INNOVATION AND STANDSTILL - EARLY APPLICATION AND DEVELOPMENT OF THE "MONIER SYSTEM" IN BERLIN

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Reinforced Concrete, Monier System, M. Koenen, G.A. Wayss, Construction History

Abstract

A variety of publications – focusing on specific countries, engineers or companies – highlight the development of reinforced concrete in continental Europe. But so far none has focused on the city of Berlin.

This comes as a surprise, as Berlin was a very dynamic major city with close to a million inhabitants when the former capital of Prussia became capital of the German Empire in 1871. In the following years the number of inhabitants tripled and it became the biggest industrial metropolis in continental Europe at the turn of the century. Within this socio-economic backdrop in Berlin first examples of reinforced concrete applications, dating back to 1880s can be found. The best known being the Reichstag with Matthias Koenen as the engineer in-charge of its structural calculations and Gustav Adolf Wayss as one of the contractors promoting the use of reinforced concrete as part of the structure. The cooperation of Koenen and Wayss counts as the starting point of scientific application of reinforced concrete in construction industry in Germany. A first outcome being the *Monier Broschüre* published in 1887 where Koenen defined an initial theory on the structural behaviour of reinforced concrete based on results from material testing.

During 1880 and 1904, a large number of industrial buildings, factories, store and warehouses were built in Berlin. With rather restrictive attitude of public construction authorities it took quite some time to get reinforced concrete acknowledged as proper building material with the earliest official German regulations being published in 1904. With significant findings showing the use of the Monier System during the early years the paper first highlights the formation of relevant building companies of that time in Berlin. Furthermore the paper outlines essential reinforced concrete applications based on an analysis of archive material. The compilation of the material will be published for the first time in this context. In conclusion the paper clarifies and discusses important developments within early reinforced concrete applications in Berlin.

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BEGINNINGS OF THE MONIER SYSTEM IN BERLIN

The 19th century is widely known as the age of iron and steel construction, but it was also the time when reinforced concrete was introduced. Men from different scientific backgrounds had pushed the development of concrete so it could be used as a structural component in the construction industry. By 1850 English and French inventors had furthermore combined iron with concrete. These early beginnings of reinforced concrete have been described in numerous publications with the latest covering the company history of Dyckerhoff & Widmann, a major German building company (Stegmann 2014).

The American entrepreneur Thadeus Hyatt (1816–1901) published his book “An Account of Some Experiments with Portland-Cement-Concrete” in 1877. According to Wermiel (2009) and Peters (1977), Hyatt defined reinforced concrete as a building material in which reinforcement counteracted the tensile forces and concrete the compression forces. Therefore, Hyatt furthermore advised that the reinforcement be located in parts exposed to tensile stress. Somehow his publication was not recognised by European scholars. While German scientists and engineers did partake in the process of producing good quality cement and steel, the main impulse to use a combination of materials such as reinforced concrete actually came from outside the country. It was Joseph Monier (1823–1906) who successfully promoted early use of reinforced concrete despite coming from a gardener’s background and using the iron reinforcement for the purpose of form-giving rather than as a load-bearing element. He had registered different patents in France before applying for patent protection at the German Patent office in 1880. His patent “system to produce things of different purpose made by combining metal framework and cement” was accepted as D.R.-Patent No.14673 and published on the 4th of August 1881. The patent for the Monier System contained construction drawings for reinforced concrete railway sleepers, a variety of containers and a tube. This seems to be the starting point for reinforced concrete in the German Empire.

Besides the examples given in the patent it was also common to use reinforced concrete as fireproof cladding, which would prevent fire from causing deformation of iron structures. Since reinforced concrete was not the primary load-bearing structure in such applications, these have not been taken into account in this study.

ESTABLISHING A CONSTRUCTION METHOD IN BERLIN – THE KEY PLAYERS

In 1871, the German Empire was founded and Berlin became its capital. With close to a million inhabitants it was already a big and dynamic city, fast on its way to becoming the biggest industrial metropolis in continental Europe. It offered great potential for building companies and other trades.

