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The Neues Museum of Berlin – restoration during the stage of structural stabilization as a first step towards reconstruction

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The restoration works of the past few years accompanied the structural stabilization and consolidation of the building after completion of the replacement foundation in 1996. Furthermore, these measures were intended to preserve as far as possible the fabric of the ruined part of the Neues Museum. With a purely conserving character, they were designed to keep options for further restoration open.
In the course of the erection of the Neues Museum building, numerous new materials and techniques were tested and used which were innovative at that time. For the current restoration works to take place, this requires large-scale material and damage analyses and studies, often prompting the development of new restoration techniques. Three examples of recent restoration works shall be used in this paper to highlight issues and strategies.

1 The Neues Museum as an architectonic field of experiment

The Neues Museum was one of the most important projects during a period of technical innovation in mid-19th century Prussia. Friedrich August Stüler and his collaborators and contractors - first and foremost the engineer Carl Wilhelm Hoffmann, the technical designer and manufacturer of iron building elements and machines August Borsig, and the architectural theoretician Carl Boetticher - erected a building which represented, for them, the initial point of a new approach to construction based on design and technical concepts - their answer to Heinrich Hübsch's question: "In which style shall we build?". The willingness of the participants to innovate was crucial to developing the Neues Museum construction site to an experimental field where revolutionary constructional methods were used. Three of these were instrumental in the erection process: the

use of steam engines by which many working procedures were mechanized which required a high amount of workforce before; the first use of pre-fabricated products; and the trial and testing of a multitude of new materials and techniques.
In 1853, Stüler wrote to the Potsdam Superior Accounting Chamber, his control authority, that, in his opinion, there was an obligation to test and to apply new constructions and materials in the erection process of any larger new building, even if the introduction of innovative methods caused additional costs and therefore financial disadvantages.
The techniques which shall be described in the following paragraphs undoubtedly belong to the set of methods which were completely new to Berlin craftsmen in Stüler's days.

2 The wire plaster ceiling in the Bernward Room

Originally, there were wire plaster ceilings in two smaller rooms of which only the Bernward Room ceiling at level two survives, severely damaged. The in-situ remnants are the earliest pieces of evidence of the application of this technique in Northern Germany. They prove, with their deficiencies and faults, the difficulties encountered in the introduction process of a new method at the age of a technical revolution in Prussian construction.
The three massive vaults above the Bernward Room were established for static reasons - they neutralize the shearing of the seven ceiling vaults in the neighbouring Modern Room. The feature of the suspended ceiling was chosen for design reasons - it repeats, in its form and decorative scheme, the Modern Room ceiling vaults.

2.1 Pre-Rabitz wire plaster ceilings

The wire plaster ceiling introduced a "deceiving element" into architecture. The surface of a scenery-like lightweight construction conceals the "real" ceiling needed for static reasons. Therefore, these suspended ceilings do not represent a decorative element in the sense of Boetticher's decorative form, i.e. a decoration which, whilst covering the structurally determined core form, explains it by means of design, thus keeping the structural system visible. Here, the suspended ceilings, by contrast, create an own level of design which does not relate to the real ceiling construction of the room (except for the points of suspension).
In Northern Germany, this technique was first applied in the Neues Museum whereas international (and predominantly French) examples already existed. In his 1862 publication, Stüler wrote "that the polygonal room for religious objects of art was spanned by a vault due to the lack of sufficient abutment. Between the wrought iron ribs, the wire mesh vaults with a two inch layer of gypsum are formed. As we know, a similar construction had been used for the dome vault above the older room of the Paris Deputies' Chamber (during the 1833 alterations to the Palais Bourbon by J. J.-B. de Joly) and for the panelled ceiling of the Walhalla near Regensburg (1830-32 by Klenze)."

Only in 1878, the Berlin master mason Carl Rabitz was granted the first patent for the manufacturing of a "fire-resistant ceiling plaster under wooden beams" where the wire mesh was tightened by a winch. He used hair-fibered lime mortar. These were two major improvements to the technique used in the Neues Museum. Wire plaster ceilings became a standard technique under the term "Rabitz ceiling".

