# THE ROLE OF IRON IN MINING ARCHITECTURE IN THE SECOND HALF OF THE 19th CENTURY, ESPECIALLY IN HEAD FRAMES AND WINDING TOWERS

Rainer Slotta

Among the most striking structures above ground in mines, which characterize the outward appearance of colliery and pit facilities, are the head frames and the winding towers (1). In a way, they have become the very symbols of mining. A closer look into the history of these buildings is fascinating because of the multitude of phenomena encountered, the different solutions adapted in different mining regions. For this reason, one will have to look separately at the different lines of development; however, before doing so, some definitions may be indicated.
The term head frame stands for a structure carrying at its top the sheaves. These sheaves serve to change the direction of the hoisting ropes. The winding plant is mostly located at ground level close to the shaft. The hoisting ropes are deflected into the shaft by the winding plant via the sheaves. However, if the winding plant is located on top of the pithead, this is called a winding tower.
The outer shape of the head frame is determined by its function. In most cases, it consists of the guide frame, inside which the guide rails of the hoisting cages are installed, the sheave frame, which accommodates the sheaves and their bearing supports, and the crossbeams absorbing the force resultant from operating the hoisting rope.
A factor decisively influencing the design of the head frame is the mining production process, for it determines the height of the frame. Depending on the height of the loading platforms, the so-called banks, at or above the shaft, and depending on the height of the cages, the overall height is calculated in accordance with the formula:
$H = h + \alpha + y + \delta$, with h being the distance between the pit bank and the upper edge of the bank, $\alpha$ the height of the cage plus the suspension gear and the capel, y the free height as defined in the mining regulations and $\delta$ the distance between the bottom edge of the safety clamp and the center of the sheave (2).
Having defined our basic terms, we now can turn to the development of the different types of head frames, again and again finding that the shapes and designs of headgear depend on the mining deposit and the technical plant conditions and machines in each mine; artistic and aesthetic elements play secondary roles and are only added as "afterthoughts."
The development of headgear is coupled with the introduction of the steam engine in mining; the use of gins, which was customary in the Middle Ages up until the twenties of this century, e.g., in Saxonian ore mining or in lignite mining in the Kassel district, also involved the development of "head frames," but those installations have nothing to do with the designs we are interested in.
Well into the 1870's, wood and brickwork were the materials mainly used for head frames, it being remarkable that cast iron never could gain ground in the construction of head frames, because the brittle material often ruptured under the sudden load changes in winding operation; only in Britain, the classic country of cast iron, and in a few head frame designs on the continent cast iron was used, but this development came to nothing (3).
In those years, between 1840 and 1870, the foundations were laid for subsequent developments, the main impulses coming from Belgium, France and Britain. The head frames topping underground mining shafts in



those years were all made of timber, most of them of relatively simple designs and rarely finding much attention in the literature. The designs used were pyramids with or without struts and trestle frames or double strut frames.
Probably the best example of a pyramid type frame is the wooden head frame built around 1847 in the Belgian mine of Grand Hornu (4) in the Borinage region, which has the sheaves supported on four short beams. The frame turned out to be wanting in stiffness, thus causing fluctuations in winding operation. Moreover, deformations occurred after the timber had dried. When these types of head frames could no longer be accommodated in the pithead buildings, the timber frames were made so large as to practically replace the pithead buildings. In the case of the Magny 2 shaft at Montceau-les-Mines (5), the head frame was erected on a brick base so that the sheaves of the required heights of 16-18 m could be accommodated, for timber 12 m in length and above was very difficult to obtain. Besides taking the tensile forces, the brickwork also had to absorb the dead weight of the pyramid frame and the wind loads. For this reason, it had been made very strong and reinforced by flying buttresses at the corners. Also wall clamps were installed. This type of pyramid frame, made of cast iron, was erected at the St. Bernard shaft of the Belgian hard coal mine of Les Ardinoises at Gilly near Charleroi in the early 1850's by the Société de Couillet (6). However, the bracings and sheaves were made of steel. No information is available about the success or otherwise of this structure.
It is easy to see that pyramid head frames, because of their small base areas, tend to tip up when subjected to tensile forces acting from one side. The addition of struts produced the strutted pyramid head frame, the best example of which is a structure build at shaft 12 of the Grand Hornu mine (7) in the years 1853-54. This was a timber frame, which had been installed in an oblong building, with struts which turned out to be very long. The frame worked very satisfactorily and, for this reason, was imitated many times. Also British mines adopted this design, but it is not clear from the literature whether the British frames were modeled on the Belgian example or were modifications of domestic precursors.
Independent of the simple or strutted pyramid type frame, there was the so-called English trestle frame, which term characterizes its area of use, not of its origin. The origins of the design are unknown, but the design as such was widely used. The trestle frame most probably grew out of stress analyses in engineering, for it could be calculated statically even in the early 19th century. Application of the parallelogram of forces helped to achieve a stability which had been missing in all other types of frames. Thus, the sheaves were mostly installed at the intersections of the struts and the stays so that no bending strains, but only pressure forces were generated. The best design of an English simple frame was achieved when the strut coincided with the flattest inclination of the resultant force. Such frames, made of timber, were built at the French Bérard mine near St. Etienne as early as in 1847 (8); in the British mining districts, this type of head frame was standard, and also the Shamrock (9) and Hibernia (10) shafts sunk in the Ruhr district by the British and the Irish, respectively, exhibited this typically "English" appearance. This type of timber head frame could be used to haul a maximum of 2 tons from a depth of about 400 m; the height was an average 15 m. However, this marked the limits of its capacity, because the specific properties of wood (low stability, shrinkage) rendered any further development impossible. That could be done only