The introduction of reinforced concrete in Berlin is inextricably linked to Gustav Adolf Wayss (1851–1917). Coming from Frankfurt am Main he bought a part of the Monier patent in 1885 and moved his business to Berlin. While in search of new building projects to improve the annual turnout he came in contact with Mathias Koenen (1849–1924), a representative of the construction administration who was supervising the most prestigious construction site at the time – the Reichstag. In the 1880s public regulations did not list reinforced concrete as a load-bearing construction method (Richthofen 1887 and Baltz 1910) and Koenen was very interested in learning more about it.

Their cooperation in undertaking initial material tests in 1886, in evaluating the results as well as in executing building projects provided a major impetus to further experimentation with this building material, and thus an expansion in the possible application of reinforced concrete.

In 1888 Koenen resigned from his position within the public authorities and joined Wayss' firm. They were able to combine the license for practical execution with their ability to provide theoretical proof of the load-bearing capacity of reinforced concrete. Thus, with the help of license and patent law both men saw and used their chance to monopolise their expertise. Already in 1889 Koenen became the second manager in the firm besides Wayss and also the technical director of the then new "Actien-Gesellschaft für Monier-Bauten".

As the advertising work of Wayss became more and more successful, it resulted in a need for hiring sub-contractors to meet the growing demand (see Fig. 1). In 1889 and again in 1891 the company of Held & Francke was first to appear in the historic records as being part of a construction team under leadership of the Actien-Gesellschaft für Monier-Bauten. The first competitor was the company Alterthum & Zadek. In 1892 they were contracted to realise plain reinforced concrete ceilings in an office building in the centre of Berlin.

In 1894 the patent license for the Monier System expired leaving room for other companies to pick up on this new construction method. But interestingly it took nearly another ten years before the number of companies implementing reinforced concrete projects increased in Berlin. The annual business reports of Actien-Gesellschaft für Monier-Bauten draw a quite solemn picture concerning the overall situation in the last decade of the 19th century (AG BuM 1890). Not only was the price for traditional materials and unskilled labourers far cheaper compared to reinforced concrete, for several subsequent years the weather conditions only allowed building sites to be open for six months. This in addition to the poor economic situation in Berlin significantly limited the number of buildings being realised. This might explain why Dyckerhoff & Widmann and Lolat Eisenbeton build their first reinforced concrete project in Berlin only in 1902 and 1903 respectively.

