Structure impact on architectural form of multi-storey factory buildings of industrial revolution

T. Šenberger & J. Hořická
Czech Technical University in Prague, Czech Republic

ABSTRACT: The contribution deals with a part, structural development played in final architectural expression of multi-storey factory buildings. Process of architectural design of 19th century, dividing internal space structure and facade (dualism), was applied also to industrial architecture in an interim period, when searching for a fitting form. Factory buildings were designed to represent newly establishing social class — monumentality and historicizing forms of massive brickwork facades bolstered an impression of embedded, strong, prospering companies. Engineers, better educated for applying new structural materials, stood in for architects at the cradle of factory building design. Contribution of multi-storey factory buildings to a development of architecture is undisputable primarily due to the use of new materials and structures. For today’s interpretation is not decisive, whether the development was participated more by architects or engineers, but the result of their work being ‘a reflection of the period, technical and social progress, successes and mistakes.’

1 FINDING A FORM

An influence of industrial buildings on 20th century architecture was described. Even Le Corbusier, “the father” of functionalist architecture, used examples of industrial architecture, e.g. well-known boat shed in Sheerness, England, 1860 — cast-iron frame with glass and timber board facade (Fig. 1) — or Lingotto car factory in Torino, 1926. Generally, new building qualities, for instance universality, variability, machinery elements, were denominated, as well as safety and health requirements were formulated. However, industrial architecture dealt with these qualities since more than 100 years, and so many industrial buildings fulfilled the requirements.

Figure 1. Boat shed, Sheerness, UK, 1860 (Déjiny architektury, ODEON 1980)

Principles of modern architecture, as formulated by Le Corbusier, were based on the use of framework replacing walls both inside the building (open floor plans) and in the facade (strip windows, curtain walls). The main load-bearing system consisted of columns in more or less regular raster, supporting floor or roof slabs — skeleton in short. There is an undisputable influ-
ence of industrial buildings on modern architecture. The skeleton structure principles were applied in material variations since the end of 18th century till the beginning of 20th century, mostly just in the multi-storey factory buildings. Due to the new attitude to architecture, the principle was transferred to other building typological categories only at the turn of the 19th century in USA, and massively in the first half of 20th century.

What was a part played by architects and engineers in the structure development in the period of industrialization though? Runaway progress of science and technology overtook noticeably social and culture progress in this period, historicist styles prevails in architecture, and the society faced uncontrolled urbanization effects. In the atmosphere of 19th century, dualism in architectural design – divided design of internal space structure and façade – was basically a reflection of the social state of affairs.

An architect, who did not have any sufficient background to design industrial buildings, accepted the role of façade decorator. A social commission was like that. Factory buildings were designed to represent newly establishing social class – monumentality and historicizing forms of massive brickwork facades bolstered an impression of tradition and strong, prospering companies. Existing contradiction of traditional form and new function, as architects realized it, led to searching for the new form in 19th century. (Fig. 2)

On the other side, engineer was a progress representative, who understood the production process, and learned qualities and potential of new structures and materials, standing in for architects at the cradle of factory building design. Together with efficient functional solution, he gave different architectural form to the buildings. Extending interior skeleton structure to façades was a significant advance, leading to abandoning traditional brickwork façades. Loose “engineer” interpretation of contemporary architectural forms in new materials and constructions, supported by a high-quality workmanship, became a typical characteristics of industrial architecture of 19th century.

![Figure 2. Shinkel’s Bauakademie, Berlin, Germany, 1836 (authors archive)](image)

2 HISTORY OF INDUSTRIAL BUILDING STRUCTURES

2.1 From timber to cast-iron

General-purpose multi-storey factory buildings were first industrial buildings with skeleton structure, developed as a new building type in England in the half of 18th century, related to the search for an optimal building for textile production. Requirements for the building were clearly defined: energy distribution from one place, open floor space to fit the machinery, quality day lighting and natural ventilation for many employees. John and Thomas Lombe’s mill, built in Derby in 1718-22, is considered the first model spinning mill, indicating future development. Six-storey brickwork block with regular lines of small windows had a timber skeleton structure inside. Industrial
buildings were designed neither by architects, often nor civil engineers, but owners of the factories being established and technology innovation inventors – first a spinning-jenny (Richard Arkwright) and later a loom (Edmund Cartwright).