when steel became available as a material.
The double strut frames originated from the desire to increase the winding capacity by double winding systems; accordingly, the shaft cross sections were enlarged. This type of frame was a combination of two trestle frames; it was also made of timber. Some examples are the double strut frame of the Manteuffel shaft (11) near Stassfurt in the rock salt mining district built in 1852 and that of the British Ryhope mine (12) (around 1860).
A very specific type of head frame is represented by the shaft towers made of brickwork, which can be found in Germany almost exclusively in the hard coal mining regions and which are limited to the period between 1850 and 1875 (with the exception of one latecomer at the "Alte Haase" mine (13) built in 1899). Starting from small pithead buildings reflecting local building customs, mining at increasing depths required a combination of all mining machines in one complex of buildings enclosing both the winding plant, the water drainage system, the boilers and the head frame, the latter being called Malakoff towers, because of their size and monumental character, which resembled the well known fort of the fortress of Sewastopol (14). The design of the beam water drainage systems already required a certain amount of height, which meant that the sheaves had to be installed even higher up; they were located in a timber support structure. Since the shocks associated with winding directly affected the support structures, these wooden parts shook quite considerably; moreover, the shocks were transferred to the brickwork of the shaft towers; as a consequence, the thickness of the walls was increased to more than 250 cm. It was evident that there were limits to this type of frame. After 1880, no such Malakoff towers were built any more; with a few exceptions, they had only been designed and built in Germany.
It took a remarkably long time for steel to be used as a material in mining. The first head frame made of steel, which can be dated with absolute assurance, was built at the French Saint Alphonse mine near Hainaut (15) in 1864, at a time when steel had long been accepted in bridge and housing construction, rolling technology had developed and joining individual steel components by riveting had already been tested. Apparently there had been no real need for this material in mining before that time, because timber seems to have been cheaper. Only when wooden beams of large dimensions became more difficult to obtain, when the idea spread that steel had a service life of 30 - 50 years, while timber only offered a maximum of 15 years, that steel also was non-burnable, steel made its way in winding tower construction. It is remarkable to see that the types of frames previously made of timber can all be found again as steel structures. This is clear proof of the fact that new materials will first be employed in ways emulating established building materials before they can fully develop their new qualities.
Pyramid frames made of steel were built both on the European continent and in Britain. Often, especially in Belgium and France, they were covered to withstand the influences of the weather. The first head frame to be made of steel in mining in Germany was such a pyramid type head frame over the Barillon shaft of Herne (16), which became famous when, after a fire in the mine had destroyed almost all installations above ground, it remained in operation, thus permitting the miners to ascend safely. At that time, U- and L-shaped beams were used to build the frame, and since thin rolled sections were employed, close-meshed structures were necessary to keep buckling lengths as short as possible. This is how the frames came to be built whose variable close-meshed structures so charm us today because