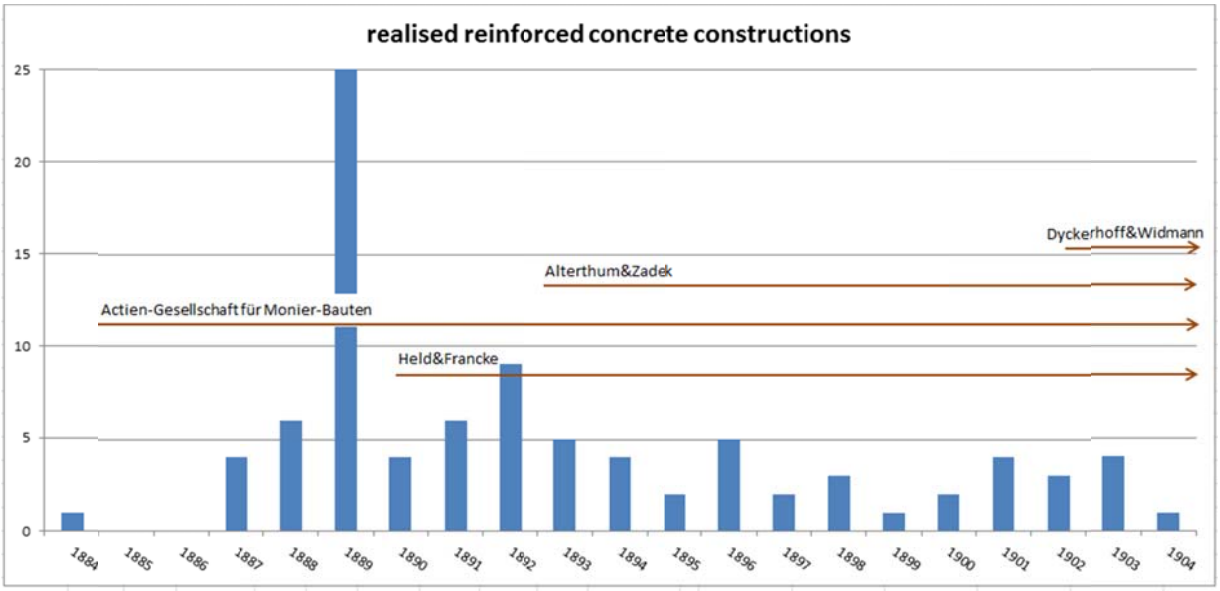


Figure 1: Realised reinforced concrete constructions in Berlin and a selection of specialised building companies

Analysing the number of realised projects shows one deviation. According to Mislin (2002) the first reinforced concrete ceiling in Berlin was realised in 1884 but so far no further information on such a construction has been found. Main objectives are therefore the projects realised after Wayss bought the Monier patent license. In addition to the actual buildings it is also of in-

terest to investigate specialised companies to be able to elaborate their specific input to the construction method. So far it seems that there was no competitor besides Wayss and Koenen for the first 15 years. Only with on-going material testing and research did other companies feel sure enough to engage in the construction method. Table 1 shows preliminary results of the current study, it does not claim to be complete. Main turning point in building with reinforced concrete was Emil Mörschs (1872–1950) ground-breaking publication “Der Eisenbeton. Seine Theorie und Anwendung” in 1902 and the first regulations on building with reinforced concrete by Prussian authorities in 1904. Thus limits the timeframe of this investigation.

Company Name	Detailed Information	First known application of R.C. in Berlin
G.A. Wayss & Co.	Originates in Frankfurt am Main around 1878. After buying a part of the Monier System license in 1885, the company moved to Berlin and became the sole promoter of the Monier System in the northern part of the German Empire.	1887
Actien-Gesellschaft für Monier-Bauten	Founded in 1889 in Berlin, it replaced G.A. Wayss & Co. The new company primarily promoted the Monier System, while also building rammed concrete structures.	1889
Held & Francke	A traditional building company founded in 1872 in Berlin. In the beginning mainly realising masonry and timber constructions.	1889
Alterthum & Zadek	No detailed information found as yet.	1892
Dyckerhoff & Widmann	Founded in 1865 under the name of Lang & Cie in Karlsruhe, it primarily specialised in rammed concrete and was active in the south-western part of the German Empire.	1902
Lolat Eisenbeton	A specialised reinforced concrete company founded in Berlin around 1903 by entrepreneur Gustav Lolat.	1903

Table 1: Specialised construction companies in Berlin

THREE STEPS TO ESTABLISH REINFORCED CONCRETE IN BERLIN

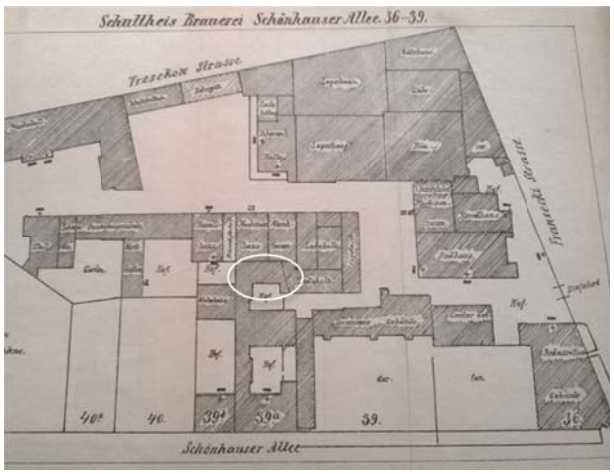
The German patent for the Monier System did not exactly list ceiling constructions it therefore is very likely that Monier shared his expertise from his older patents. He therefore enabled Wayss to compete with the variety of traditional ceiling constructions that were available on the market. Wayss was rather successful in promoting this new method and he was able to acquire numerous building contracts.

