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Structural shaping of some early concrete structures in Wroclaw

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Abstract

The paper presents two examples of creative application of structural concrete from the beginnings of 20th century. Fascinating time of industrial development, emergence of new trends in the art and social changes opened new opportunities for architectural design. While some former tendencies remained still influential, new forms appeared, determined mostly by their structural system.

Keywords: Wroclaw Dome, historical structures, concrete structures

1. Introduction

Appearance of a new structural material – (modern) concrete and reinforced concrete, in the 19th century, opened new, exciting possibilities for designers. It was also a challenge for them to develop forms suitable for this material.

Two buildings located in Wroclaw: the Centennial Hall (also known as Wroclaw Dome) and Covered Market Hall, both constructed at the beginnings of the 20th century, are beautiful examples of early designs. The first one is the building that broke the ancient record of clear span set by Roman Panteon cupola. In the second one, main arches are shaped according to flow of forces.

Review of these two buildings reveals the designers "way that of thinking". Their structural idea can be clearly traced through the original calculations, mostly graphical, and construction process.

2. Wroclaw Dome

Wroclaw Dome was built as the main object of the exposition complex for 1913 Centennial Exposition organized in the city, Fig. 1. From this event comes its original name: Centennial Hall. The structure drew inspiration and refers to its great ancestors: the Roman Pantheon (span 44 m), Florence Cathedral Dome (42 m), Hagia Sophia (31 m) and St. Peters Basilic Dome (40 m). However, imagination and skilling of its designers: architects Max Berg, Hans Poelzig and Richard Konwiarz as well as structural engineers Günther Trauer and Willy Gehler created the structure exceeding all previous achievements. With its span of 65 m and creative applications of novel material – reinforced concrete, Wroclaw Dome became a symbol of the birth of the Modern Movement.

Figure 1: Present-day aerial view of Wroclaw Dome and surroundings

2.1. General idea of structural system

The Wroclaw Dome is laid out on a symmetrical circular plan with attached four semicircular apses, forming a distinctive, quatrefoil ground floor, Fig. 2. The structure is composed of two parts: lower and upper. Both parts are independent and the upper one is movably supported on the lower part, Fig. 3.

The lower structure consists of four massive curved arches arranged on cylindrical surface with a circular base. Diameter of this cylinder is 65.0 m and its height is 19.0 m. The arches of the lower part are opened to four apses and topped with a massive perimetrical ring. Span of each arch is 41.23 m and its height is 16.73 m. Between arches, ring is supported by two additional columns. Each of four apses is enclosed by a sector of ribbed dome, consisting of six secondary arches laterally supporting the main curved arches. Only four of these secondary arches are structurally important, while two other are for esthetical reasons only. Arrangement of the lower part is shown on Fig. 4.

