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Construction History as a Part of Assessment of Heritage Buildings

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Abstract

Issues related to the processes of maintenance and ensure the continued serviceability of heritage buildings and civil engineering structures are closely related to the processes of assessment of their technical state, repair and strengthening procedures. One extremely important element for a proper diagnosis of the technical condition of historic buildings and also for the adequate design of the actions associated with prolonging their service life should be to perform architectural and structural historical survey. This analysis must be related to the following aspects of construction history occurring during the design and the construction of such objects: design solutions, methods of structural analysis and dimensioning of structural components, properties of building materials, technologies of their production and also the technology of construction. These studies, supported of course by the use of the full range of modern material examination techniques and computational simulations, allow a more complete understanding of analyzed structures. Furthermore, such a program should also contain a prediction of the development of existing or creation of new damages and degradation of the material, as well as guidelines for repair and renovation works in order to ensure structure's further safe operation. From the point of view of the completeness of such a program and with regards to architecture and structural design, its indispensable elements should be both the historical analysis of the design and the construction of the building, as well as of the entire course of its exploitation.

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1. Introduction

Research as well as practical problems concerning the issues related to the proper maintenance and ensure of safe exploitation of historic buildings are without a doubt linked to the processes of the diagnosis of their technical state and further selection of repair and strengthening methods in case of the formation of damages or naturally resulting technical wear. What is more, if a building has historic value and is listed as a law protected monument, also numerous aspects related to the conservatory requirements must be taken into account during the refurbishment process. All these problems can concern not only very old buildings but also quite new structures which already can be considered as historical ones, due to their uniqueness or historical innovation.

Concrete as a building material was introduced in our modern life in the mid-nineteenth century when it started to be used for the construction of massive hydro-technical and military structures. However, only the beginning of the twentieth century brought the development of the construction of many revolutionary reinforced concrete engineering structures that in previous years were impossible to build (e.g. [1], [2], [3], [4]). In those days' concrete was considered to be an extremely durable material and structures made of it were considered to be free from the need of maintenance and with no need to be protected against possible environmental influences during their operational life. This was due to the lack of experience in the use of structures made of concrete, as well as the lack of knowledge of the different environmental impacts that can destroy this material. Only from the mid-twentieth century there has been the development of methods and techniques applied to understand the durability of concrete and reinforced concrete, and evolution of related methods of diagnosis and repair (e.g. [5]).

One extremely important element necessary for a proper diagnosis of the technical condition of historic buildings is implementing of the architectural and structural historical analysis of their former service life. Such an analysis is also required for the adequate design of the process of their refurbishment and maintenance, as well as for the actions associated with the prolonging their serviceability. This analysis should take into consideration, among others, the following elements of the design and construction process of historical buildings: architectural design and calculation methods of structural analysis, dimensioning methods of structural components made from iron, steel, concrete, timber or masonry, properties of building materials and technologies of their production, and also the technology of construction, including the quality of workmanship (e.g. [5], [6]). What is more, such activities should be taken not only from the point of view of the architectural and conservational requirements, but also to gain knowledge of applied historic structural design solutions and techniques that influence the safety of old structures working in nowadays environmental and operational conditions. Such research, supported of course by the use of the modern material testing methods and computer aided numerical simulations, allows a more complete and adequate understanding of analyzed historical structures. It also provides a possibility to use the best technical solutions in the broadly defined actions with an aim to prolong the service life of heritage structures.

2. Selected elements of the construction history on example of the market hall RC structure

2.1. Architectural and constructional design aspects

The architectural design of the considered historical market hall building on Piaskowa Street in Wrocław was made in the years 1901-1903 by the city architect Richard Plüdemann [4]. The conceptual design of the hall was executed between 1904-1906 by the city building inspector Richard Friese [4] and considered a construction of the steel structure in the aboveground part, based on the reinforced concrete foundation. However, in 1906, during the execution of foundation works, a decision to replace the aboveground steel structure with the reinforced one (Fig. 1) was taken at the request of the design engineer Hans Küster ([7], [8], [9]).

This concept was put forward after analysing a variety of design solutions of different market hall buildings existing at the time, but most of all due to the properties of concrete structures such as: durability, fire resistance and no need of maintenance which this material was expected to grant. An important factor that also influenced such a decision were anticipated economical savings in the cost of the construction, including those arising from the lower costs of maintaining concrete structures comparing with steel ones. Finally, the building (Fig. 1) with a horizontal projection similar to a rectangle, with a total length of 85.97 m and a width from 38.97 m to 56.33 m, was designed and constructed as a fully concrete one in 1908 [4].