In order to withstand the economic competition with traditional building materials it was all the more a reason to enlarge the variety of applications of the Monier System besides ceiling constructions. But not before the material testing results were analysed in the *Monier Broschüre* did the construction variety increase (Koenen, 1886), (Wayss, 1887). Now there was proof that certain structures would withstand their loading and there were layout examples. It enabled public representatives to accept constructions that were not covered by regulations more easily by single case permissions. The final step within the development of the construction method was the combination of single elements to a monolithic structure. To illustrate the progress three buildings within the city of Berlin will be described in the following. So far these buildings have not been investigated in the context of reinforced concrete and it is the first time that parts of the remaining archive material is published.

Close to the Monier System – ceiling constructions

A model application of the Monier System was realised within the building complex of the Schultheiss Brewery in the borough of Prenzlauer Berg. The successful company expanded in 1887 and commissioned the architect Franz Heinrich Schwechten (1841–1924) to design a new ensemble of buildings. The company premises ranged over 20.000 m² and included different factory, storage and apartment houses that were realised until 1891. From the outside the buildings' façades are structured using yellow bricks and sandstone in a Neo-Romanesque round arch architecture. It is one of Berlins' biggest industrial complexes that largely remained in its original layout until today.

Constructed in 1887 the building itself was used to process and store bottled beer. It does not exist anymore. The ceilings have been described as *Monier-Isoliergewölbe* (Monierinsulation vaults) with a span of 6.50 m and a thickness of 4.5 cm of which in total around 1000 m² of barrel-vault like ceiling constructions were built (Wayss 1889). A more detailed description of the construction has not been found. In order to generate sufficient insulation the ceiling was made of two layers. According to the construction drawings the 'load-bearing' ceiling was positioned underneath an 'insulation' ceiling. Curved ceiling elements of the former were reinforced with iron bars (diameters of 5 to 7 mm and parallel positioned with a distance of 8 cm, see Fig. 3) and spanned between iron I-girders. The latter was also a reinforced construction positioned above the load-bearing ceiling and leaving a hollow space in between. It spanned crosswise to the 'load-bearing' ceiling (see. Fig.3). So far this large ceiling structure was one of the earliest examples of the Monier System that could be determined so far in Berlin. Although the application already exceeds the specifications given in the German Monier patent, is still is in favour of 'traditional' Monier structures.



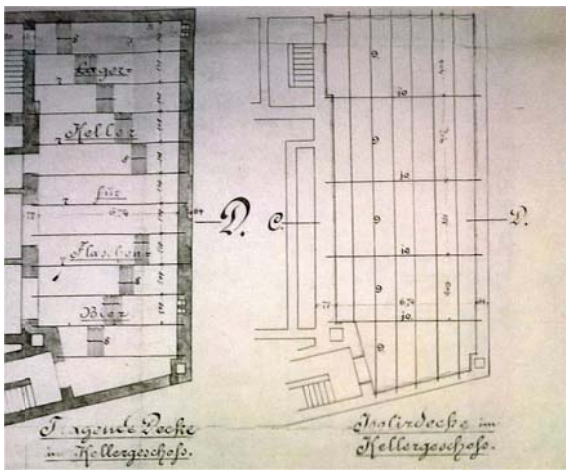
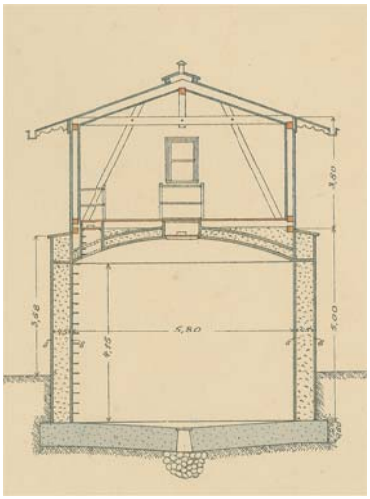