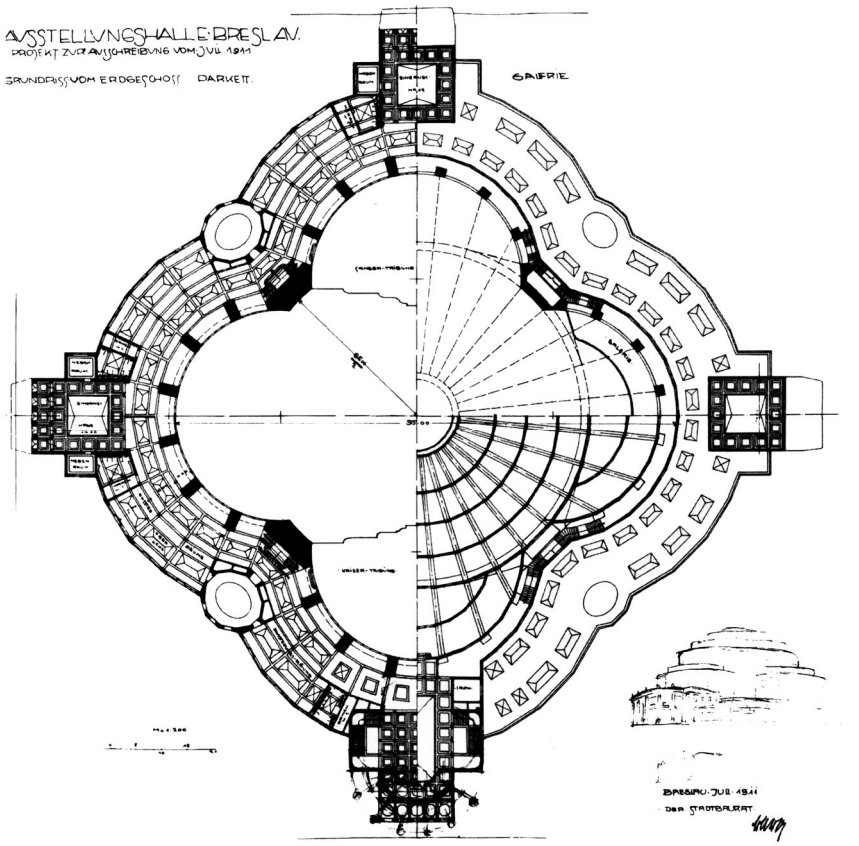

Figure 2: Quatrefoil ground floor (left) and concentric arrangement of upper part ribs (right) of the Wroclaw Dome

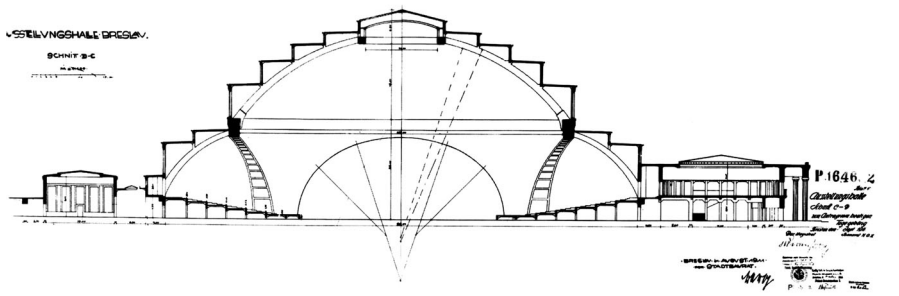

Figure 3: Cross-section of the Wroclaw Dome

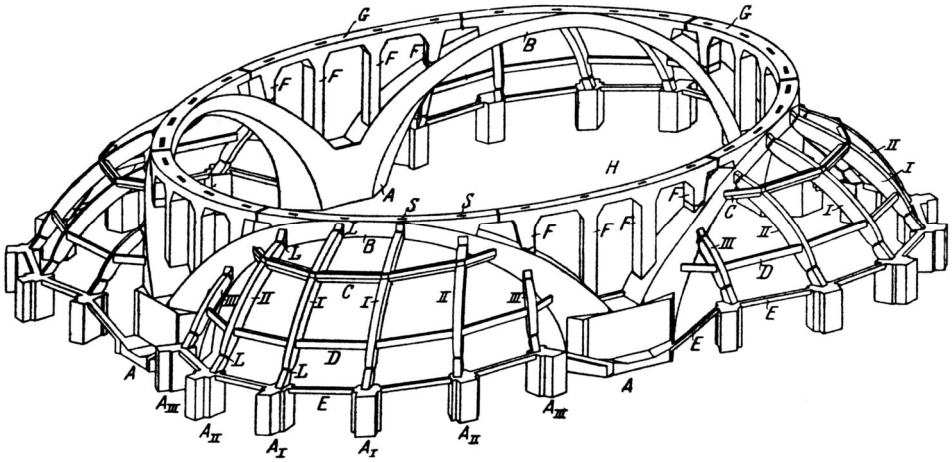

Figure 4: Arrangement of the structural system of lower part of the Wroclaw Dome

The upper part is shaped as a cap of spherical ribbed dome. Its height is 23 m. Structural system of upper part consists of 32 arched ribs, anchored in circular tensioned ring at the bottom and in compressed ring at the top. Diameters of both rings are respectively 65.0 m and 14.4 m. For stabilization of the ribs, three additional circular rings are regularly placed. On the upper ring a lantern in the form of small dome is situated. The structure of this lantern is composed of four concentric rigid frames. Arrangement of the upper part is shown on Fig. 5.

