Building a Masterpiece of Concrete-Technology: The Deutsches Museum in Munich (1906-1911)

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ABSTRACT: The Collection-Building of the Deutsches Museum in Munich (Germany), built between 1906 and 1911 represents a significant monument for the history of concrete because it marks a well documented milestone of improving construction-methods in the city of Munich around 1900. Munich was one of the important sites for the development and diffusion of concrete technology in Germany, where concrete was used to build thin shells for domes, innovative bridges of rammed and armoured concrete, exposition halls and other high buildings. Considerable construction companies throughout Bavaria were founded at this time and extended their research to concrete-engineering. They designed the necessary equipment and optimized rules and procedures. At the same time significant architects and engineers met the challenge and began successfully to use the new construction material. Within this context the Museum was one of the main buildings of this type and the largest construction site of its time in Europe where concrete was used and thus nearly all contemporary innovative construction techniques and tools have been exemplary employed there. Fortunately the construction process has been documented extensively in the Museum's archives throughout the whole construction time, allowing a new interpretation of this building today.

INTRODUCTION

The construction of the -so called- collection- Building of the Deutsches Museum in Munich (Germany) between 1906 and 1911 is a significant event for the history of concrete not only in Bavaria; it marks a milestone of improving construction-methods in the city of Munich around 1900. At this time Munich was one of the major sites for the diffusion of concrete technology in Germany, where concrete was used to build thin shells for domes (Museum of the Army, Anatomy-Building), innovative bridges of rammed and armoured concrete, exposition halls and other high buildings.

Important construction companies throughout Bavaria were founded at this time and extended their research to concrete-engineering, designed the necessary equipment and optimized procedures. Important architects and engineers in Germany and especially in Bavaria met the challenge and began to use the new construction material. The Museum building was the largest construction site of its time in Europe and nearly all innovative building techniques and tools have been exemplary employed there.

Furthermore the building process, the production methods and materials used have been documented extensively throughout the whole construction time. These documents in the Museum's archives have not been evaluated until now with respect to their value for the history of construction.

This approach illustrates how the construction of the Museum represents an essential document for the study of the achievements of concrete technology in the first decade of the 20th century. This paper is the first report of a larger investigation about the construction of the three parts of the Museum, the Collection building the Library and the Congress-hall.