of the manifold, constantly changing patterns they create as we view them from different angles.
Also the strut type pyramid frames were made of steel, but soon the system of the British trestle frame replaced them.
Consequently, this type of frame never had a chance. Around 1867, a slightly modified pyramid frame design was developed in France at the St. Louis mine near St. Etienne (17), in which the sheaves were not supported by horizontal beams but by a strut. Following a French model, another frame of this type built out of old rails was erected at the Robert mine (18) in the Belgian city of Ahun only one year later.
In 1864 the first head frames made of steel appeared in Britain and in France. They also included the British trestle frames at the Deep Duffryn mine in Mountainash in South Wales (19) and at the Saint Alphonse mine near Hainaut (20) in France. The frame built in South Wales merits closer inspection, all the more so since it is still in existence and still being used. It is 18 m high, which was quite an achievement at the time when it was built. The remarkable feature of this head frame design is the fact that the axis of the sheave does not coincide with the line intersecting the strut and the support. Two crossbeams carry the ends of four horizontal sheave supports, transmitting forces to triangular gusset plates, which ensure a rigid connection of the strut and the support without any movement. Inclined crossbars between the struts and the supports minimize strains on the frame arising from the eccentric sheave arrangement. All connecting points are riveted. Bracing of the frame at right angles to the main load carrying direction is ensured by a diagonal cross in the strut and by three crossbars rigidly connected to the shafts in the support. All shafts of the frame consist of old rails, all of them located on the periphery of a circle and held in place by arched tie plates. The crossbars and diagonals are box-shaped girders with close-meshed lattice work of the webs. The curved bottom chords of the crossbars between the struts and the supports were probably used in this way for aesthetic reasons.

In 1868, the engineer Carl Erdmann introduced a new form of head frame, which differed from the English type of trestle in the way it supported the sheaves. Since the Belgian mining manager Tomson particularly advocated the use of this type of frame, the design became known as "Tomson trestles." (21) They were mainly found in the mines of the Harpener Bergwerks-AG and can thus almost be called a symbol of that mining company. After the first Tomson trestle had been built at shaft No. 7 of the Charbonnage du Gouffre near Châtelineau in Belgium (22) in 1868, soon the same type of frame was also made in Germany. Especially in the Ruhr area, the trestle type frame design was employed very frequently up until 1900 (23).
In 1870, the head frame design used by the Graf Beust mine of Essen (24) initiated the development of the German strut type frame out of the British trestle design. The high prices of steel made the designer of the system, Geisler, replace the heavy support of the British trestle by a bracing of the strut top. The inclination of the strut was then selected so that the bracing in the direction of the winding plant was always kept under tension in operation, while the strut only needed to accommodate pressure forces.
The design of this strut is interesting insofar as it no longer resembles any timber model, but has a frame structure, which is an independent development of steel construction. It was composed of L-shaped sections and flat bars, constituting a large box cross

section characterized by high stiffness and low weight. The fish belly shape of the strut in addition ensured a high resistance to buckling while consuming only a minimum amount of material. The frame with an overall height of 13.3 m is said to have worked excellently in practice, but the fact that no other frame of this type was ever built seems to be indicative of some unsatisfactory operating experience. Most probably, there were major vibrations.
The head frames at the Emscher mine of the Kölner Bergwerks-Verein at Essen-Altenessen (25) and at the Hugo mine of Gelsenkirchen-Buer (26), respectively, which were built in 1874 by the engineer Promnitz, constituted advancements of the Geisler frame. The bracing, which had been a disturbing feature in Geisler's design, disappeared and was replaced by the guide frame, which for the first time served both for winding by means of a frame and for dissipation of the load of the rope. Assigning two functions to one component was an excellent engineering achievement, which cannot be valued highly enough, because it not only meant a considerable reduction in materials expenditure, but also results in a simpler design consisting of fewer parts and joints. In the seventies and eighties of the 19th century, this type of frame gradually spread throughout many German hard coal mines, especially in Westphalia, under the name of "German strut frame".

Towards the end of the century, more and more frequently shafts were installed with double winding systems. Initially, simply two strut frames were put up side by side, and the two adjacent struts of the single frames were combined in one central strut pole, thus producing "three-pole frames," but soon major failures were encountered due to differential settling of the foundations. As a consequence, only two struts were used instead of three, so that this type of frame used for double winding differed from that used for simple winding only in its greater width.
When winding by means of the so-called Koepe driving pulleys became more and more widespread, thus causing drum-and-reel winding systems to lose significance, also two-story strut frames were built, which had their sheaves arranged at two levels above each other. Again, it was Promnitz who first built such a double-story strut frame in 1877.

Again for double winding shafts, the so-called double strut frame was developed towards the end of the century, which is one of the most important frame designs developed in Germany. Actually, it was a duplication of a two-story strut frame design, but this new type of frame is characterized by a solid, calm appearance absent in all other designs. One of the first frames of this type was built at shaft VI of the Zollverein mine at Essen-Katernberg (27) in 1896. This double strut frame then made its way not only in hard coal mining: Also in the budding potassium and rock salt mining industries with their wide double winding shafts this type of frame soon became widely used; one early example is found at the Hattorf mine (28) in the Werra district (1906).
The use of solid sections for building head frames was introduced at a relatively late date, only in 1925; the first example was the two-story strut frame of the Baden shaft at the Buggingen potassium mine (29) near Freiburg.
All the examples mentioned above were head frames in which the winding plants had been installed by the side of the shafts. However, we must also discuss the development of winding towers in which the winding plants are located right on top of the shafts, i.e., which ultimately simulated the winding method of the winch. The development of tower winding systems was able to gain ground only after Carl Friedrich



