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 coal mining, 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 these types of buildings could no longer be accommodated in the pithead buildings of 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 Ardennoises at Gilly near Charleroi in the early 1890'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 heads which were the result of the structural design of shaft 12 of the Grand Horum 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 treble 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 treble frame most of the time was a reaction against the 19th century, and the head frame design which was introduced at the beginning of the 19th century in England, the English simple treble frame, where the frame coincided with the flattest inclination of the resultant force. Such frames, made of timber, were built at the French Béarn mine near St. Etienne as early as in 1847 (8); in the German Ruhr district, the 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 type of head frame. 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, and the low stability properties of wooden shafts (11) 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 windage of the double winding systems and to make the cross sections more available. This type of frame was a combination of two trestle frames; it was also made of timbers. Some examples are the frame of the Newcufelt shaft at the Newcufelt mine in the Rock salt mining district built in 1852 and that of the British Rhyope mine (12) (around 1860).

A different 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 years 1850 and 1875 (with the exception of one latecomer at the "Alte Hase" 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 head 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 1860, no such Malakoff towers were built any more; with a few exceptions, they had only been designed and built in Germany.

It took a long time for steel to be used as a material in mining. The first head frames made of steel, which can be dated with absolute assurance, was built at the French Saint Alphonse mine near Lamont (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, a pyramidal steel tower was non-burnable, made its way in winding tower construction. It is remarkable to see that the types of frames previously made of steel were cut down again in operation, thus permitting the miners to ascend safely. At that time, U- and L-shaped beams were put to use all the frame, and since thin rolled sections were employed, close-meshed structures were necessary to keep the frame as long as possible. This is how the frames came to be built whose variable close-meshed structures do harm 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. Compared with the latter, this is a type of frame needing 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 put in front of the struts. This was a struts and frame. Following a French model, another frame of this type built out of old metal and constructed at the Robert mine (18) in the Belgian city of Ahun only one year later.

In 1866 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 Lamont (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 struts and the support without any movement. Inclined crossbars between the struts and the supports minimize stresses 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 crossbeam running by three or more bars 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 timbers. The curved bottom chords of the crossbars between the struts and the supports were probably used in this way for aesthetic reasons.

In 1866, the engineer Carl Ermann introduced a new form of head frame, which differed from the English pyramid 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 a standard in Belgium and also in other countries. (21) It is clear proof of the fact that new materials will first be employed in ways of establishing building materials before they can fully develop.

Pyramidal 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 influence of the environment. The first head frame to be made of steel in mining in Germany was another pyramidal 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 intact and permitted the miners to ascend safely. At that time, U- and L-shaped beams were put to use all the frame, and since thin rolled sections were employed, close-meshed structures were necessary to keep the frame as long as possible. This is how the frames came to be built whose variable close-meshed structures do harm us today because
section characterized by high stiffness and low weight. The fish bellieshape 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 m is said to be a prototype. The winding frame is the only one of this type that is still used 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 firm of the Berg- und Hüttenwerke-Verein at Essen-Altenessen (25) and the Hugo mine of Gelsenkirchen-Buer (26), respectively, which were built in 1874 by the engineer Promitz, combine the components of the device 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 in 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 the winding frame 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 the Lune River 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 of the Baden shaft at the Buggingen potassium mine (29) near Freiburg. 

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 Bugging potassium mine near Freiburg. However, one early example is found at the Hattorf mine (28) in the Werra district (1906).

All the examples mentioned above were head frames in which the winding plant was installed by the side of the shaft. It 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 machine are many and, in many cases, they are the only advantage, which today would make an additional effort necessary. For instance, in a position most advantageous for operation without any consideration of 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 usually 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. The 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 1886 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 in the Belgian hard coal mine of Ligny-les-Aire in 1909 at shaft II (32), which was run by the Compagnie des Mines de Houille. Although it was only 27.56 m high and could serve a winding depth of 400 m, it created quite a stir at the time. The first German winding tower made of steel was built at the Kleenze shaft of the Bavarian Hausham mine (33) of Miesbach, followed one year later by the Ulrich shaft of the Gelsenstein 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 Gelsenstein mine of Hanover near Rehden (36). It is an almost identical replica of the Ulrich shaft tower. Even the original machine equipment has been preserved. 