2.2 Wire plaster in the Neues Museum

In two of the Neues Museum rooms, the wire plaster technique was used. The one-bay Bernward Room at level two got a plaster vault suspended from the massive ceiling vaults; at level three, the Star Room mentioned by Stüler (see above) was situated with its copy of a late Gothic star vault suspended from the rooftruss. We have quite precise records of the construction of the ceiling in 1847: The star vault ribs consisted of flat iron bars on edge which were fixed to each other by bolted angles and were mortised into the walls at the points of support. Mesh wire was tightened between the ribs. To establish the plaster coat, two procedures were mentioned: the pouring of the mortar from above and the plastering of the vaults. This is confirmed by the few surviving fragments. Roman cement and gypsum were used as cementing agents for the pouring; gypsum and hydrated lime were used for the plastering. A thin finish coat which consisted of pure lime mortar formed the base for the facing. The existing written evidence from the time of erection does not reveal any detail of the composition of the shuttering. Many of the surviving undercoat fragments show, at their upper sides, the pattern of the grout layer, i.e. the positive of the shuttering surface. The imprinted pattern leads to the assumption that a coarse basketwork-like structure had been used for shuttering. This seems to be plausible with a maximum width of the star vaults of appr. 2 meters. The more sophisticated construction of a wooden shuttering was not required. After shuttering removal, a well-structured surface was established which was an appropriate plaster base.
We do not know exactly when the wire plaster ceiling in the Bernward Room was constructed. From the reports of the completion of the second floor wall paintings in 1850, we can conclude that the ceiling was carried out simultaneously to the Star Room ceiling. The pouring technique could not be applied to the simple Bernward Room vault because the wire plaster ceiling was positioned at a very close distance to the load-bearing structure. The upper side of the ceiling shows the typical mortar appearance, the pattern of the wire mesh can be seen very clearly, the lower side is a typical example of the mortar levelled on the wire mesh. The layer composition is similar to the Star Room: the upper mortar and one undercoat layer consist of a gypsum-lime mortar. Different compositions of the plaster reveal the fact that experiments were made to find out an ideal mortar composition and that the technique was far from perfect. Multiple repairs and improvements can be seen very clearly in the present state. The finish coat, which is up to 5 mms thick and serves as the base for ceiling paintings, consists of a highly compacted and smoothed lime mortar to which

very fine sand was added, as well as a large portion of cementing agent. This composition can be found very often in the Neues Museum building. The wire mesh also proves the lacking experience of the craftsmen who did not succeed in tightening it properly, thus making pressing-out and plastering probably extremely difficult.

2.3 Nature of and reasons for damage

The main reason for damage is the explosive effect of the corroded iron wire mesh. The high gypsum concentration in the mortar supported the corrosion of the iron. Due to the exposition of the room to exterior climate conditions, moisture got into the room leading to condensation on the brickwork surfaces, especially in spring. The wire mesh sits immediately on the lower side of the pressed-out mortar which was levelled with a trowel. This methodical error contributed to the adhesive failure of the undercoat plaster. Mechanical impact and the untightened wire mesh further contributed to the progression of the damage, with the result that, at the time when the stabilization works started, all possible states of damage had to be treated. Only very tiny fragments of the finish coat with the facing survive.

2.4 Securing measures

The first measures taken were intended to move the load off the exposed parts of the wire mesh. Rubble deposits were removed, the surviving plaster pieces were hung on a supporting construction made of round-bar steel. This construction was inserted between the massive ceiling and the suspended ceiling.
The most difficult conservation problem was to protect the iron from corrosion in the slightly acid gypsum-lime mortar milieu. The method of re-alkalization, which had already been used in concrete conservation, was considered most promising. It had to be adapted to the special conditions on the wire plaster ceiling. The principle which underlies re-alkalization is the electro-chemical replacement of the sulphate ions immediately surrounding the iron with carbonate ions, i.e. the conversion of gypsum causing corrosion to calcium carbonate. After positive outcomes of laboratory tests and of an on-site sample surface treatment, re-alkalization was applied to the surviving parts of the Bernward Room wire plaster ceiling. Exposed parts of mesh wire had to be re-embedded into mortar. Mortar-free spots were filled with lime mortar. At spots where original mortar survives, the lower side, with its exposed wire mesh, got a thin limewash coat. On the prepared surface, corrosion-resistant anode plates made of platinized titanium were embedded into the lime mortar, with an in-between distance of about 10 cms. The original wire functioned as a cathode, with a voltage of 40 V applied. In the course of a fortnight, the ceiling surface was sprayed in regular intervals with lime water, having an electrolytic effect. Then, with the voltage still applied, it could get dry. The expected effect was proven by several analyses: On the wire surface, calcite crystal deposits could be iden-

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tified, the area immediately surrounding the wire is sulphate-free, with a strong alkaline reaction.
A permanent installation of this cathodic protection to the original mesh wire is necessary to keep the present state stable and to prevent further corrosion to occur, even with a possible impact of moisture. The procedure has been applied successfully for quite a long time to protect underground iron pipelines from corrosion. The permanent system will be identical to re-alkalization, with the exception that the anodes are fixed to the upper side of the suspended ceiling.