THE CONCRETE COMPANIES

The history of industrial production of cement and hence also the history of the concrete construction companies begins in Bavaria with the opening of the first factory for the so called Romancement in1832 in Munich that helped to disseminate all over Bavaria the installation of more cement plants until 1845. From 1847 on the lime-factory *Schwenk* in Ulm was the main supplier for Roman-, later for Portland cement in southern Germany. The first factory of Portland cement in Germany had been installed in 1855 in Züllchow near Stettin. This was at a time when –for instance- in Rüdersdorf near Berlin -where enormous lime deposits had been exploited since the 16th century- still just hydraulic limes had been produced until as late as in 1884 Portland cement was first produced. Besides the cement factory of *Schwenk* in Ulm the foundation of the cement factory in Amöneburg near Mainz, under the management of *Wilhelm Gustav* (1805-1894) and *Eugen Dyckerhoff* (1844-1924) in1865 was an essential contribution to the cement supply in southern Germany. Just one generation later members of this dynasty of factory owners founded the most important construction company *Dyckerhoff und Widmann AG (DYWIDAG)* which later hold engineers like *Franz Dischinger* (1887-1953) and *Ulrich Finsterwalder* (1897-1988) pioneers of modern concrete applications (Bühler 2003 p. 475). *Dyckerhoff und Widmann AG* will later build also the Hall III of the exhibition centre on the Theresienhöhe (1907-08), today the Verkehrszentrum of the Deutsches Museum and will be part of the contractor's pool for the main building of the museum.
Concrete, together with new methods for framework, ramming and reinforcing acquired a broad use –for instance- for bridge constructions after an inundation in 1899 had destroyed many of the bridges over the Isar River in Munich. Before, in 1892 the first concrete bridge had been built over the Nymphenburger Kanal by the *Akt.-Ges. für Beton- und Monierbau* from Berlin and in 1898 the so called Kabelsteg was built by the *Wayss & Freytag AG* Munich. The architectural design was still completely in agreement with he stylistic rules and imperatives of the time, the new material should not be perceived by the spectator: it was nearly always revetted with the typical Bavarian lime-stones. *Prinzregent Luitpold* (1821-1912) and the major of Munich, *Wilhelm Georg von Borscht* (1857-1919) assigned the planning of the six new bridges to *Theodor Fischer* (1862-1938) and *Friedrich von Thiersch* (1852-1921). The first two of them was to be built -like nearly all the other ones- by the company *Sager & Woerner* in 1900-01: the Luitpold- and the Max-Joseph-Brücke later the Cornelius-Brücke (1901-03), the Reichenbachbrücke (1902-03), Maximiliansbrücke (1903-05) and finally the Wittelsbacher Brücke (1904-05) should be built with a similar structural and design layout (Bühler 2008). The first bridge made with reinforced concrete was built in 1904 in Grünwald near Munich -with arches spanning 70 m - according to the design of *Emil Mörsch* (1872-1950), the director of the engineering office of the *Wayss & Freytag* Company in Munich.
In the area of high rise buildings the *Heilmann & Littmann* Company built in 1896-97 the first reinforced vault in Munich for the Hofbräuhaus. In 1902 the *Gebrüder Rank* Company purchases the concession for the Hennebique-structures and began to build single family houses with ceilings made of concrete, later they have built many office and public buildings. In 1907-08 they were contracted to build the Entrance to the exhibition centre on the Theresienhöhe and the main customs building (1909-12).
In 1903 the *Eisenbeton-Gesellschaft* was founded by merging the Companies *Heilmann & Littmann + Wayss & Freytag AG*. They were contracted -more frequently than the *Gebrüder Rank*- for public and educational buildings like in 1903 for the Psychiatrische Klinik, but they also built churches between 1903 and 1914, silos and many office and commercial buildings in Munich. Two main structures, built by the *Eisenbeton-Gesellschaft* are the cupolas of the Bayerisches Armeemuseum (1903-04) and the Königliche Anatomie (1905-07).
Another important company will be *Leonhardt Moll*, contracted for the new University building annex (1906-09) by *German Bestelmeyer* (1874-1942), market halls (1911-12) and the *Dickhäuterhaus* (1914) in the Munich Zoo.

OSKAR VON MILLER AND HIS MUSEUM

Oskar von Miller (1855-1934), founder of the Deutsches Museum, wanted not only his expositions to show authentic masterpieces from the fields of natural sciences and technology: his museum building also should represent the state of the art of construction-technology and was meant to be a masterpiece itself, not so much of modern architecture but even more of civil engineering. *Miller*, who had studied civil engineering in Munich, had worked long before closely with the cement industry and qualified construction companies in other projects so it was quite obvious that the new museum had to be a modern concrete construction, using the most innovative techniques, systems and tools. Therefore a lot of material and tools have been sponsored by the companies involved, while *Miller* on the other hand felt obliged to promote cement and concrete construction in Southern Germany. Additionally to the implication of the building itself as an engineering masterpiece, the founder of the Museum collected important, nowadays unique objects referring to concrete technology and presented them in his exhibitions. So the civil engineer *Oskar von Miller* was already familiar with the practice and management of concrete long before he was planning the museum. However, his enthusiasm for the construction business was very limited as he admits (Füßl 2005: p. 229) during his short time as active civil engineer in 1878, when he was in charge as a project engineer for the railroad tracks, tunnels and bridges on behalf of the Bavarian government.
He felt –opposed to his original education- a particular vocation to get involved in the electrification of his country and this vocation should have a strong influence on his professional future. His very personal career as promoter of the electrification has a curious but noteworthy relation to concrete because it starts with a Portland Cement Plant: Miller's biographer, *Wilhelm Füßl* (Füßl 2005, p. 121) writes:

> Millers decision [to find out the possibilities for long distance electric power transmission] was due to a fortuitous event (even before the *International Electro Technical Exposition* of 1891 when he first succeeded in public): In the city of Lauffen on Neckar the *Württembergische Portland-Cementwerk* had been founded in 1888. The water power available at the site […] exceeded by far the necessities of the plant, a fact that lead to the significant and far-reaching consideration to send the electric power left-over to the nearby city of Heilbronn, in order to provide the community with electric lighting and motor drive.