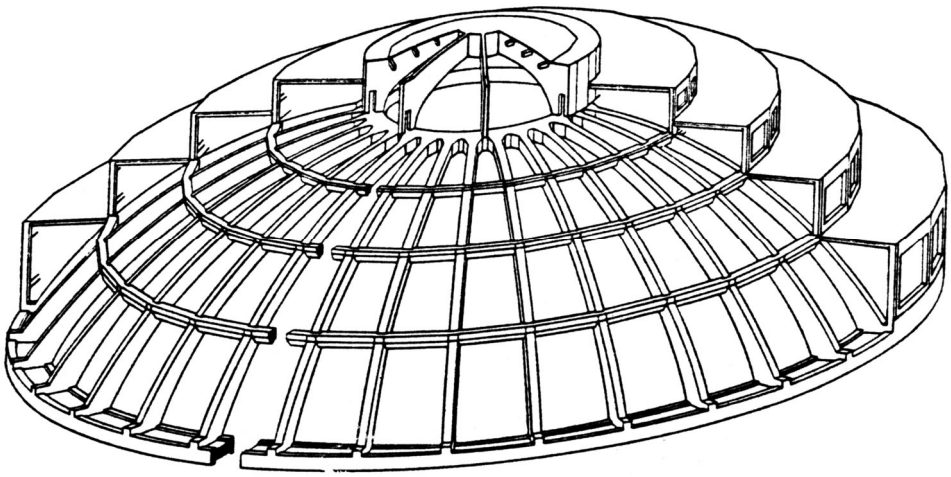

Figure 5: Structural system of the upper part of the Wroclaw Dome

2.2. Details of the structure

The main curved arches of the lower part, from the structural point of view, are the most sophisticated elements of the whole system. They are shaped as circular arches wrapped on the cylindrical surface. Rectangular cross-section is continuously changing and neighbouring arches are merging at the bottom. Scheme of the arch is shown on Fig. 6 and schematic diagram for statical analyze – on Fig. 7.

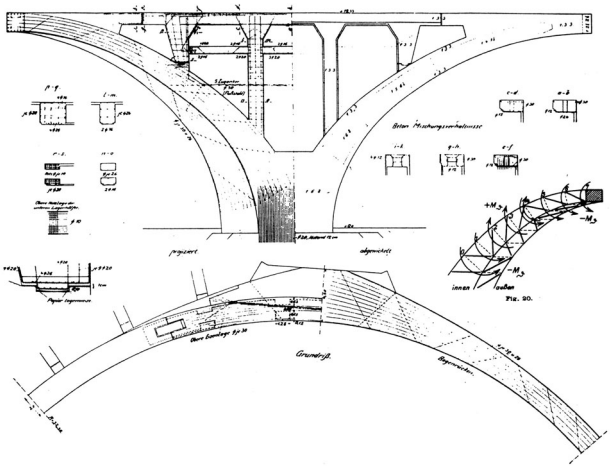

Figure 6: Main curved arch of the lower part

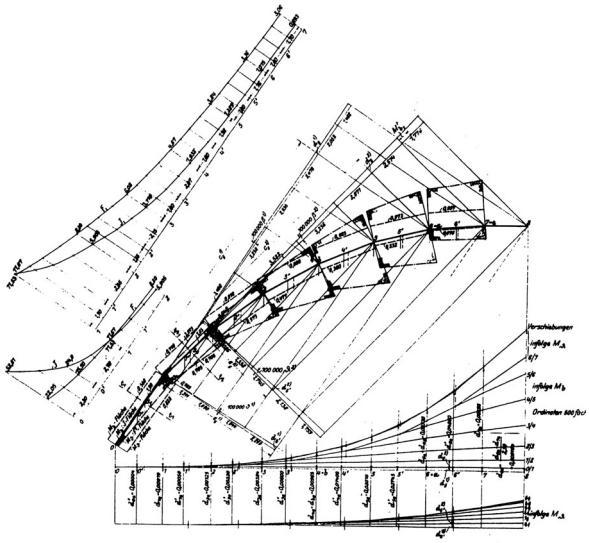

Figure 7: Diagram for statical calculations of the main curved arch

Structural stability of curved arches is obtained due to the system of lateral supports – secondary arches situated in apses, Fig. 8