Concrete 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 compressive forces. In his method of cast reinforced concrete, the foundations for the sensible and economic application of this compound building material. The high ductility, good economy and resistance to fire caused him in 1888 to recommend the use of reinforced concrete 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 Pforzheim, as the Rehden (36). 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 continued mentioning again the particular characteristics of this high rising type of industrial structure. This characteristic was discovered first by Mr. and Mrs. Becker, 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.

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 Britj 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 the 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 girdir 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 trestle 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 supporting 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 the pillars were just put on top of the walls, and the roofs were curved and arched steel shapes influenced by art nouveau 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 head frames designed there have "Beaux-Arts" Romanesque-Tudor 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 contours 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, for instance, the head frame of the Lahte potassium mine of Bergmannssee (40), which was built in 1910 and whose curved crane track owes much to art nouveau, constituting a repetition of the contours of the other installations above ground. On the other hand, the winding towers made of wood or steel, of course, must be mentioned whose powerful monumental character is quite naturally "German" and resembles "German character". The architectural development along these lines in head frame designs and facades with modernist or historic forms shows clear reminiscences of knight's castles and palace architecture, which is also indicative of what must have been in the mind 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, the filigree structure of a head frame of great aesthetic appeal; in the case of the first head frame made of reinforced concrete at the Wallach mining plant, a Polish head frame designer had designed it. The Société Coly, and Netherlands and Belgian capital was also involved in the ownership of the head frames of the Sophia-Jacobs hard coal mine.

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 materials preferred in hard coal and rock salt mining were 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 façades 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 it is not the intention here to present a detailed description of this 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 the mining plant, formerly the different systems had been set up all over the mining area. Formally, the machine hall building was modeled on the pavilion of the Gute-Hoffungs-Hütte at the 1902 Düsseldorf Industry, Trade and Arts Fair. Architects like Hector Quimard 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 1970's, one had not yet penetrated to the great depths one could not design head frames with head frames made of steel for the construction of head frames was pioneered in hard coal mining, while the more traditional sector of ore mining with its red-brown wheeler mining plants held on to its tradition until 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 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 been built made of timber, i.e., the mining regions neglected the qualities of the material used. However, very soon new types of head frames were developed, which took into account the special characteristics of steel. In Germany, the 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
17. Die Wetterfahne, die 1790 von Geisler entwickelt wurde, wurde an den Turm der Schlossbrücke in Kassel angebracht; sie diente als Indikator für die Windrichtung und wurde in der Öffentlichkeit aufgelegt. Es ist bemerkenswert, dass die German mining industry an die neuen technischen Entwicklungen in England und Deutschland anknüpfte, während die britischen und walloonischen Unternehmen noch an den alten Methoden festhielten. (42)

Notes


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)

The industrialization of America, the demand for more buildings, especially those for business purposes, led to the development of new materials and construction techniques. Iron, in particular, played a crucial role in the construction of buildings and structures.

In Europe, before its widespread use, iron was mainly used for small-scale architectural components like doors, windows, and railings. However, in the USA, iron was adopted on a larger scale, especially in the 19th century, leading to the construction of iron-frame buildings. These buildings were characterized by their use of iron as a structural element, which allowed for the creation of large, open spaces and higher ceilings.

Iron-frame buildings were not only found in urban areas but also in rural settings, where they were used for various purposes, including homes. The use of iron in the construction of these buildings was a significant milestone in the development of American architecture.

The adoption of iron in architecture in the USA was influenced by various factors, including the availability of iron, the demand for new buildings, and the technological advancements that made iron a viable construction material. This period saw the development of new iron fabrication techniques and the introduction of standardized iron components, which made the construction process more efficient and cost-effective.

The availability of iron in the USA was facilitated by the discovery of large iron deposits, particularly in Pennsylvania and Ohio. These deposits provided a reliable source of iron, which was crucial for the development of the iron-frame building movement.

The demand for iron-frame buildings was driven by factors such as population growth, urbanization, and the need for new and larger buildings to accommodate the growing population. The development of iron-frame buildings was also influenced by the need for new and efficient construction methods, which were made possible by the technological advancements of the time.

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In conclusion, the use of iron in the construction of buildings in the USA during the second part of the 19th century was a significant event in the history of American architecture. It marked the beginning of a new era in architecture, characterized by the use of new materials and techniques, which were to shape the future of American architecture. The adoption of iron in architecture in the USA was influenced by various factors, including the availability of iron, the demand for new buildings, and the technological advancements that made iron a viable construction material. This period saw the development of new iron fabrication techniques and the introduction of standardized iron components, which made the construction process more efficient and cost-effective.

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