Koepe had invented the winding pulley, which replaced the mighty drums or sheaves of earlier winding machines.
The important advantages to winding operation of the tower winding system are self-explanatory: The winding plant can be installed in a position most advantageous for operation without any consideration needing to be given to space conditions. In addition, the space for the machine hall occupied by floor level winding machines can be used for other purposes, given the space constraints always existing at mining sites. The space requirement of a winding tower is low compared with a strut frame, because the winding tower can do without struts. However, the many advantages of winding towers must be paid for by higher overall costs.
Some first winding towers, still made of timber, were introduced in lignite mining as early as in 1860, but the depth of the shafts was only 32 m (30). Also the installation by Koepe in 1888 of a winding tower in the Malakoff tower of the Hanover II hard coal mine of Bochum did not result in the expected breakthrough. (31) Only when electric winding machines became available, winding towers were generally accepted.
The first winding tower to be equipped with an electric winding machine by Koepe was introduced on the Belgian hard coal mine of Ligny-les-Aire in 1905 at shaft II (32), which was run by the Compagnie des Mines de Houille. Although it was only 27.36 m high and could serve a winding depth of 400 m, it created quite a stir at that time. Only in 1907, the first German winding tower made of steel was built at the Klenze shaft of the Bavarian Hausham mine (33) of Miesbach, followed one year later by the Ulrich shaft of the Cleophas mine (34) in Upper Silesia and shaft I of the Deutschland mine of Schwientochlowitz (35), also in Upper Silesia. A very beautiful example still existing of such a winding tower is the tower located at the shaft of the Glückauf potassium mine of Sarstedt near Hanover (36), which is an almost identical replica of the Ulrich shaft tower. Even the original machine equipment has been preserved.
While steel finally was accepted as a structural material for head frames around 1880, it soon met with the dangerous competition of reinforced concrete employed in building construction and bridge building, especially after Mathias Koenen in 1886 had correctly recognized the importance of the steel reinforcement bars in concrete: Koenen pointed out that in all components exposed to bending stresses, steel accommodated the tensile forces, while concrete absorbed the compression forces. In his method of calculation, he laid the foundations for the sensible and economic application of this compound building material. The high ductility, good economy and resistance to fire caused Möhrle in 1908 to recommend reinforced concrete also for use in head frames (37). In 1911, the first winding tower made of reinforced concrete was built for the Camphausen hard coal mine near Fischbach in the Saarland (38). But also head frames were made of reinforced concrete, which material was used particularly frequently in Wallonia. However, also for reinforced concrete it must be said that the material took a long time being accepted in the construction of head frames. As in the case of steel, the mining industry was very slow in introducing the new material. This branch of industry seems to be rather inclined to adhere to its traditional techniques.(39)

This short and very summary description of head frames cannot be concluded without mentioning again the particular aesthetic appeal of this high rising type of industrial structure. This characteristic was discovered first by Mr. and Mrs. Becher, who clearly recognized and also described the variable impressions of head frames as experienced by a person walking around these structures. In addition, there are so many variants and types that I may be permitted to highlight a few head frames typical of specific regions and bring them in line with my earlier descriptions.

English head frames, above all the trestle designs, have a certain bizarre element in their outward appearance, irrespective of the building material used, which may be a general part of British character. The wide spreading of the struts from the stanchion, the filigree of the frame girders, the mere thought of building a frame out of rails, which would give every German engineer a headache and, on the other hand, the simplicity of construction without any regard to outward appearances, once the feasibility of the idea has been proved, seem to be characteristic of English head frames, thus reflecting the englishness of English art. Undoubtedly, these early head frames of the frame girder design have the most profound impact on us.