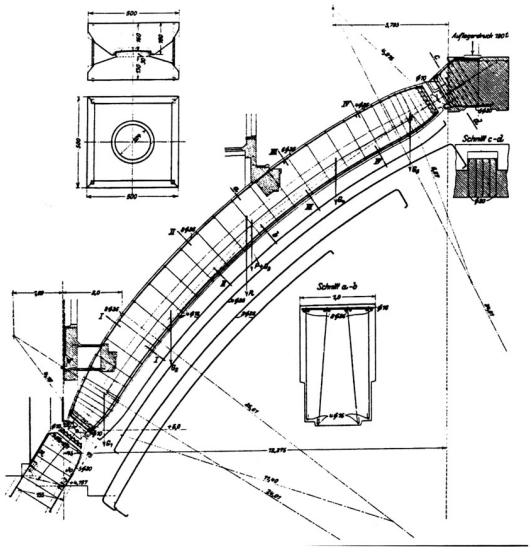

Figure 8: Secondary arch of the apse – lateral support of the main curved arch

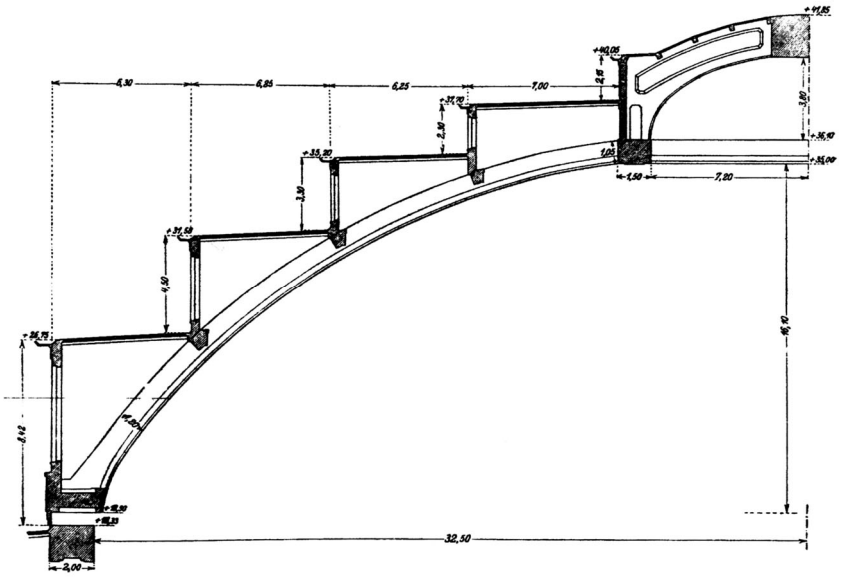

Figure 9: Cross-section of the upper part of the structure

The ribs of upper structure are covered by four tiers of walls, supported on three concentric, stiffening rings, Fig. 9. These walls, in a terraced arrangement, are totally glazed and equipped with system of curtains for adjusting the amount of light permeating inside. Figure 10 presents working drawing of upper rib.