Figure 2: Site map of the Schultheiss Brewery complex, indicated is the building with Monier ceilings. (LAB 01)
Figure 3: Construction drawing detail of the ceiling above basement indicating the reinforcement for the 'load-bearing' ceiling (left) and the girders' position within the 'insulation' ceiling (right). (LAB 02)

Exploring the variety of applications – integral approach

The following example illustrates the range of using reinforced concrete in construction after the material tests of 1886/87. As part of the building complex of the Charité, a famous and well established hospital during the times of the German Empire, it was a building designed to store ice since artificial cooling systems had not been developed yet. The building does not exist anymore.

The ice cellar was made of reinforced wall and ceiling elements of the Monier System. It was designed as a closed cylinder with a diameter of 5,80 m built into a rectangular housing that was covered with a gabled roof made of timber. The reinforced ceilings and walls were built in two layers, the distance in between being filled with coke ashes. Four masonry pillars were located in the corners of the cube. These seem to have been the fixing point for the outer walls. Two openings in the ceiling offered access to the cylinder. One opening located at the edge allowed access for people to maintain the inner space, having a diameter of 60 cm. Iron steps were located to cover the distance to the bottom ca. 4,5 m. A second opening in the middle of the ceiling with a diameter of 90 cm was used to fill in ice. In order to provide a circular-shaped inner wall the cylinder was made in one piece. To stabilise the cylinder structure short wall sections were integrated between cylinder and outer walls, which were made of four large wall sheets. Both the cylinder and outside walls had a thickness of 8 cm and the inner wall sections of 6 cm. It is not clear whether the individual reinforced concrete sheets were interconnected with reinforcement or rather just jointed using concrete mortar. Despite the small scale of the building it is a fine example showing an integral approach in using reinforced concrete. Here the results from the material tests nearly become visible. Reinforced concrete elements are now used to build a spatial structure - indicating what will be possible about a decade later.



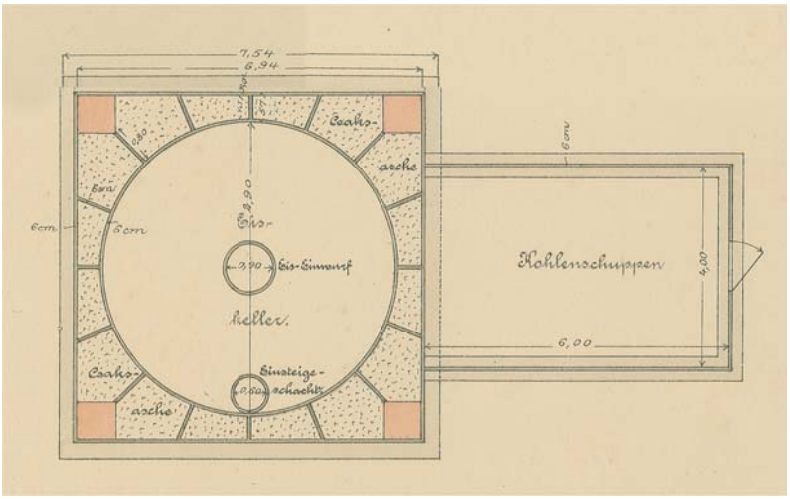


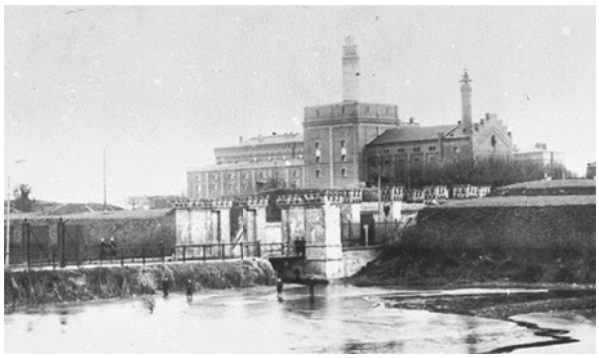
Figure 4: Cross section showing the design of ceiling and wall sections in layers of. (LAB 03)
Figure 5: Ground floor plan showing the bracing concept with the inner wall sections and the openings in the roof. (LAB 04)

Reinforced concrete beyond the Monier System – monolithic structures

The first monolithic structure in Berlin was supposedly realised between 1900 and 1902. It was a factory building close to the river Havel between the cities of Berlin and Spandau (see Fig. 6).

