martinikenfelde (1897 and 1898) for a use load of 1500 kg and spanning 3 m (Mislin 2002). (fig. 12).

Stone floors with solid plate and enforcing ribs on end or joined bricks were rarely used in Berliner shops. In this context mention should be made of that all buildings with reinforced concrete needed a special building permit. Only on decree of the ministry for public works, on April 16th 1904, standards for the use of reinforced concrete in design and construction of buildings were released, thereby facilitating a building permit (Baltz 1905).

SKLELETON STRUCTURES

Plain iron constructions of the Berliner industrial architecture were not openly performed, but hidden behind masonry walls:

— 1844–48 Royal Mills at the Mühlendammbrücke (fig. 6).
— 1878 Tobacco Factory W. Ermeler & Co.
— 1882 Machine Hall L. Loewe at Kreuzberg (fig. 10).

The factory buildings of L. Loewe at the Huttenstraße (1896–99) mark a turning point in the history of constructions and of industrial buildings. For the three storied building reinforced rib floors, cast iron columns and masonry wall were combined to make a true skeleton building. The outer walls were reduced to piers and apron walls, instead of the hitherto known masonry walls vast window panes were created.

At the beginning of the twentieth century the well known assembly halls by P. Behrens for the AEG at Moabit (1908) and at Wedding (1911) self-assuredly represent the skeleton construction of modern architecture.

REFERENCE LIST

Allmeine Bauzeitung. 1838. 187.
Allgemeine Bauzeitung. 1838. 244.
LAB Rep. 10–02: 2139.
Roth 1849. Konstruktionen.