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In France the new type of building construction began with the turn of the century. In 1801 planning of Pont des Arts was started in Paris, a bridge dedicated on September 24, 1803. The transparent iron structure resting on eight stone pillars spans the River Seine in nine arches of 18.25 m each between the Collège des Quatre-Nations and the Louvre which, at that time, was called Musée des Arts; hence the name, Pont des Arts. The design was by de Cessart, construction by Dillon. The cast iron arch sections, which have their origins in the iron roof frame structures of theatres, are reinforced by forged ties and by the solid structure of the pavement. Although the bridge was more than 9 m wide, it had been designed only for pedestrians and had been embellished with ornamental trees. Passage was 1 sou of bridge toll. Yet, it was a purely practical building, and Napoleon, who was accustomed to monumental stone buildings, condemned the structure: "The bridge does not make a solid impression, there is nothing grandiose about it." The bridge is now threatened by demolition.

In a way, Pont de Cubzac offered a more grandiose view. It was built over the River Dordogne near Cubzac, not far from Bordeaux, for the road linking Paris and Bordeaux; the bridge was designed and built in 1835-39 by Emil Martin and Fortuné de Vergez. Because of the swampy ground and the width of the river, which changed greatly as a result of the tides, a suspension bridge was selected. In 1825 Marc Séguin had built the first suspension bridge in France with 85 m spans over the River Rhone near Tournon. The pillars of the new bridge were composed of drum-shaped cast iron elements so that the weight of a pillar was less than 1% of the weight of a stone pillar. The viaduct 1545 m long, whose central section of 545 m length over the water was subdivided into five spans of equal lengths, had a road width of 6 m; the pavement was 28 m above the water level. The hollow towers more than 41 m high were composed of 17 tapering drums, the uppermost of which carried the movable support over which 12 suspension cables were stressed. Each of the four pairs of pillars were interconnected by a cast iron arch underneath the road. The combination of skeleton-type round towers, horizontal, slightly curved road and transparent lattice work of the cables must have given that bridge an imposing and, at the same time, picturesque appearance. In 1882 it was replaced by a design by Eiffel.

After the collapse of the suspension bridge of Angers in 1850, a disaster which killed 226 people, France refrained from building more suspension bridges. For this reason, Gustave Eiffel in 1880-84 designed a special type of arched bridge when constructing a single-track railway bridge over the Tuyère gorge in the Can Valley, the Viaduc de Gabarit, which is 565 m long. Gabarit is not the name of a village but, in French, means model, i.e. the loading width of a railway car. The bridge is not wider than necessary to allow a railway car to pass. Originally, the trains ran from one side to the other on top of a central arch of 165 m span at a level of 122 m above the river. Today, the water level has risen because of a dam so that the original height has decreased. Five pillars of the viaduct, which taper off strongly, are resolved in steel girder structures, the largest two pillars flanking the arch having the considerable height of approx. 80 m. The girders and lattices were riveted together of commercial L, U and I-beams. In order to reinforce the structure against pressure forces, Eiffel designed his arches, which were

parabolic in cross section, with internal contours different from the external ones. In the horizontal box-like web formed by St. Andrew's crosses the railway track was embedded so that the railway cars would not fall into the river in case they were derailed. The resolution of solid bridge pillars in steel structures allowing the wind to penetrate enabled Eiffel in 1889 to design his tower in Paris, which is immediately preceded by the Viaduc de Gabarit.

Building construction of iron is first encountered in France in the Halle au Blé. Concern about sufficient food supplies to the capital, the shortage of food having once been one of the causes of the 1789 revolution, made Napoleon enlarge the Paris granaries by having a dome erected over their round inner courtyard. Belanger and Brunet in 1807-11 erected a suspended dome above the circular 18th century building, whose support arches were bolted together out of cast iron sections. Over a diameter of 40 m the dome rose to a height of 45 m. Annular horizontal braces reinforced the vertical arches so that a panel-type interior lattice with a glazed skylight was produced. The resemblance to the Rome Pantheon, which is approximately the same size, is evident. The original dome has been preserved to this day in the 1887 building of the Bourse du Commerce.

By contrast, the construction of St. Eugène's Church has medieval connotations. It was built in 1854-55 by Louis-Auguste Boileau within 20 months at a cost of only 530,000 Francs. The building has a rectangular floor plan; it is a three-nave hall church surrounded by a gallery with chapels underneath, a sort of Gothic staging of a church whose load carrying members, apart from the enclosing walls, are dematerialized to such an extent as to no longer appear as architecture, but rather as an image. All details of the cast iron structure have Gothic forms, and yet the floor plan and the spatial impression created already have the characteristics of modern democratic convention halls.