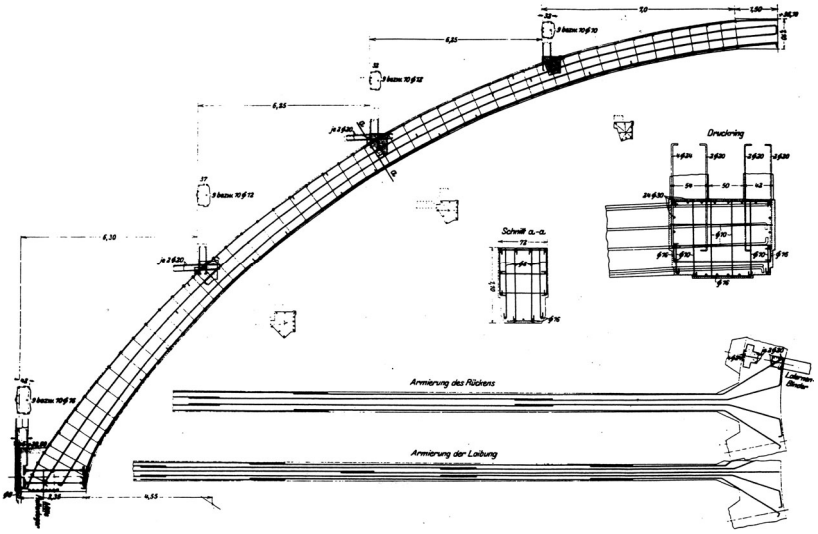

Figure 10: Working drawing of the arched rib of the upper part

An element extremely important, for the global safety of the building, is tensioned ring, forming a base for the ribs of upper part. Structural solution chosen by designers reflects level of knowledge about reliability of concrete structures available at the time. They just didn't trust that the reinforced concrete is able to carry huge tension forces. So, the ring is composed of two horizontal steel trusses covered by concrete cleading, Fig. 11.

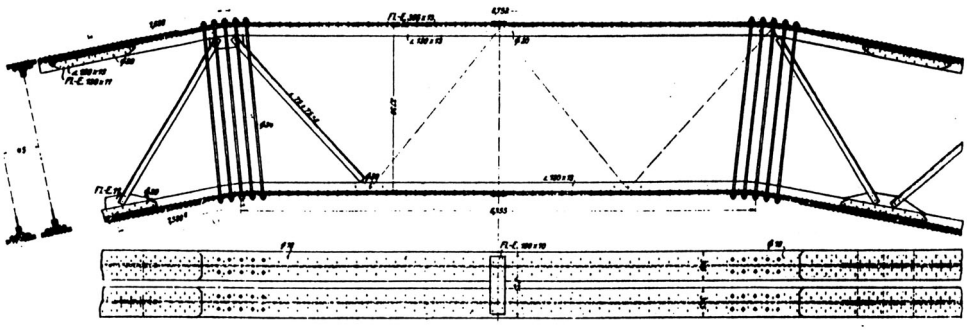

Figure 11: Horizontal steel trusses – reinforcement of the tensioned ring

The tensioned ring is supported on 32 hinged bearings made of brass. The bearings are placed on the top perimetrical ring of the lower part. Figure 12 presents construction of the bearing, its present view (photo) and cross-section of the structure near the bearing.

