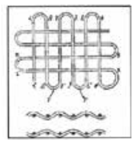
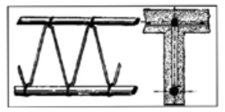
Techniques, damage processes and conservation of concrete stone and cement plaster

Ivo Hammer, with contributions of Marko Goetz[1]

Villa Lebrun, 1828/29, Marssac-sur-Tarn; possibly the first known house since ancient times to be built entirely of concrete. The facade is whitewashed, most probably with lime, off-white and gray.
Photo: Reinhard Dietrich, 2015, wikimedia commons.





(right) Saint Denis, Maison François Coignet, 1853. "Monument Historique" since 1998.
First house made of reinforced concrete, *ferciment*. The facade is plastered.
Photo: Eric Bajart, 2010, wikimedia commons.

Our eyes always see forms and spaces of architecture through the mediation of a defined surface. The surface is the interface, the aesthetic and material level of communication on the one hand between the architecture as volume, as an enclosed space, as design and on the other hand the environment, including the viewer. The surface is the basis of the authenticity of the building.

Diversity of concrete surfaces

The concrete surfaces of the structures that were erected or coated with concrete, their materials, techniques and colors are far too little known to this day. In the more recent literature on the preservation of concrete architecture[2] one finds a lot e.g. on the vocabulary of design of shapes, on technical parameters, on compressive and tensile strength, thickness of the concrete layer over the steel reinforcement, the location and condition of the reinforcing bars, the depth of carbonation, the damage, the pollution, etc., but surprisingly little information on materials, technology and aesthetics of the original surfaces.[3] In the following, a few cursory remarks should encourage further research.

At the World Exhibition in Paris in 1855, Francois Coignet presented his invention of stamped concrete with Portland cement, *béton agloméré*,[4] based on the traditional *pisé* technique of rammed earth or rammed adobe and earlier buildings made of rammed concrete such as the Lebrun house in Marssac-sur-Tarn by Francois Martin Lebrun from 1828/29.[5]

These structures were certainly coated with whitewash pigmented with fine sand or colored paints. Further research is necessary while there are still remains of the original surface.

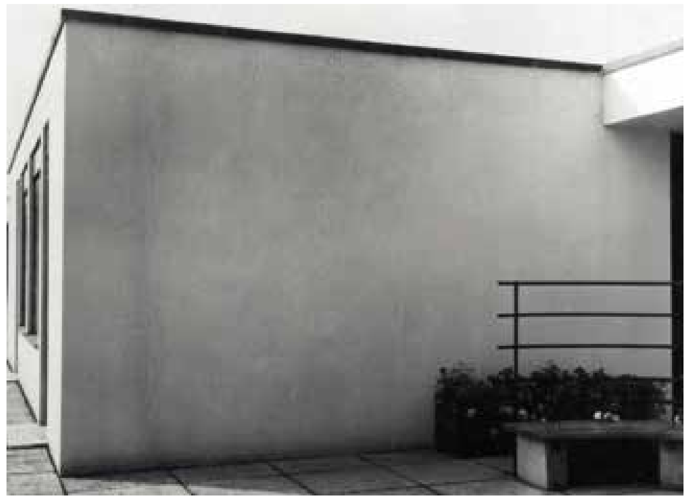
After the filing of patents for reinforced concrete, first in 1854 by the English master plasterer William Boutland Wilkinson (1819-1902), then in 1855 by the French Joseph-Louis Lambot (1814-1887) and Francois Coignet (1814-1888) and finally in 1867, 1881 in Germany, by Joseph Monier (1823-1906) it took a few decades for reinforced concrete construction to prevail alongside traditional brick and stone construction, especially in England, the USA,[6] France, Germany and the Habsburgs-Monarchy. A significant step in this development was the invention of the Belgian stonemason and building contractor Francois Hennebique in Paris, patented in 1892, whose company had branches in Brussels and London. Joseph Monier's patent protection expired

1. This publication includes: Götz, Hammer 2008. Translation: Ivo Hammer.
2. See the annotated bibliography Conserving Concrete Heritage of the Getty Conservation Institute, Custance-Baker et. al. 2015. This bibliography is limited to publications in English language, with two Italian exceptions.
3. Exceptions: See articles in the publications of docomomo International, e.g. van den Heuvel 2008; Pursche 2003; Vereinigung der Landesdenkmalpfleger in der Bundesrepublik Deutschland 2008; Croft, Macdonald 2018.
4. Kierdorf, Hilsdorf, p. 23.
5. Werner 2016. https://de.wikipedia.org/wiki/Villa_Lebrun (access May 22, 2021). The hydraulic binder was probably the *ciment calcaire* published by Louis-Joseph Vicat (1786-1861) in 1818 and widespread until the late 19th century, or *Roman cement*, developed probably at the suggestion of John Smeaton and patented in 1796 (James Parker).
6. Thaddäus Hyatt (1816-1901).
7. Krieg 2008, p. 59.