First buildings had massive brickwork facades and multi-storey timber skeleton, inspired with rural barns and sheds. First Arkwrights’, Struts’ and Needs’ spinning mills were built this way in 1770s and 1780s. The threat of frequent fires, caused by presence of a natural fiber dust, forced the owners to find new, non-flammable structure variants. Primarily, structures – columns and slabs – were coated with whitewash, or covered with plaster, and later timber columns were replaced with cast-iron. Slabs remained timber structure. The development was significantly forwarded with the fire of Albion Mill, the latest London factory on 2nd March 1791, established by Matthew Boulton & James Watt in 1786, and built by pioneer engineer John Rennie.

A radical solution was constituted by eliminating timber in the load-bearing structure. The brickwork façade was maintained – mainly for its massiveness and stability, but the timber structure was replaced with cast-iron skeleton. Marshall, Benyon a Bage flax mill, designed by Charles Bage, and built in Ditherington, Shrewsbury in 1797, is the first recorded building with full iron skeleton structure. The structure comprise of cast-iron columns of cross shaped section, cast-iron beams and brickwork arches. (Fig. 3) The structure was improved to tape by Boulton and Watt in Philip & Lee spinning mill in Salford four years later. It consisted of hollow cast-iron columns of 230 mm diameter, and cast-iron beams of I section and variable height. Slab structure was supplemented with brickwork arches in between beams. These factory buildings were imported to Czech lands in complex deliveries from England, providing the building plans together with textile machinery. Johan Faltis flax mill (1859) in Trutnov was most likely built this way, having an identical structure to the Boulton and Watt’s type. (Fig. 4)

Figure 3. Flax Mill, Ditherington, Shrewsbury, UK (Information leaflet, 2001)

2.2 Steel century

For following 100 years, iron skeleton dominated in mill structures, and other production or storage building structures, where general-purpose and variable floor space was required. As steel production was improved gradually, cast-iron was first replaced with structural shear steel, later with better soft-cast steel and rolled steel profiles. (Production of rolled steel profiles was initiated in Czech lands in Vitkovice in 1836, and in Kladno in 1855.)
Changing spatial demands, mainly the length of spinning machinery, and changing the moving force—water wheel to steam engine, building lay-out was changed, as well. Englishman Sidney Stott (1858–1937) was a significant textile mills designer, innovator and efficient businessman. He forwarded the textile mills design to the type of modern building, fulfilling not only the functional demands, but also representing a new point of view on their architectural form. One of more than 80 factory buildings realized according to his conception was built in Smržovka, the Czech Republic—Johann Priebsche heirs’ spinning mill, so-called Cloister, still dressed into the historicist façades. (Fig. 5)

2.3 Reinforced concrete find

Another dramatic change of skeleton structure material came with applying reinforced concrete. Primarily, reinforced concrete was experimentally used for floor slabs laid on steel skeleton structure of spinning mills (in England in the last decades of the 19th century.) Significant designer of industrial buildings Karl Arnold Séquin (originally a mechanical engineer) used this exact combination of steel skeleton structure and reinforced concrete floor slab, designing many textile mills in Czech lands (swiss Séquin & Knobel office) – Friedrich Mattausch & son spinning mill in Benešov nad Ploučnicí, built in 1902, or Honoré De Liser spinning mill in Kvíček u Slaného, built in 1903. (Fig. 6)