The Belgian and French head frame designs show quite different concepts and structures, aside from the resemblances in timber structures. The head frames made of steel closely resemble German head frame designs in respect of height and overall proportions. However, they differ profoundly from German designs in the structure of the crane topping the head frame, which almost always has a roof structure. Sometimes this is a saddle roof, sometimes a simple or double pyramid type roof, but it always emphasizes the overall character of the head frame, introducing a light, sometimes even playful element into the austere structure determined merely by aspects of statics, thus mitigating the general impression. Sometimes even little cottages were put on top of the sheave platforms, and curved and arched steel shapes influenced by art noveau carried the shafts of the pyramid roofs. The ultimately irrational use of these design forms may perhaps reveal a Walloon characteristic, which can smile even in the most serious situations.
The same trait appears in the use of reinforced concrete in the mining districts of Wallonia. Some of the frames designed there have "Gothic" arches, cornices in a "neo-classical" style, molded fasciae and even parapets of reinforced concrete looking like wooden railings. At the Puits Cheratte mine of Liège, which was built in 1914, the existence of the cottage on top of the head frame can only be explained by the aesthetic sense of the engineer-architect who designed it. Such head frame would be impossible to think of in Germany.
The head frames built in Germany are typically German: clear in their structure, rational in their form and designed exclusively in the light of statics and static requirements. Only very rarely has a design been dared which incorporated aesthetic elements independent of statics. This was the case, for instance, in the head frame of the Lehrte potassium mine of Bergmannssegen (40), which was built in 1910 and whose curved crane track owes much to art noveau, constituting a repetition of the contours of the other installations above ground. On the other hand, the winding towers made of solid brickwork, of course, must be mentioned whose powerful monumental character is quite naturally "German" and resembles "German character". The architectural design of these huge fronts and facades with a multiplicity of historic forms shows clear reminiscences of knight's castles and palace architecture, which is also indicative of what must have been in the back of the industrialists' minds. Contrasted with the low buildings in the villages of the Ruhr and Saar districts, these bulky,



gigantic towers must have had a profound impact. Where head frames of other shapes were used in Germany foreign influences are mostly easily detected: In the case of the Tomson trestle it was the Belgian mining director Ernest Tomson who caused his favorite type of head frame to be used in the Ruhr district, thus introducing a filigree structure of a head frame of great aesthetic appeal; in the case of the first head frames made of reinforced concrete at the Wallach shafts of the Borth rock salt mine, the builder had been the Belgian Société Solvay, and Netherlands and Belgian capital was also involved in the ownership of the head frames of the Sophia-Jacoba hard coal mine at Hückelhoven on the Lower Rhine River.

Let us finally have a brief look at the mining architecture of the steel frame type. Although no specific studies have been carried out as yet, the mining industry seems to have adopted this type of design only very late and probably for less important buildings first. Since most mining enterprises included brickworks, the building material preferred in hard coal and rock salt mining was bricks, while the ore mining industries mainly used half timber work and ashlar. This habit seems to have persisted right into the 20th century: The new mining structures built late in the 19th century in hard coal and rock salt mines almost exclusively use bricks, arranging their fronts and facades in historicizing forms. However, rolled steel girders were mostly used to bridge the spans, which often were quite large.
The first hall of larger dimensions in a German hard coal mine obviously is the machine hall of the Zollern II/IV mine of Dortmund-Bövinghausen (41), which was built in 1902-1904 on the basis of plans by Reinhold Krohn and the aesthetic design by the architect Bruno Möhring. Extensive literature is available on this hall structure and its importance, so there is no need for a more detailed explanation in this paper. It only remains to be said that this hall is the first in all mining architecture to combine in one hall building all power plants of a whole mining plant, while formerly the different systems had been set up all over the mining area.Formally, the machine hall building was modeled on the pavillion of the Gute-Hoffnungs-Hütte at the 1902 Düsseldorf Industry, Trade and Arts Fair. Architects like Hector Guimard of Paris had an influence on Möhring's style.
If we wanted to draw a summary we could say that steel was introduced into mining installations in the second half of the 19th century, rather late and rather reluctantly. The reason why this material was not employed lies in the basic technical and mining conditions. Until the 1870's, one had not yet penetrated to the great depths one could no longer have reached with head frames made of timber. The use of steel for the construction of head frames was pioneered in hard coal mining, while the more traditional sector of ore mining with its relatively small mining plants held on to its reservations against the new material until far in the 20th century. The young sectors of potassium and rock salt mining, however, immediately followed the example of hard coal mining, accepting steel as a material.
Only as one penetrated into greater depths one had to deal with steel as a material. In this connection, it is remarkable to note that all mining regions first built head frames of steel which had previously had already been made of timber, i.e., that frames were built which neglected the qualities of the material used. However, very soon new types of head frames were developed, which took into account the specific characteristics of steel. In Germany, the first head frame made of steel was built at the Barillon shaft in Herne in 1869; it was an adaptation of a pyramid frame made of timber. But already in

1870, the head frame designed by Geisler was erected at the Graf Beust shaft of Essen; it served as a model for all subsequent German strut frames. It is also remarkable to see that the German mining industry was later in using steel than its British and Walloon competitors, but then very soon produced independent designs. (42)