Projects concerning strictly water management or even hydraulic engineering never have been the business of the Technisches Bureau Oscar von Miller, München (Füßl 2005, p. 99) [later called Ingenieurbüro Oskar von Miller (Füßl 2005, p. 96 and 99)] For the construction of the electric power station in Hermannstadt in the year 1894 the following division of work had been agreed, which was typical for other projects too:

> The Technische Bureau Oscar von Miller […] assumed responsibility as a general contractor for the delivery and completion of the complete part of engines and electrical components and the construction company *Pittel & Brausewetter* from Vienna was in charge of the construction. (Füßl 2005, p. 157)

Within the construction works to be carried out a supply channel made of concrete had been mentioned specially, surely not the only part of the building made by this material (Füßl 2005, p. 157).
In order to promote the electrification of his state, Miller took on many business travels and campaigned his ideas, encouraging authorities and businessmen for the construction of hydraulic power plants. During these travels he was always accompanied by contractors and planners because he wanted them to build the power houses, channels, dams or weirs for the power plants which *Miller* supplied with the electrical equipment. For nearly all these buildings the contractors and planners relied on the new and cheep material: which was concrete, a material whose technical possibilities and innovative appliances were explored systematically, improving its use steadily.
The construction company *Kunz* from Kempten (Bühler 2003, p. 483) was one of those, who kept close contact to *Miller*. They planned and build several hydraulic power plants together -of course using concrete- in the cities of Mittenwald, Dachau and Schwandorf (Oberpfalz). (Alfred Kunz 1982, p. 10) Together with *Alfred Kunz Oskar von Miller* promotes the construction of hydraulic power plants in Bavaria and Baden Württemberg (Alfred Kunz 1982, p. 93-94), this was a co-operation of the two entrepreneurs which was finally crowned by the construction of the Walchensee power plant (Alfred Kunz 1982, p.103). Furthermore the *Dyckerhoff & Widmann* company came out ahead -after an ideas competition- in 1907 with their proposition, prepared in co-operation with the *Maschinenfabrik Augsburg-Nürnberg AG* and *Siemens-Schuckertwerke* for the Walchensee power plant (Füßl 2005, p. 170). A lot of convincing and planning was still necessary until finally in 1918 the decision was taken to build the plant, which was inaugurated January 24th of 1924.

THE LAYOUT AND DESIGN OF THE DEUTSCHES MUSEUM

The approach to the layout and design of the museum has to be a double one: on one hand we have to observe the museum building within the general architectural stiles present in Munich at this time but we have to focus also other museum and trade fair buildings which worked as models for the new projected museum.

The architectural proposition

The City of Munich had placed the Kohleninsel (so called because it was the place where -at the timber disembarked site from rafts- charcoal was produced) at the disposal for the museum building with an area of around 36.000 m². The Island occupies a privileged place in the expanding city of Munich and had been used before as a trade fair place too. Even *Theodor Fischer*, Munichs famous urban planner of the time, had already made plans for a monumental museum on this place, plans that have been frustrated by its later planner (Nerdinger 1988 p. 13). The architecture of the Deutsches Museum as the Bayerische Nationalmuseum and the Armeemuseum was considered to be monumental and hence had to be approved by the "commission for monumental buildings" created by *Prinzregent Luitpold* in 1902 (Albers 1980 p.18).
The architecture of the city was still dominated by the influence and authority of *Friedrich von Thiersch*, professor at the polytechnic school and one of the main representatives of the architecture of historism in Germany. By the beginning of the 20th century –the Art Nouveau was already nearly out of fashion- the historic style, limited to reproduce just one historic style in the best possible –or even better- way (still present in the neobaroque Justizpalast, 1890-1897) (Habel 1980, p. 26) was followed by a period that offered a more open interpretation of historic styles, combining different ages in different parts of the building (Habel 1980 p. 30).
One of these options realized *Gabriel von Seidl* (1848-1913) with his building of the Bayerisches Nationalmuseum (1895-1900), which offers a new interpretation of historic architectural design. So it was precisely this renowned Munich architect and close friend of *Miller* who was assigned to plan the new museum, because he had also set other landmarks before for industrial construction with the Trade fair halls in the Theresienhöhe in Munich (1907-1908). Miller had commissioned *Seidl* to make a preliminary plan, containing the main concepts for the building, which had been approved in 1905 by the building commission of Munich. However the municipality insisted in inviting a larger number of architects to participate in a general competition for the monumental building: Of course *Seidls* proposition came off as winner out of the 31 designs submitted (*Deutsche Bauzeitung* 1906, several Issues). He came to know the result just two days before the laying of the foundation stone for the collection building on November 13th of 1906. Past this famous date a two years in-