The same character is evident in the Bibliothèque Nationale by Henry Labrouste, a building of 1862-68. In the stone wall enclosure the architect placed 16 thin cast iron supports, each 11 m high, which carry nine domes of ceramic plates. The skylights of the domes perforated in the centres and the light entering sideways through the lunettes in the entrance wall illuminate the reading room, which can seat 360, so that an adequate impression is created of the width of the room. Again, the architect is not above using some stage effects out of the repertoire of libraries which are supposed to create the proper atmosphere in the study rooms of the learned.

The large complex of market halls built by Victor Baltard in 1853-58 on the site of some old wooden huts made a sober impression adequate to the new building material. The ten pavilions, each of them reserved for one category of merchandise, properly graded in height and equipped with venetian blinds for ventilation or the commodities, were grouped around roofed streets to ease loading and unloading operations and protect against the weather. Les Halles Centrales were the first large ensemble of modern commercial architecture of cast iron and forged iron. Their design soon was copied in innumerable market halls all over France constructed in the following years. The demolition of the Paris halles, which could well have been used for other purposes, is an irretrievable loss to the European history of architecture and has destroyed one of the most colourful parts of metropolitan Paris.

In the second half of the century the buildings of the Paris International Exhibitions became experiments in steel construction. The Palais de l'Industrie built by Cendrier and Viel in 1853-55 is still modelled upon the Gare de l'Est, which had been built in Paris

in 1847-50. The floor area of the inner hall, which is 192 m long and 48 m wide, was topped by a semi-circular iron-glass structure 33 m high. A stone enclosure built in Renaissance style forms gave the building a representative, historic character, and also concealed the iron structure. The cast iron girders were supplied by a British company. Yet, the building programme was not unequivocally peaceful in nature, as had been the Crystal Palace of London. For, in the tendering documents it had been demanded that the hall should be able to accommodate also 18,000 soldiers and 6000 horses, which resulted in the construction of galleries around all sides. This dual purpose is characteristic of the ambivalent character of the reign of Napoleon III. Since there was still not enough room, a warehouse with skylights was built along the River Seine over a length of 1.2 km with a width of 28 m and a height of 17 m which was to accommodate heavy machinery and raw materials from the colonies. This was the first "Galerie des machines."

A more original structure than the Palais de l'Industrie, and one precisely tailored to the programme of an international exhibition, was the oval design for the international exhibition of 1867 designed by Frédéric Le Play and built by J.B. Krantz. In his plans Le Play expanded on the idea of a dual classification system. In the annular arrangement of all galleries identical types of goods were shown side by side, whereas in the radial sectors products were arranged by origins, i.e., by nations. This gave visitors a fair chance to compare in one gallery all products of the same kind and, at the same time, assess the productivity of a nation by walking through this sector. The building, which was about 500 m long and some 400 m wide, consisted of five galleries surrounding an inner courtyard like rings; their areas were twice as large as that of the London Crystal Palace. The halls, which were made of steel, were erected in only 13 months.

A very different solution was found by Dutert and Contamin when they built the Galerie des Machines for the International Exhibition of 1889. Quite rightly this design has become one of the shining examples in the history of modern building, although it was demolished in 1910 by people who should have known better. To display the machines exhibited by all countries a hall was needed with as few supports as possible and a relatively high ceiling. With a width of 115 m and a length of 420 m the hall fully met this purpose, being one of the first buildings to show functional design on a large scale. It consisted of a three-joint arched structure which gave the huge steel structure the appearance of fleeting lightness, which must have greatly impressed contemporaries. The top of the bright hall was 43 m high. Lower transepts spanning a 15 m wide gallery laterally opposed the thrust exerted by the tremendous areas of the vault. The simplicity of design and the spacious width of the hall made an overwhelming, even gigantic impression. The Galerie des Machines was an achievement of the 1889 exhibition surely matching that of the Eiffel Tower.

Although these two buildings by far exceeded the dimensions of earlier traditional architecture, there were also more modest and yet original solutions to be found in the private building sector. Let me finally show you the Menier chocolate factory of Noisiel-sur-Marne built by Jules Saulnier in 1871-72. The factory is the first lattice work structure made all of iron girders. It overhung the river, half a mill, half a French Renaissance castle on the River Loire. The building is supported on four brick pillars set on top of box-type steel girders. The walls are diagonally reinforced, cast iron supports carry the ceilings inside the building.

As in rural half timber houses, the structure is also the decorative element subdividing the facade, the infill consisting of red bricks. The rich polychrome outside front of the building alternately shows the M of Menier and a flower of the cacao tree.

"Iron, steel and imagination" could be a headline describing the development of French steel architecture in the 19th century of which I have been able to mention only a few examples in the 15 minutes allotted to me. I hope I conveyed an impression of the richness of ideas and the spirit of experimentation of the architects of that time and the high quality of their buildings which, unfortunately, is not frequently found in the international style of the 20th century.