Notes

1. The following essay is based in all major respects on the research by Heinrich Schönberg (Die technische Entwicklung der Fördergerüste und -türme des Bergbaus. In: Bernhard and Hilla Becher, Die Architektur der Förder- und Wassertürme, Munich, 1971 (3 Studien zur Kunst des 19. Jahrhunderts, vol. 13), pp. 245-324).
2. Cf. Theodor Möhrle, Das Fördergerüst - seine Entwicklung, Berechnung und Konstruktion, Leipzig, 1909, pp. 32-33.
3. Cf. Schönberg, op. cit., pp. 268 ff, Möhrle, op. cit., pp. 25 ff, Carl Hartmann, Handbuch des Steinkohlen-Bergbaus oder Darstellung des in den bedeutendsten Steinkohlen-Bergwerken Europa's zur Aufsuchung, Gewinnung und Förderung der brennbaren Mineralien angewendeten Verfahrens nach dem Werke des belgischen Bergingenieurs A.T. Ponson bearbeitet, Weimar, 1856, col. 710-711, Tables 29-31. Wilhelm Müller, Seilscheibengerüste und Seilscheiben. In: Die Entwicklung des Niederrheinisch-Westfälischen Steinkohlen-Bergbaues in der zweiten Hälfte des 19. Jahrhunderts, vol. 5, Förderung, Berlin, 1902, pp. 359 ff. A. Eichenauer, Die Seilscheibengerüste der Bergwerks-Förderanlagen, Leipzig, 1977, p. 3.
4. Cf. Schönberg, op. cit., p. 273, Fig. 31. Neuer Schauplatz der Bergwerkskunde, Pt. 4: Die Grubenförderung, Quedlinburg/Leipzig, 1847, Table 15.
5. Cf. Schönberg, op. cit., p. 273, Fig. 32 and 33. A. Burat, Les Houillères en 1868, Paris 1869, Atlas, Tables 14 and 15. R. Janniaud, Le Visage de la Mine à travers les grandes périodes d'exploitation du Bassin de Blanzy (ed. by Ecomusée de la Communauté de Creusot-Montceau, Le Creusot, 1979, p. 19, Fig. 20).
6. Cf. Eichenauer, op. cit., p. 144. - C. Erdmann, Eiserne Förderthürme. In: Zs. d. VDI, 17, 1873, col. 401.
7. Cf. Schönberg, op. cit., p. 275 f., Fig. 37. - A. Ponson, C.Hartmann, op. cit., Atlas, Table 55. - Le Règne de la Machine - Rencontre avec l'Archéologie Industrielle (ed. Crédit Communal de Belgique, Brussels, 1975, pp. 11/12 and p. 75).
8. Cf. Schönberg, op. cit., p. 278, Fig. 42. - Neuer Schauplatz.. (1847), Table 19.
9. Cf. R. Slotta, Bemerkungen zur Abhängigkeit der Bergbau-Architekturen von Lagerstätte und Unternehmenspolitik. In: ICOHTEC - Internationales Symposium zur Geschichte des Bergbaus und Hüttenwesens. Papers (edited by E. Wächtler and R. Engewald), Freiberg, 1978, vol. 2, p. 423. - G. Gebhardt, Ruhrbergbau. Geschichte, Aufbau und Verflechtung seiner Gesellschaften und Organisationen. Essen, 1957, pp. 330 ff.
10. Cf. Gebhardt, op. cit., pp. 330 ff. - Gabriele Unverferth, Evelyn Kroker, Der Arbeitsplatz des Bergmanns in historischen Bildern und Dokumenten. Bochum, 1981 (= Veröffentlichungen aus dem Deutschen Bergbau-Museum Bochum, No. 15 = Schriften des Bergbau-Archivs, No. 2), p. 20, Fig. 7.
11. Cf. Schönberg, op.cit., p. 281, Fig. 50. - Eichenauer, op.cit., p.78.
12. Cf. Schönberg, op.cit., p. 281, Fig.51. - Serlo, v.Rohr, Engelhardt, Der Steinkohlenbergbau in England und Schottland. In: Zs.f.d.Berg-, Hütten- und Salinenwesen im Preußischen Staate, 10, 1862, Table 5.