tense detail planning phase began. In this period the original design of *Gabriel von Seidl* –to his great displeasure- was changed constantly due to *Millers* indications for the operation and functionality of the museum (Pilsak 1989 p. 36-38). At the same time contractors presented their calculations and their own technical propositions. The original design of *Seidl* for an original historic museum had been purged to a more functional one but without reaching the expressivity of a really modern building (Preiss 1993 p. 134) (Fig. 1 and 2). The opinions and analysis around these topics of style, intentions and results lead to controversy answers (Nerdinger 1980 p.47), but this debate doesn't fit the purpose of this article; just one result seems to be for sure: the architectural design of the museum stays behind the opportunities, whereas the building technology represents the state of the art. When *Gabriel von Seidl* died on April 27th of 1913 his brother *Emmanuel* (1856-1919) took over and could only finish the shell construction according to his brothers' plans before World War I.
The final general outline of the Collection Building (Fig. 3 and 4) is constituted by four wings, each four stories high, arranged on a rectangular ground plan and built around a courtyard enclosing one main and two lateral halls. The main wing is the northern one, which includes in its oval shaped centre the attractive entrance vestibule, the representative hall of fame in the first floor and the planetarium in the second, connected by a monumental staircase. Four additional staircases were provided in the corners of the building, one of them inside the tower, the landmark of the island.
In the years after the war the collection building could be opened only until 1925. The Library Building was finished in 1932 and the Congress Building in 1935 according to the plans of *German Bestelmeyer* (1874-1942). In 1937 the Autohalle could finally be inaugurated. These buildings follow new design and technical concepts.

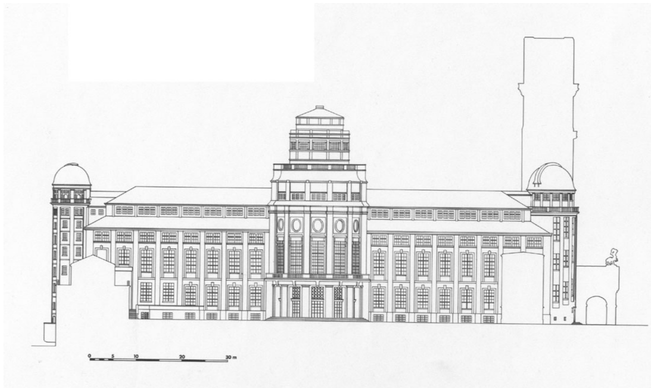
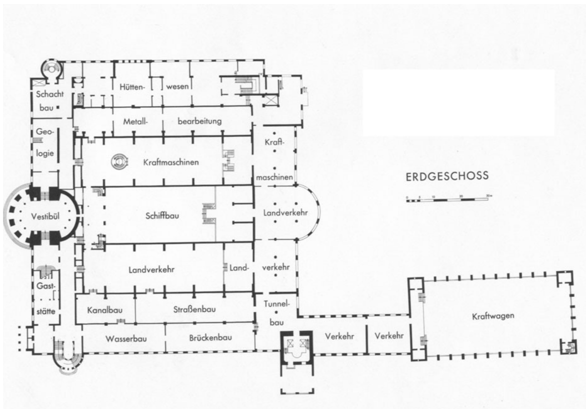



Figure 1(left): Perspective of the Collection building today; (ABDM-BN_73518)
Figure 2 (right): The Main façade of the Collection building ; (ABDM-BN_36540)