At the end of the 19th century the traditional layout and architecture of brewery buildings had changed. It now was popular to make the different working processes more visible from the outside. What originally had been included in one building was now divided into a malting house, a brewery and so one. The building in question was built as a malting house belonging to C. Gregory. He probably cooperated with the Berlin-Spandau Brewery which was located close by. Once more, information on the building is very limited: The edifice has been destroyed and nearly no archival material has been preserved. Nevertheless one picture remains showing the exterior layout of the malting house. It was a large rectangular-shaped building with a prominent middle

section. The façade was made of bricks and structured with small round arched windows and elongated juts. The interior of the malting house can be seen in Fig. 7. It shows a large open space with a flat ceiling that is supported by beams and pillars. The picture is subscribed “ceiling in the Maltinghouse C. Gregory, Spandau, for 2000 kg/m² living loads” (Beton-Verein 1902). The layout of the ceiling structure and the slim rectangular pillars appear to be fully made of reinforced concrete (Dittrich 1990). Supposedly this is the first monolithic structure in Berlin, even before public regulations were published in 1904.



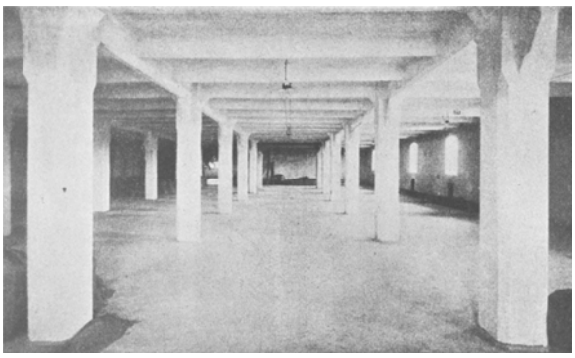


Figure 6: Exterior view of the factory showing a structured brick façade, photograph from 1903 (LAB 05)
Figure 7: On the inside the malting house offered large storage space with a seemingly monolithic reinforced concrete frame structure (Beton-Verein 1902, 149)

CONCLUSION

The above-mentioned examples perfectly illustrate an evolution in the understanding and application of reinforced concrete in Berlin. Starting with its application for realising a simple idea this new building material gradually began to be used for implementing rather comprehensive solutions, which can perhaps be interpreted as a kind of natural evolution in man-made construction. In the beginning the application of reinforced concrete was tied to the specifications given in the Monier patents. Wayss and Koenen pioneered in enhancing the Monier System in Berlin leaving other European countries behind for some years. Their cooperation was ground breaking. It was in Berlin that a first design theory for reinforced concrete was defined, based on material test results. Yet, at the time neither Wayss nor Koenen were able to comprehend the possibilities of a monolithic reinforced concrete structure. The situation in Berlin came to a standstill. Might it be due to the economic situation that resulted in an absence of specialised companies competing in a race against each other to improve the building method? Or might it be because of German engineers that had become depended on calculating their structures in every detail rather than building them by way of rule of thumb? The structures design remained within the given limits of the Monier System and also limits that were set by the capability of contemporary structural analysis.

However, in 1902, with the construction of the first monolithic reinforced concrete structure, finally the limitations had been overcome. As Kurrer (2008) points out, the beginning to fully understand reinforced concrete as a monolithic structure has to be credited to the German Engineer Emil Mörsch. His theoretical assumptions in fact were again based on repetitive material tests, but had probably been more influenced by Paul Christophe and François Hennebique rather than Monier. From this moment on and with the safety of public regulation in 1904 building with reinforced concrete in Berlin gained a different significance. Yet again it was possible to construct elaborate structures that were seeking its equals in Europe. But this is a different story.

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