13. Cf. Gebhardt, op.cit., pp. 467 ff. - Vereinigte Elektrizitätswerke Westfalen AG. Festschrift, ed. by W. Lipken, Dortmund 1930, pp. 64 ff.
14. On Malakoff towers, see also R. Müller, Malakoff-Türme auf den Schachtanlagen des Ruhrgebietes, ein Überblick über ihre Entwicklung und den Stand ihrer Erhaltung. In: Burgen und Schlösser. Zs. f. Burgenkunde und Burgenpflege, f. Wehrbau, f. Schloss- und Landhausbau 3, 1962, pp. 27 ff. - Schönberg, op. cit., pp.268 ff.
15. Schönberg, op. cit., p. 282. - Des divers matériaux employés pour la construction des chassis à molettes. In: Révue universelle des mines 32, 1872, p. 75.
16. Cf. Schönberg, op. cit., pp. 290 f. - Eichenauer, op. cit. p.136. - Erdmann, op. cit., col. 401.
17. Cf. Schönberg, op. cit., pp. 293 f. and Fig. 68. - A. Burat, Cours d'exploitation des mines. Paris, 1881, Atlas, Table 108.
18. Cf. Schönberg, op. cit., p. 293. - M. Robert, Note sur le chevalement en fer du puits Robert. In: Bulletin de la Société de l'Industrie minérale, 2ème série, t.2, 1873, p. 295.
19. Cf. Schönberg, op. cit., pp. 294 ff.
20. Cf. Schönberg, op. cit., pp. 294 ff. and Fig. 75. - Des divers matériaux (1872), p. 75.
21. Cf. Schönberg, op. cit., p. 297.
22. Cf. Eichenauer, op. cit., p. 135. - Erdmann, op. cit., col. 402.
23. Cf. R. Slotta, Architekturen des Bergbaus im Spiegel seiner Entwicklung. In: Der Anschnitt, 29, 1977, No. 2-3, pp. 71 f. - On the history of the Harpener Bergbau-AG, cf. A.Heinrichsbauer, Harpener Bergbau-Aktien-Gesellschaft 1856 - 1936. 80 Jahre Ruhrkohlen-Bergbau, Essen 1936. - F. Mariaux, Gedenkwort zum Hundertjährigen Bestehen der Harpener Bergbau-Aktien-Gesellschaft, Dortmund 1956. - On frames, cf. F. Schulte, Die neue Schachtanlage Zeche Preussen I der Harpener Bergbau-Aktien-Gesellschaft in Dortmund. In: Glückauf, 1895, pp. 1110 f. - E. Tomson, Förderanlagen für große Teufen. In: Glückauf, 1898, pp. 2 ff. - F.Schulte, Die neue Schachtanlage Scharnhorst in Brackel bei Dortmund. In: Glückauf, 1901, pp. 794-802.
24. Cf. Schönberg, op. cit., pp. 299 f. - Eichenauer, op.cit., pp. 115 ff. - Erdmann, op.cit., col. 403.
25. Cf. Eichenauer, op. cit., pp. 134 f. - Note in Zs.f.d. Berg-, Hütten- u. Salinenwesen im preußischen Staate, 24, 1876, p. 165.
26. Cf. Schönberg, op. cit., pp. 301 f. - Eichenauer, op.cit., pp. 115 ff. - Note in Zs.f.d.Berg-, Hütten- u. Salinenwesen im preußischen Staate, 24, 1876, p. 165.
27. Cf. Schönberg, op. cit., p. 310. - Müller, op.cit., Fig. 268.
28. Cf. R. Slotta, Technische Denkmäler in der Bundesrepublik Deutschland, vol. 3: Die Denkmäler der Kali- und Steinsalzindustrie (= Veröffentlichungen aus dem Deutschen Bergbau-Museum Bochum, No. 18). Bochum, 1980, pp. 307-323.
29. Cf. Schönberg, op. cit., pp. 308 f. and Fig. 97. - J.Wolff, Neuzeitliche Fördertechnik. In: Die Bautechnik, 6, 1928, p.410, Fig. 4. - Slotta, op.cit., pp. 372-387.
30. Cf. Schönberg, op. cit., pp. 281 f.
31. Cf. Schönberg, op. cit., pp. 312 ff. - F. Lange, Wege zur Vierseilförderung. In: Glückauf, 81/84, 1948, pp. 105 ff.
32. Cf. Damm, Die elektrisch betriebene Hauptschachtfördermaschine der Compagnie des mines de Houille de Ligny-les-Aire. In: Glückauf, 42, 1906, pp. 1201-1215. - Schönberg, op.cit., pp.314 ff.
33. Cf. Schönberg, op.cit., p.315. - Möhrle, op.cit., p. 265.
34. Cf. Schönberg, op.cit., p. 315. - Möhrle, op.cit., pp.265-270.