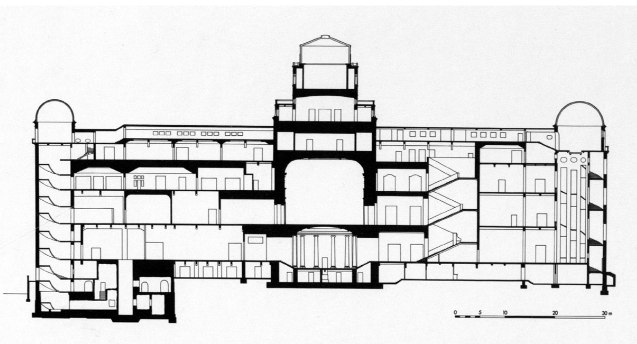


Figure 3 (left): Ground Floor Plan of the Collection Building; (ABDM-BN _36545)
Figure 4 (right): Cross Section of the Collection building; (ABDM-BN _36549)

Museum concepts

The conception of the Deutsches Museum has to be seen on one hand as an expression of the changing ideas on museology during the1900s: these changes had been motivated by the general concern about the national education and at the same time by the unalterable faith in progress and technology, including the commercialization and popularization of technical products. According to the ideas of a reformed museum, art, science and technology should not be separated any more in special collections, i.e. the *Studiensammlung* for scientists and the *Schausammlung* as popular showroom. All cultural achievements should be open equally to the public (Preiß 1993 p. 54) as in the so proliferating popular trade fairs of the time and –of course- the trade fair architecture will influence the built results. The influence of the customer and his concepts on the architectural solutions increases considerably (Preiß 1993 p. 55). In this sense *Millers* conflict with *Seidl*, as observed in Munich is a new quality in the relation between museum owners and their architects.

On the other hand the Deutsches Museum is inscribed in the tradition of the Musée des Arts et Métiers in Paris, existing since 1799 as a scientific collection of the polytechnic school Conservatoire des Arts et Métiers. But also the debate about other technical and scientific museums to be founded around and after1900 and the competition between them stimulated its creation and success. With this background the foundation of the Deutsches Museum is an exceptional event not only for the vigour of its realization but primarily for its unique physical size, complex layout, the quality of it's collection and the introduction of interactive demonstrations to the museum concept by *Oskar von Miller*. In these issues the Deutsches Museum remains still unbeatable. Other countries copied this prototype instantly with collections including all fields of scientific knowledge combined with a presentation technical masterpieces: Prague (1910), Vienna (1918) and the most famous competitor: the Science Museum in London, built in 1914-1918 according to the plans of *Richard Allison* (1869-1958).

BUILDING THE MUSEUM

According to the construction process the main innovations employed during the erection of the Collection building can be presented with a selection of the enormous photographic and drawing documentation in the museum archives. To begin with, *Millers* relationship to the cement industry was close and helpful enough that the weekly journal *Zement und Beton* quoted in his edition dated October 2nd of 1908 (Nr. 40, p. 637) that:

> The cement industry has decided to donate 450 railway carriages of best Portland cement from their member factories with an accounting value of 120.000 German Marks for the building of the Deutsches Museum in Munich. The contractors have agreed also to facilitate not only the completion of the structural works but also the heating and air conditioning equipment partially as donation and partially by accounting only at their own cost price.

Considering this background, the new Museum of Science and Technology just could be built with this innovative and promising construction material -even more –as *Füßl* (Füßl 2005, p. 266-271) remarks- „the building itself should be -according to Millers vision- erected as a technical masterpiece. […]".
Conrad Matschoss records in 1925 for the *Verein Deutscher Ingenieure* (VDI):

> In order to attain the best construction techniques available at that time for the structural work and its components, the drawings and plans for the building have been developed with the highest accuracy to be submitted to the most outstanding construction companies.

The bids made have been examined and compared not only by the directing board of the museum but also by technical experts. All the competing companies had to be present during the examination and were even forced to reveal their business secrets in order to "guarantee the most functional completion and construction of all building elements, the right choice of building materials and facilities". Long before this time the decision already had been taken to build the museum with concrete; if this was due to fire protecting motives is not conveyed, but we can assume that this was another deciding factor. Hence the selected companies were the ones with the longest possible tradition and committed to concrete construction: such as the *Dyckerhoff & Widmann* Company, who at the same time was owner of a cement plant, and other companies like *Wolle* from Leipzig and the *Gebrüder Rank* in cooperation with *Ed. Züblin* which were explicitly concrete constructors.