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3 The Neues Museum main entrance door

Besides the monument to Gutenberg in Frankfurt-on-Main, the exterior copper facings of the two main entrance doorwings represent the earliest examples of large-size galvanoplastic objects.

3.1 Evolution of galvanoplastics

In parallel to the evolution of electrotechnics, methods of galvanic coating and electroplating were developed.
Moritz von Jacobi (1801-1874) first presented galvanoplastic objects in 1838: These were metallic forms made of coins and similar objects. The Jacobi galvano apparatus used the principle of the Daniel element: A receptacle was filled with diluted sulphuric acid and had at its open bottom a pig's gut diaphragm. This receptacle contained the zinc anode and was completely immersed in a concentrated copper sulphate solution in another receptacle also containing the mould to be copperized. The mould's surface was bronzed or made conductive with graphite. Anode and cathode were short-circuited, no voltage had to be applied. The distance between the diaphragm and the mould was to be appr. 5 cms at any point.
In 1848, the Berlin Association of the Trades awarded a galvanoplastic figure manufactured by a Baron of Hackewitz (Julius Winkelmann, the later director of the Berlin Galvanoplastic Institute, was head of manufacturing in the Hakkewitz laboratory). The female figure was appr. thirty inches high (i.e. 785 mms) and had been pre-fabricated as a hollow galvano consisting of five individual pieces which were also galvanically linked to each other.
The most famous early galvanoplastic objects are the three main figures of the Gutenberg monument in Frankfurt-on-Main, each of them with a height of appr. 3 metres. They were manufactured from 1851 to 1858 by Georg Ludwig Kress as hollow galvanoes consisting of individual pieces.

Only when Werner von Siemens invented the generator in 1866, the manufacturing of large-size galvanoplastic objects became a method competitive to bronze casting. The 1890s were the years of large-scale manufacturing, predominantly in the Württemberg Metalware Factory.
The Berlin protagonists of galvanoplastics, Baron of Hackewitz and Julius Winkelmann, have nearly fallen into oblivion today, maybe due to the later dominance of the Württemberg Metalware Factory. At the 1850 Berlin Art Exhibition, Julius Winkelmann presented, as director of the Royal Galvanoplastic Institute, a "colossal Juno bust" whose individual form parts were galvanically linked to each other.

3.2 Composition of the main entrance door copper finish

Winkelmann presented, also in 1850, the cost estimate for the exterior finishes of the Neues Museum main entrance door. There is evidence of the completion date: In April 1852, the master joiner Wanschaff was sent a reminder by the project engineer Adler to complete the doorwings "since Herr Winkelmann has already finished his electroplating works". In 1853, Friedrich Adler mentioned, in his publication in the Journal of Construction, the main entrance as just completed "which was electroplated and bronzed in the Berlin Royal Galvanoplastic Institute, using models by Berges, Schiffelmann et al.".
The exterior copper sides of the main entrance door (with a height of 4.46 m and a width of appr. 1.15 m) correspond, in formal and structural terms, to the panel constructions of the massive oak-wood doorframes. The copper frames were made of rolled sheet, the five panels of one doorwing show rich ornamental and figurative elements and were manufactured as hollow copper galvanoes. They were fixed to the frame by iron braces. After the assembly of the doorwings, they were electroplated with copper in order to create a homogeneous finish. Lastly, an artificial patination was performed to achieve a bronze-like appearance.

3.3 Damage

The doorwings have suffered minor damage from shell splinters in 1945. The fixing elements on the oak-wood doorwings were made of iron, galvanic corrosion destroyed them to a very large extent. The main damage is a deposit of grained green corrosion products on the originally bronzed copper finish. This was caused by a decade-long storage in an environment with a high impact of moisture and dirt. All iron fixing elements were damaged by galvanic corrosion.

3.4 Restoration of metalworks

The currently undertaken conservation works are mainly aimed at re-exposing the original finish by removing the corroded layer mechanically. Due to the extreme vulnerability of the surviving original bronzing layer, this can only be performed manually using scalpels and extremely fine brass brushes. The treat-

ment of the two doorwings, mainly consisting of ornamental and figurative reliefs, requires a considerable amount of time and a very conscious and careful approach by experienced restorers sensible of the problems.
The holes caused by shell splinters are being closed by soft-soldered copper pieces, with the deformations not being completely revised. The new material is inserted in a slightly recessed position, it is given an artificially bronzed finish nearly identical to the original, but in a slightly brighter tone. After these measures, the doorwings can again be perceived and interpreted as works of art. However, at a closer distance, war damage can still be identified resulting from shell-fire at Museum Island which was declared a fortress during the last days of the Second World War. The restored finish will be conserved with hard wax, the iron fixing elements have to be replaced with matching brass elements.