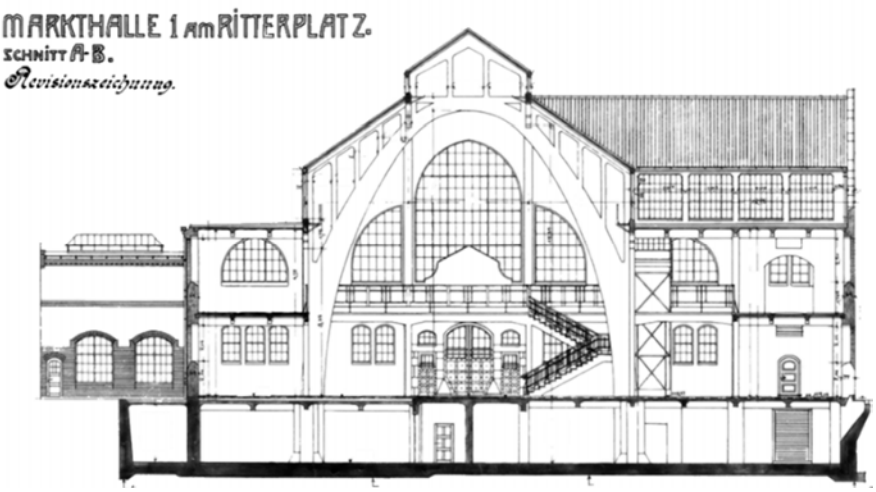

Figure 1. Cross-section of the market hall main nave – RC structure [10].

The main load-bearing structure consists of 6 parabolic arches made of reinforced concrete (Figs 1 & 2) with a total height of 20.80 meters, spaced every 12.00 m. These arches are connected on two levels by castellated reinforced concrete beams (Fig. 3). Smaller, but very similar arches, were designed in three transverse aisles. In addition, stiffening of the overall structure was assured by the reinforced concrete gallery, located at the first floor level and extending around the entire hall. The roof was made of prefabricated reinforced concrete slabs (Fig. 3), with cork as thermal insulation, and covered by ceramic tiles. Due to the high groundwater level, situated above the bottom of the basement, the foundation has been formed as a reinforced concrete slab having a thickness of 50 cm, monolithically connected to the walls of the basement. As a result of such a solution these elements created a waterproof basin without dilatation. Its tightness was assured by insulation of 2 bonded layers made of felt and asphalt, derived 20 cm above the maximum level of the groundwater.

Figure 2. View of the main structural arches.

Figure 3. View of the castellated stiffening beams.

2.2. Aspects of the static model

From the point of view of structural analysis, reinforced concrete main arches were modelled as 2D bi-articulated ones. The calculations of the internal forces were made graphically (Fig. 4) for every considered load scheme, including the influence of temperature changes. The applied graphic solution made it possible to determine the position of the structural connections so that it was granted to centre vertical loads on the pillars and walls of the basement [11]. Archival technical documentation [10] summarizes the loads and their location, which allows to perform their verification in the case of the analysis for the current state of loads.