The Foundation

According to the finally authorized plans, the foundation works for the new building were carried out, using modern concrete technologies, among others the recently patented *Strauss* pile foundation. These pile foundation works could only get started after the conclusion of tedious previous soil exploration in the glacial gravel ground of the Isar Island on July 31st of 1910. The following methods for pile foundation have been used: The ram pile system *Wolle* (Fig. 5) consisted of pentagonal piles with a section of 30 x 30 cm and a maximum length of 7 m. They had a load capacity of 700 kN each and have been prefabricated in a formwork outside the building pit. After six weeks of curing they have been rammed in their mounting places in the western wing including the tower, around the southern wing and in the western part of the northern wing. The required

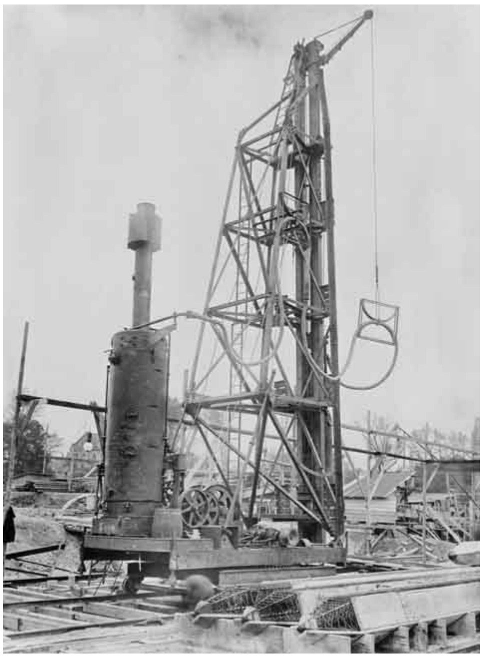


Figure 5 (left): Prefabrication of *Wolle* piles; (ABDM-BN_36974)
Figure 6 (right): Steam rams working with *Wolle* piles; (ABDM-BN_10136)

length/depth of the piles had been explored by wash boring previously. 900 of these piles have been employed by the *Wolle* and *Züblin* contractors. For testing purposes some of these piles have been uncovered up to reinforcement. Steam rams (Fig. 6) worked with these reinforced concrete piles. The foundation for the tower consists of 123 *Züblin* piles with a length of 6 to 9 m each in an area of 14 to 14 m. The final foundation for the tower beyond these piles is a reinforced concrete slab with a thickness of 1,5 m, finished in October 1910. The second type used was the mentioned *Strauss* pile, patented in 1903 by *Anton Strauss* from Kiew (Patent-Nr. 189182, dated 6.12.1903, published 2.11.1907). They have been employed by the *Dyckerhoff & Widmann* contractors. Iron tubes with a diameter of 30 cm had to be drilled manually (Fig. 7) into the ground within a distance of 80 to 100 centimetres and lengths up to 6 m for this purpose. The material, remaining in the tubes, was cleared out with bore heads or gravel pumps. The empty tubes were filled with rammed concrete, while the iron tube was removed upwards step by step according to the casting and ramming process. 637 of these piles have been employed for the foundation in the eastern longitudinal (Fig. 8) and in the eastern transverse wings. In order to examine the result of the Strauss-pile system some concrete piles were excavated after casting and curing (Fig. 9). Their load capacity reached 400 kN.

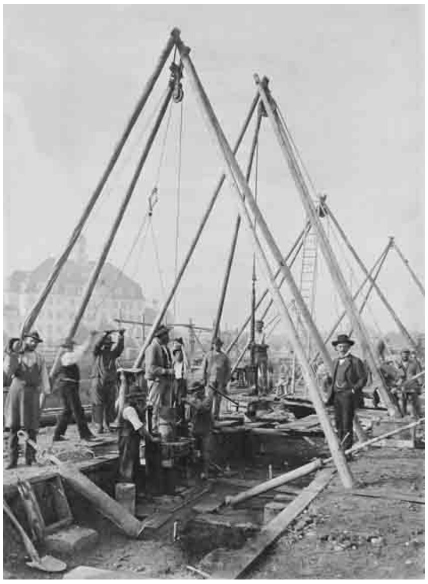


Figure 7 (left): Manual drilling for Strauss piles 1909; (ABDM-BN_36969)
Figure 8 (centre): Strauss piles; (ABDM-BN_10146)
Figure 9 (right): Excavated Strauss piles; (ABDM-BN_23395)

The foundation pile works ended on April 5th of 1910. For the foundation of the museum building 1500 piles of all different systems have been used, adding up a total length of 8100 m.
The final foundation, made of reinforced concrete was casted above the piles during April of 1910.