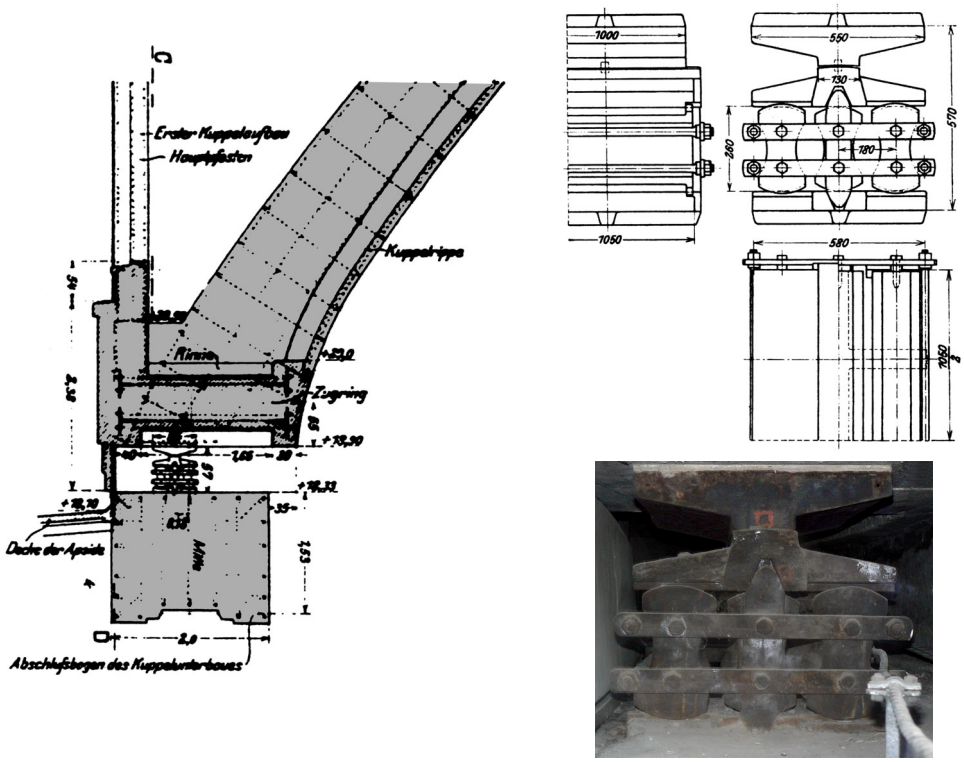

Figure 12: Hinged bearing of the tensioned ring

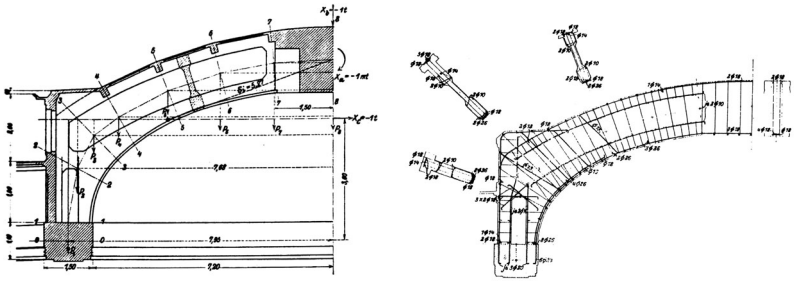

Figure 13: Frame of the top lantern – view and working drawing

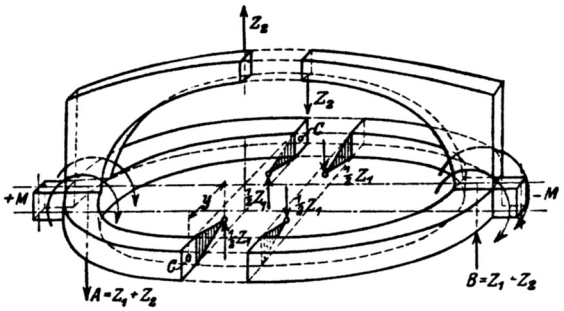

Figure 14: Frame of the top lantern – statical scheme

All 32 ribs of upper part are connected at the top by compression ring. This ring is a base for the top lantern. The lantern is constructed of four concentric rigid frames meeting at the central point, Fig. 13 and Fig. 14. General schematic diagram of the upper part for statical analyze is shown on Fig. 15.

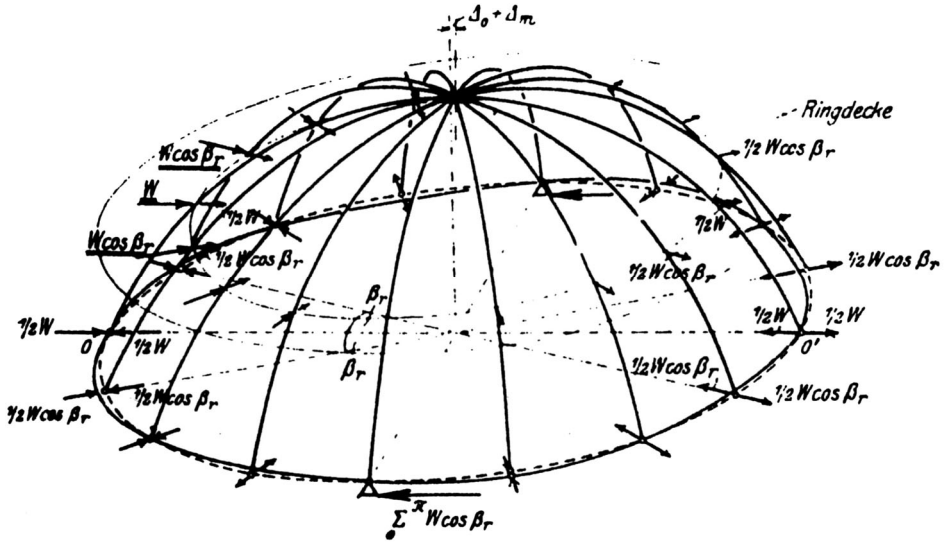

Figure 15: Schematic diagram of the upper part for statical analyze

2.3. Construction of the Wroclaw Dome

The construction of such a complicated structure was possible only due to very high competence of building workers, especially carpenters. Figure 16 presents photographs of scaffoldings and formworks, which were referred to be "…the paramount of building skill". All formworks have been built of wood, and considered to ensure much smaller risk to

collapse than the iron ones. Anyway, workers were afraid to dismantle the formwork and leave the structure self-supporting. Preparatory works for the Wroclaw Dome started in May 1911 and formwork for the main structure was constructed since April 1912. The concrete structure was completed in December 1912.