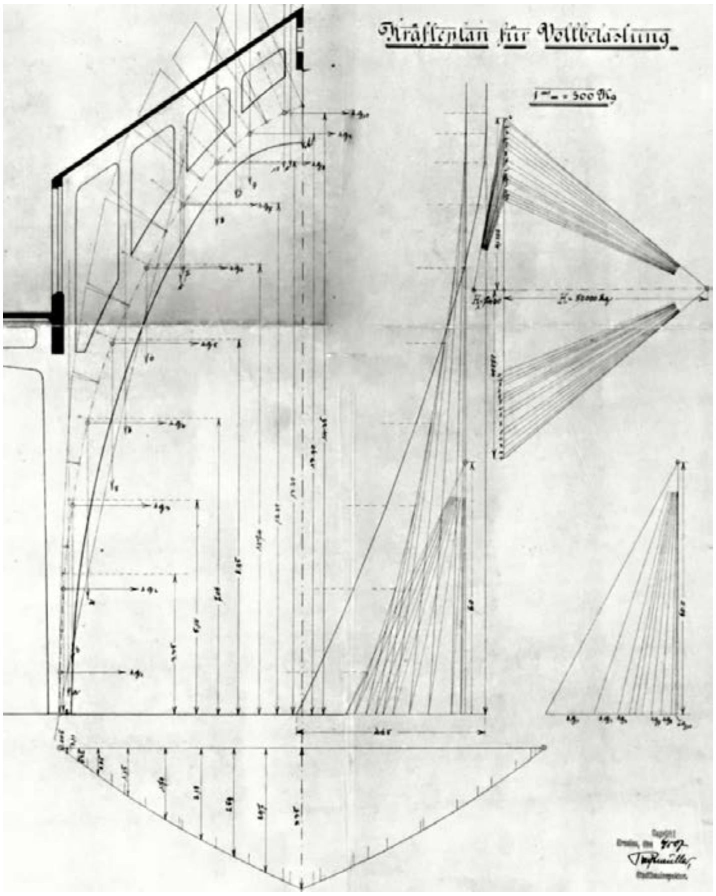

Figure 4. Graphical calculations of the RC small arch, [10].

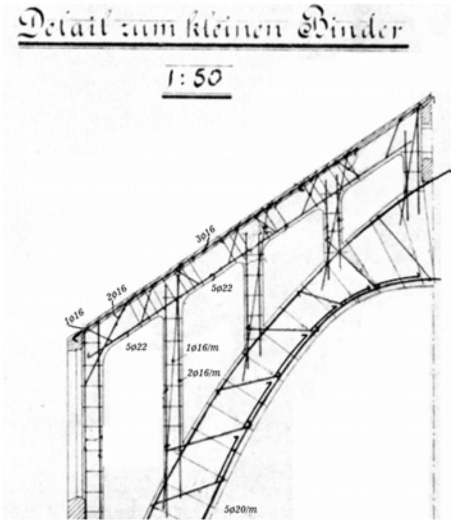

Figure 5. Rebar disposition in the RC small arch, [10].

2.3. Aspects of the material properties

Issues relating the chemical, physical and mechanical properties of materials used to construct the building are crucial in the assessment of the structural strength and prediction of further service life time of historical buildings (e.g. [12]). Based on the analysis of archival records [10] and the literature (e.g. [13]) there can be found properties of steel and concrete used in those historical times. However, nowadays NDT or semi-destructive methods allow to identify and verify these properties with high accuracy and reliability.

2.4. Aspects of the rebar design

Calculations and drawings of the reinforcement distribution (Fig. 5) for the load-bearing structural elements of the market hall building are also included in the archival documentation [10]. That can also be verified by making NDT examinations or visual inspection.

2.5. Aspects of the former maintenance process

The considered market hall was built in the first decade of the twentieth century (Fig. 6) and during operation time it was subjected to all kinds of minor refurbishment, primarily pertaining to elements of finishing (years 1936-1938). The first important structural intervention took place after World War II in order to repair some minor damage caused by the war. A fragment of the roof was reconstructed and a section of the reinforced concrete ceiling above the basement was replaced by a segmental ceiling on steel beams.

It was only in 1971-73 and 1979-1982 when the expert reports and the modernization design were prepared. In the period from 1980 to 1983 the building was subjected to a major repair (Fig. 7). These works certainly had a positive impact on the current technical condition of the building.

Figure 6. View of the rear façade in 1909, A. Pilcher [14].

Figure 7. View of the front façade during repair works in 1980-83, [14].

Environmental conditions of the operational life of the facility were decisive for the lack of serious damage. The whole reinforced concrete structure of the market hall is practically located inside the building and therefore was protected against all environmental influences that have a destructive impact on the concrete. Small local damages to the structural elements (minor cracks, stains, efflorescence, spalling of concrete cover, honeycombs), however, do not threaten the overall reliability of the building structure.

3. Final remarks

The presented historic market hall, undoubtedly an outstanding example of the use of reinforced concrete for construction of the pioneering engineering structures in the beginning of the 20th century, was used to explain some of the important issues that have to be taken into consideration in the process of designing refurbishment and developing proper maintenance program for heritage structures.

Based on the analysis of the previous use time and current technical state such a program should also include a prediction of the development of existing or creation of new damages and degradation of the material, as well as guidelines for repair and renovation works in order to ensure further, safe operation of such buildings. From the point of view of the completeness of such a program and with regards to architectural, design and conservatory requirements its indispensable elements should both consider historical analysis of the design and the construction of such buildings, as well as the entire course of their exploitation.

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