The Building

According to the layout of the building different types of structures were employed and documented accurately. More than that even every day construction techniques have been focused by the photographers, which documented for instance workers bending iron stirrups for the reinforcement, formwork for ceilings and iron reinforcement for beams or the concrete mixers with their material hoists (Fig. 10).


Figure 10 (left): Mixer and hoist; (ABDM-BN_57858)
Figure 11 (right): Ceiling of the first floor; (ABDM-BN_10155)

Figure 12: Formwork and reinforcement for the roof; (ABDM-BN_10151)

The structure of the four wings with their four stories and a basement (used for workshops and storage areas) enclosing the courtyard was similar to the *Hennebique* system, previously patented by the *Gebrüder Rank* contractors (Fig. 11). These galleries were planned as large, open multipurpose halls, supported by a system of rows of columns. Unfortunately this structure has been reveted in later years. The only bolted iron beam in the collection building exists in the mining exposition because this gallery had to stay without piles, columns and other installations. This unique rolled iron beam has a length of 17 m and a height of 1,70 m. However, the land marking tower of the museum is made of rammed concrete.

The roof construction in the exterior four storied rectangle of the Collection building consisted of prefabricated reinforced concrete beams, carried out as timber formwork and prepared for casting with concrete.
The exposition halls inside the courtyard on the western and eastern sides are 62 m long with a height of 13,5 m. The central hall has the same length with a height of 22,5 m. The lateral halls are covered by an open concrete vault, with a free span of 17,5 m (Fig.13). The central hall with a span of 20,5 is covered by a steel construction. They are supported by parabolic reinforcement arches. *Matschoss* (Matschoss 1925 p. 74) reports about that:

> The main halls consist of a reinforced concrete framework, composed by a row of reinforced concrete beams, filled up with a concrete wall. The beams are designed as parabolic arcs and connected to the adjacent halls by joints on the height of the imposts. Only the roof of the middle hall is a steel construction with a suspended Rabitz cloth lath.

Another highlight of construction technology is the staircase in the north-east corner: It consists of cantilevered reinforced concrete steps, inserted into the surrounding wall. The spindle of the hollow newel stair has no supporting function (Fig. 14).


Figure 13 (left): Concrete vault of lateral hall 21.11.1910; (ABDM-BN_10167)
Figure 14 (right): The hollow newel stair seen from above; (ABDM-BN_10168)

Special structures were planned for the ceilings of the vestibule, today's entrance hall and the Hall of Fame. These ceilings were assembled with reinforced concrete beams spanning 17 m and arranged with little spacing in-between and „constructed with a shallow vault with a small cavity, resting on a row of fluted, discreetly articulated columns made of "artificial concrete" (Matschoss 1925 p. 75) (Fig. 15). The perspective of the northern wing seen from the south out of the 2nd floor (Fig. 16) shows the construction of the Hall of fame with the climbing scaffold and the austerity of the original structure.


Figure 15 (left): Shell construction for the Hall of Fame; (ABDM-BN_10164)
Figure 16 (right): Northern wing from the south 21.11.1910; (ABDM-BN_10150)

The composition of the exterior walls proves the creativity of these early concrete constructors: whereas the core of these walls is made of reinforced concrete, the visible façade was completed with fair faced concrete. In order to receive a “vivid, warm tonality” (Matschoss 1925 p. 78) for the exterior, face concrete was mixed with squeezed shell limestone. After completition this face concrete received its final texture by a treatment with chisels or sticks (Fig. 18).