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4 Plastering techniques

Since Antiquity, marmorino plaster and stucco lustro are well-known in construction. The levelled and polished finishes and the marble imitations were in high demand when it came to designing state-of-the-art interiors. The ancient techniques required, however, a very high amount of time and workforce since the finish coat made of slaked lime and marble powder was levelled with a hot trowel until it was press-polished. In the course of time, this prompted numerous experiments with new material compositions to achieve a productivity increase, apparently also during the construction of the Neues Museum. This has partly led to damage.

4.1 Plastering techniques in the Neues Museum

The upper wall paintings in the exhibition rooms were given a quite coarse lime plaster probably with the intention to create a fresco-like character of the paintings (which were bound by oil wax resp. water glass). Stüler placed a special emphasis on the quality of the finishes on the walls' central sections as they formed the background to the exhibits. The plasterer, as is still common today, had first to correct the imprecisions of the mason. This was made with a levelling plaster coat, partly with several layers and with an overall thickness of up to 8 cms. This plaster consisted of a coarse-grained sand with up to 30 per cent gypsum and lime. Normally, an undercoat plaster was produced which contained lime as cementing agent and a smaller portion of gypsum or no gypsum at all.
The finish coat, only a few millimeters thick, created the base for the facing. It contained solely lime as cementing agent. Plastered areas which were to be covered by an opaque wax paint coat were added finest quartz sand. Marmorino plaster (i.e. lime plaster with marble powder aggregate) was applied where glazing paints were to be used. Stucco lustro served to achieve an extraordinary

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high finish quality in selected rooms. It was a coloured marmorino plaster with marble painting which was press-polished in several consecutive treatments.

4.2 Reasons for damage

The most frequent type of damage to the different types of finish coat is their detachment from the undercoat plaster, causing deformations, cracking and fragmentarization of larger areas. Originally, assumptions had been made that the damage was due to the inappropriate layer composition of the plaster (the upper finish coat layer is the most rigid one) or to a lack resp. variation of the layers' thickness, as well as to movements caused by thermic load. Studies were commissioned to verify the assumptions, including a mapping of the damage and of the thickness of the finish coat layer in selected areas and an establishment of strength profiles of the plaster layers via drilling resistance measurement. None of the initial assumptions could be confirmed. After a study of building records in which the technique was precisely described and after an analysis of the marmorino plaster and of the undercoat plasters, there is a strong case for the assumption that the cracks were caused by an inappropriate manufacturing technology: A very thin finish coat which was far too fat was put on a levelled and cemented undercoat plaster. It was then compacted by pounding and smoothing. Dependent on the degree of compaction, it was hardly possible to establish an adhesion of the two plaster coats.
It was crucial to find out the original plaster composition in order to develop a composition of a replacement mortar and to identify the reasons for damage. This is difficult with marmorino plasters because cementing agent and aggregate are chemically identical. We used a multi-step solution process to extract the aggregate without a considerable loss (with the possible exception that dust particles could have been solved). The result confirmed the estimates made with the help of a series of micro-photographs showing embedded ground sections: The ratio of lime and marble is 2 to 1, the aggregate is extremely fine-grained. The finish coat is extremely compacted, almost no pores are visible in the ground parts of the material. Different compositions can be found in the individual rooms with characteristics more different than could be explained by imprecisions typical of the construction process. This leads to the assumption that experiments were made by the contractors. One example to prove the probable failure of such an experiment is the smoothed and polished marmorino plaster in the Niobid Room which had got crackle-like fissures and was covered by a thick opaque wax paint coat.

4.3 Tests to develop conservation techniques

After determining the reasons for damage, it is now essential to stop the progression of damage and decay, as well as to develop restoration techniques. The separation of the layers of undercoat plaster and levelling plaster causes no difficulties, tried and tested filling and consolidation materials can be applied. It

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is however problematic that, particularly where marmorino plaster can be found, larger lump-like sections of the finish coat have detached from the undercoat plaster. In several experiments, we applied silicic acid ester to small sample surfaces to consolidate the soft undercoat plaster and to fix the lumps of finish coat in their original position. Such a treatment of the finish coat at the edges of voids allows a replacement mortar to be used which is very close to the original. However, this consolidation technique is not applicable to the many square metres of wall surfaces (e.g. in the Niobid Room) due to the high amount of time and workforce needed. Moreover, no permanent and complete gluing of the loose finish coat to the undercoat plaster can be achieved by this method. An effective securing technique to be applied to the larger finish coat sections with severe damage has yet to be developed. Further tests and studies will therefore be required.

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