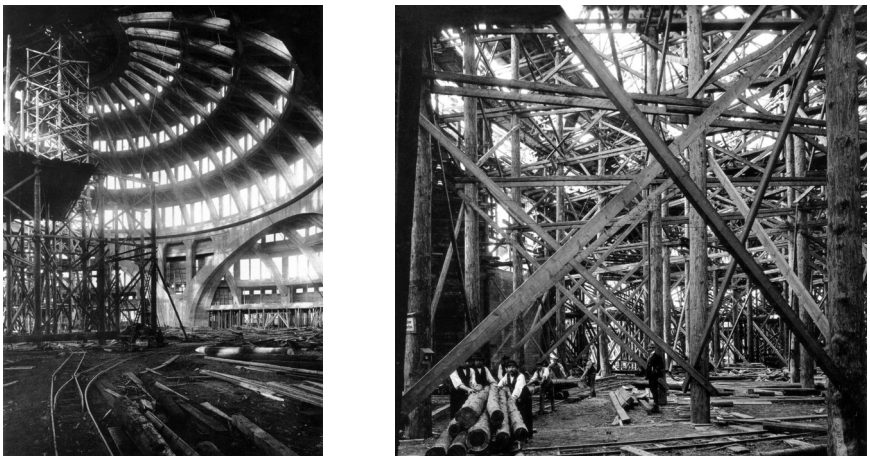

Figure 16: Scaffoldings and formwork during construction of the Wroclaw Dome

3. The Covered Market Hall

The Covered Market Hall was built in 1908. It was one of the two buildings of this type erected simultaneously in the city, both designed by architect Richard Plüddemann and structural engineer Heinrich Küster. The Hall was the first in Germany with the construction based on parabolic arches, Fig. 17 (right) and Fig. 18.

Figure 17: External (left) and internal (right) view of Covered Market Hall in Wroclaw

The building is three-aisled, its length is 86 m, width – 39 m and height – 20 m. The building is distinctive with the contrast between its very traditional external shape and modern, spacious and bright interior, Fig. 17.

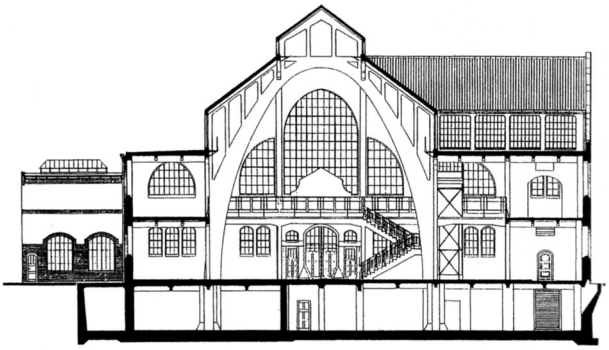

Figure 18: Cross-section of Covered Market Hall

The structural system reveals typical for early concrete structures hesitance. The arrangement is typical for Neo-Gothic style: crossing aisles, shape of window openings and sloping roof supported by arches, Fig. 19. The structural elements however are lightweight, shaped economically, according to the flow of forces.

Figure 19: Intersection of longitudinal and transversal aisles

4. Conclusions

Two early concrete structures presented above, are examples of proper solutions, shaped in accordance to the properties of this novel material. But visual perception of both is completely different. Disregarding different scale of these objects, one – the Covered Market Hall – is designed in accordance to the old but still valid at the time, very traditional esthetical paradigm. Modern internal structure is bashfully hidden behind brick walls.

Another one – the Wroclaw Dome – is a gorgeous example of creative interaction of structural and architectural form-finding.

References

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