Figure 17: State of the building site in 1914; (ABDM-BN_08751)

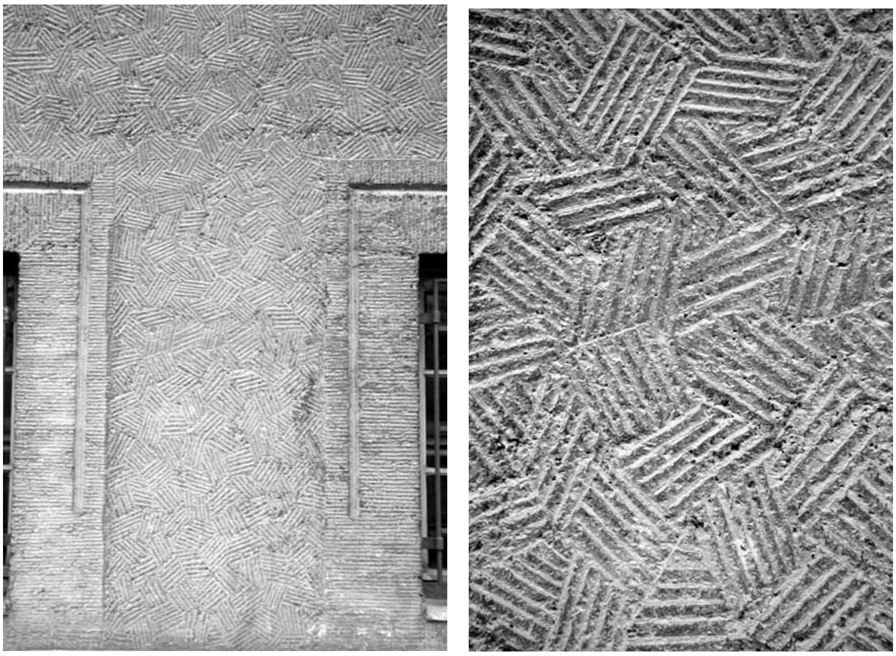


Figure 18: Details of the surface finishing; (Author, 2007)

On the inner side of the walls a layer of 10 centimetres of pumice concrete has been applied in order to improve thermal insulation and facilitate the fixing up of nails. Only few parts of the building, like the façade of the hall of fame and the exterior staircases, are really reveted with panels of shell limestone, tuff or basalt.

Until the traditional roofing ceremony on October 5th, 1911 12.000 m³ timber, 60.000 m³ gravel and sand, 3.000 tons of iron, 400 railway carriages of chalk and finally 1.700 railway carriages of cement had been processed for the construction. The finishings and the completition of the building weren’t suspended immediately at the outbreak of the war, but the workers diminished when they had to accomplish their military service and after all building material ran in short in a way that by December 1916 the workings had to be cancelled (Ill 17). On June 9th, 1917 work ended definitively by an official order, it was even more: the copper sheets for the cupolas had been removed for further military use. Only some years after the end of the War works have been resumed unspectacularly and without further incidents. The finished building with its exhibitions could be inaugurated on May 5th, 1925, two days before *Millers* 70th birthday.

THE OBJECTS RELATED TO CONCRETE

But *Miller* was not only realizing his ideas about concrete in the building itself, he also collected at the same time systematically and visionary objects related to the production and quality control of cement and concrete. This is why the museum owns today unique models of early concrete buildings, concrete tubes, replicas of ornaments and sculptures or cement and concrete test apparatus, but also material test items. The DYWIDAG donated objects since 1906 objects such as a *Zerreißungsapparat* by John Grant for cement quality tests or the painting of a Portland cement kiln by *Dyckerhoff*. *Hennebique* construction method was present in the building but also as a picture or another one of the first reinforced concrete building by *Josef Monier*. The famous doghouse, the *Freytag* family donated to the museum in 1933 as the first building made of reinforced concrete in Germany is a real highlight of the collection. Another singular piece is the model of one of the earliest concrete mixers: the so called *Sonthofener Betonmischer* form 1909 (Bühler 2003, p. 490). In this sense the museum represents a most complete and unique legacy for concrete construction around 1900.

CONCLUSION

The study of the general conditions (owner, architects and contractors), materials and techniques used to build the Collection-Building of the Deutsches Museum, the documentation referring to this construction and the collection of concrete related objects makes it possible to present this building as an important monument of early concrete construction not only in Munich. The construction methods have been innovative, some of them even still experimental and substantial for the development of concrete technology at that time. However, when the museum was opened in 1925 it did not represent any more the state of the art in concrete technology it was originally built with, a circumstance that causes serious constructive and conservation problems today. The Autohalle opened in 1937 was still built of concrete. The Library and Congress buildings on the other hand, planned by *German Bestelmeyer* have been built as –at this time- even more modern steel constructions between 1928 and 1932 (Library) and 1935 (Congress-Building).

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