35. Cf. footnote 34.
36. Cf. Slotta, 1980, op. cit., pp. 560-572.
37. Cf. Th. Möhrle, Eisenbeton im Dienste des Bergbaus. In: Technischer Centralanzeiger Kohle und Erz, 16, 1908, pp. 285 ff.
38. Cf. Schönberg, op. cit., p. 317. - W. Groß, 100 Jahre Grube Camphausen 1871-1971. - Slotta, 1980, op.cit., p. 70.
39. On the use of reinforced concrete in frames and winding towers, see F. Kögler, Fördertürme und Fördergerüste in Eisenbeton. In: Glückauf, 57 (1921), pp. 901-906, 929-935 and 957-960. - dto., Neue Fördertürme und Fördergerüste in Eisenbeton. In: Glückauf, 58, 1922, pp. 917-922. - dto., Neuere Fördertürme und Fördergerüste aus Eisenbeton. In: Glückauf, 63, 1927, pp. 185-193.
40. Cf. Slotta, 1980, op. cit., pp. 207-210. - ibid., Bemerkungen zum Verhältnis von "Technik" und "Kunst" am Industrie- und Maschinenbau. In:Die Nützlichen Künste (ed. by T. Buddensieg and H. Rogge), Berlin, 1981, p. 204.
41. Cf. B. u. H. Becher, H.G. Conrad, E.G.Neumann, Zeche Zollern 2 - Aufbruch zur modernen Industriearchitektur und Technik. Munich, 1977 (= Studien zur Kunst des 19. Jahrhunderts, vol. 34).
42. See also various volumes of pictures, e.g., Bernhard and Hilla Becher, Fotografien 1957 - 1975 (ed. by K. Honnef), Bonn, 1975 (= Kunst und Altertum am Rhein - Führer des Rhein. Landesmuseums in Bonn, No. 59). - Special literature is available on specific types of frame designs. Especially the volumes of the journal Zs.f.d.Berg-, Hütten- u.Salinenwesen im preußischen Staate will be a rich source of information.



# IRON AS A BUILDING MATERIAL IN THE ARCHITECTURE OF HOUSES IN THE SECOND PART OF THE NINETEENTH CENTURY - INQUIRIES ABOUT THE DEVELOPMENT IN THE USA

Barbara Lipps-Kant

"The age of iron" in American architecture includes the time between 1850 and 1880. The following will attest that this important part of the American art history has been relatively unknown. (1)
Since bridges, conservatories, arcades, exhibition buildings, railway stations and trainsheds were built in Europe much earlier in similar ways, they will not be regarded in this essay. In contrast to Europe in the Americas, beginning first in the U.S., iron as a building material played an important part in the construction of houses after 1850. Elaborately decorated iron fronts characterized the streets in the cities. Warehouses, stores, office buildings, hotels, theaters, libraries, dwellings, townhouses, business buildings, but also factories, granaries, arsenals, ferry houses, light houses etc. had been constructed completely or at least partly from iron. Since the middle of the century iron was available in large amounts and was cast in this country. (2) The technology of the casting was known and reached the same level as in England. Soon the iron foundries offered a large variety of architectural parts. In the second part of the nineteenth century the revival of former styles became important in architecture. With cast iron as a building material these ideas gained special influence. The different patterns came from the Renaissance, the Gothic, the Romanesque, the French Empire and the Moresque architecture etc.. During the seventies and even more the following decade a tendency to accentuate the construction became important. A dramatic change in the facade pattern took place. Not only were the iron parts reduced in size in favour of increased windows, but the decoration was reduced as well. This early functionalism is a predessesor of later ideas in architecture. (3) After 1880 cast iron was less involved as a visible building material, (4) but took a significant part in the construction of houses as well as skyscrapers, where it was used as a material for the frame. Finally, displaced by steel structures, cast iron appeared only in the ornamental architecture.(5)
In 1854 William Fairbairns basic book about iron architecture "On the Application of Cast and Wrought Iron to Building Purposes" was published in New York City after an earlier London edition. (6) Thomas Tredgolds detailed results from his research about the strength and the properties of cast iron and other metals, (7) William V.Picket's "A New System of Architecture, Founded in the Forms of Nature, and Developing the Properties of Metals", (8) and other special literature were discussed amongst American architects.(9) The fashions of building in the old world and especially in England were reviewed regularly in the periodicals of art and architecture.
In 1856 James Bogardus published John W. Thomson's pamphlet "Cast Iron Buildings: Their Construction and Advantages" (10) - a passionate appeal for cast iron and its use in building. During the following years a series of books about iron and, most importantly, about the application of cast iron appeared. (11)
Besides Bogardus' paper however another work published in 1865 is of interest for research. The pattern book "Illustrations of Iron Architecture Made by the Architectural Iron Works of the City of New York", (12) which is equipped with many precious lithographs,