François Hennebique only improved previous experiments with reinforced concrete, and patented monolithic reinforced concrete skeleton system in 1892. As a result, there were several spinning mills with monolithic reinforced concrete skeleton structure built in France by the end of 19th century. Spinning mill for Chares Six in Tourcoing, and a similar one for Barrois brothers in Lille were built in 1896. Swiss construction entrepreneur Eduard Züblin built a spinning mill ‘La Cité’ in Mullhouse in 1900, following Hennebique’s patent. Due to stability and solidi-
ty of the reinforced concrete structure, massive load-bearing brickwork was eliminated even in these early projects, and columns became part of the façade. (Fig. 7) – Vonwiller spinning mill in Žamberk, built in 1912, is considered an exclusive example in the Czech Republic. The four-storey building has a span of 13 meters without any interior columns. (Fig. 8)
Until the World War I, there were many multi-storey factory buildings with monolithic reinforced concrete skeleton built in Czech lands, mainly or textile production purposes – For instance one of the first concrete spinning mill in Austria-Hungary, Johann Liebig spinning mill was built in Velké Hamry in 1907.

2.4 New façades

Only in the inter-war period, concrete structures expanded to other industrial branches. Robert Maillart’s invention of flat-slab (beamless) structure with mushroom ceiling, first used in a store house in Zurich in 1910, enabled the use of the reinforced concrete for store houses structure. Examples to be found in Prague are a Public warehouse (F.Bartoš, 1928) or Žižkov freight rail terminal (K.Caivas, V.Weiss, 1935) were designed by respected architects and built by renowned Škorkovský construction company. (Fig. 9)

However, history of architecture in the Czech lands was mostly influenced by realization of Baťa’s multi-story production buildings in Zlín. Reinforced concrete skeleton of circle-sectioned columns in module of 6,15 m by 6,15 m, based on the proved floor plan of multi-storey factory buildings, was as a general-purpose structure transferred to store houses, office buildings and a hotel, all designed by significant architects of the period. (Fig. 10)
Replacing a load-bearing façade with a curtain wall was another structural innovation that opened the possibilities of a new esthetics of an inter-war architecture. A tobacco factory in Rotterdam, designed by J.A. Brinkmann, L.C. van der Vlugt and M. Stam, and built in 1930 is considered a textbook example of all-glass curtain façade completely separated from the load-bearing reinforced concrete structure. (Fig. 11) Parallelly, these structures were applied in other building types.

3 INDUSTRIAL BUILDINGS ASSET

Basic load-bearing structures – skeletons of multi-storey production buildings document a development of not only industrial buildings, but also the modern architecture in a broader context. Engineers’ part was unsubstitutable at least in the early period of this development, but their importance was not reduced even during the whole 19th century. Architecture form of industrial buildings was free from all formal and other dependences, but had variety of open architectural solutions. Architectural values are not a product of pure art intentions, but rational relations reflecting newly formed needs. And these values became a basis of modern architecture then.
One more positive legacy is possible to follow. Due to the described qualities – universality, variability and also rationality of the structures, these buildings are, losing their original function nowadays, easy to reuse and ready to accept new function – production or non-production. Many outstanding adaptive reused multi-storey factory buildings serve for new purposes all over the world. One of the most famous is Fiat Lingotto factory in Torino, adapted for multi-purpose centre of 2006 Winter Olympics capital, designed by Renzo Piano office. Czech examples involve Moravan textile factory in Brno, adapted for flats and offices in 2005, or Stock steam mill in Prague-Holešovice, adapted for offices to lease in 2009. (Fig. 12)

Great qualities of these buildings enabled their preservation and adaptation back to active life after losing their original function, opening the possibility to reveal and utilize qualities hided in running production process so far, including conceptional, structural, spatial and craft qualities.

Figure 12. Stock steam mill, Prague-Holešovice, Czech Republic (authors archive)

REFERENCES


ACKNOWLEDGEMENT

This study has been conducted within the research project DF12P01OVV040 supported by the Ministry of Culture of the Czech Republic.