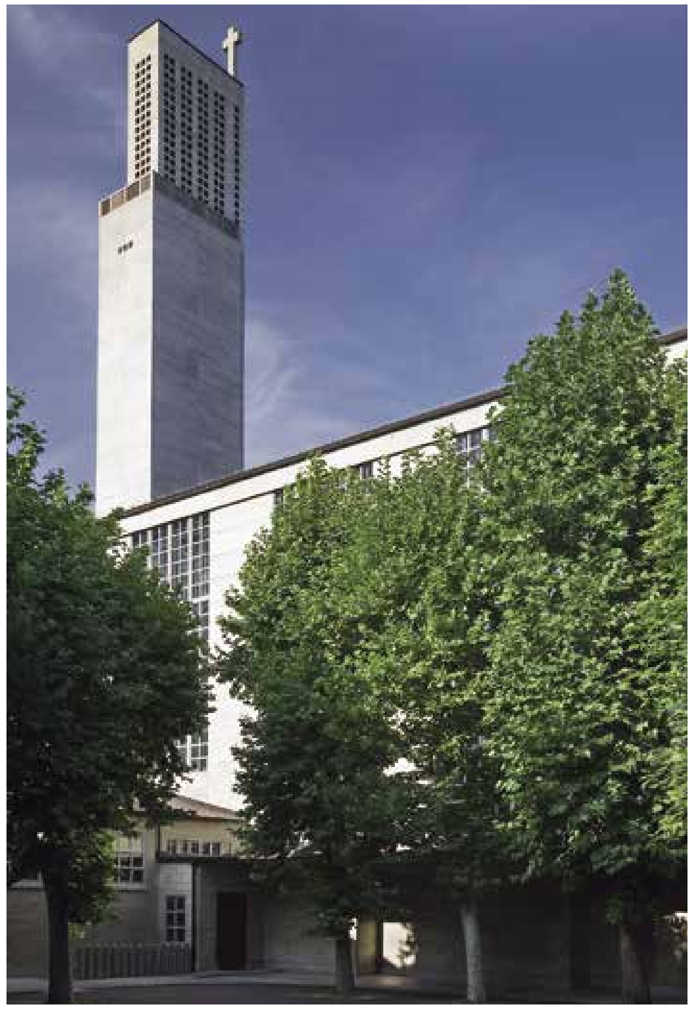
Breslau Market Hall (Hala Targowa) 1906-1908, Architects: Richard Plüddemann and Heinrich Küster. Reinforced concrete, the facade clad with exposed bricks, plaster and natural stones, "simple painterly treatment of the interior surfaces of the hall… whereby the concrete color of the supporting structures is retained and an element that is foreign to the building material is not brought into it by plaster and plastering work."[10] Photo: Ivo Hammer, 2009, after a historic photograph on site.

Ulm, ev. Paulus church, 1908-1910, according to plans by Theodor Fischer. Facade with pre-mixed concrete: trickled concrete (cement, sand, bean gravel 1:1:2), processed with two-pointed edge. Photo: Density, 2007, wikimedia commons.

Basel, Antoniuskirche, 1925-1927, architect Karl Moser. The first church in Switzerland made of pure exposed concrete. Photo: Ikiwaner 2007, wikipedia. commons.



Brno, Tugendhat House, upper terrace, east wall of the dormitory of Grete Tugendhat. Photo: Rudolf de Sandalo 1931 approx., detail. The crack on the attika, which is caused by the differing thermal expansion of the concrete ceiling and brick wall, was retouched in the photo by de Sandalo.



in France in 1892, that of Hennebique in 1903, and soon thereafter in other countries. The facade of the oldest reinforced concrete building in Germany, the C.G. Röder in Leipzig from 1898 according to the *well-proven Hennebique system*[7], was traditionally smooth. It was plastered, and possibly also whitewashed with lime. The segmental arches were decorated with exposed bricks.

In this early phase of concrete construction up to the twenties, as far as is known, functional buildings such as silos, warehouses, train stations etc. had an additional layer over the load- bearing concrete of plaster, bricks, natural stone and cast stone, or even just a coat of paint, usually a whitewash mixed with fine sand. The smooth plastering of the walls of the wholesale market hall in Frankfurt / Main by the architect Martin Elsässer from 1926-1928 painted in off-white may also have had practical requirements of hygiene, brightness and ease of maintenance.

In 1914, the master painter Hugo Hillig in Hamburg (1877-1926) recommended a treatment to refine the surface of the concrete, because
"the concrete construction cannot be self-sufficient in its appearance like noble stone material, but requires an ingredient that enhances the appearance of the cement ... stone and brick and wood are overcome here. In place of these building materials, which are always characteristic in color, cement, a material of uneven coloring, inconspicuous, characterless in its color, is also subject to various physical and chemical changes on its surface." [8]

Hillig also finds that "painting or decorative painting on cement concrete is a surface treatment that naturally adapts to the material, especially since there are technical options to choose paint and coating materials that chemically fuse with the cement to form a whole." [9]

Around the turn of the century and into the twenties, the most common form of coating on the facade of concrete buildings, at least at the base, was facing concrete.
"The actual structural concrete is 'placed in front' of a finer-grained, mostly fatter and softer concrete mixture within the formwork and tamped together with the concrete behind it, which creates a good connection between the two, a unified whole."[11]

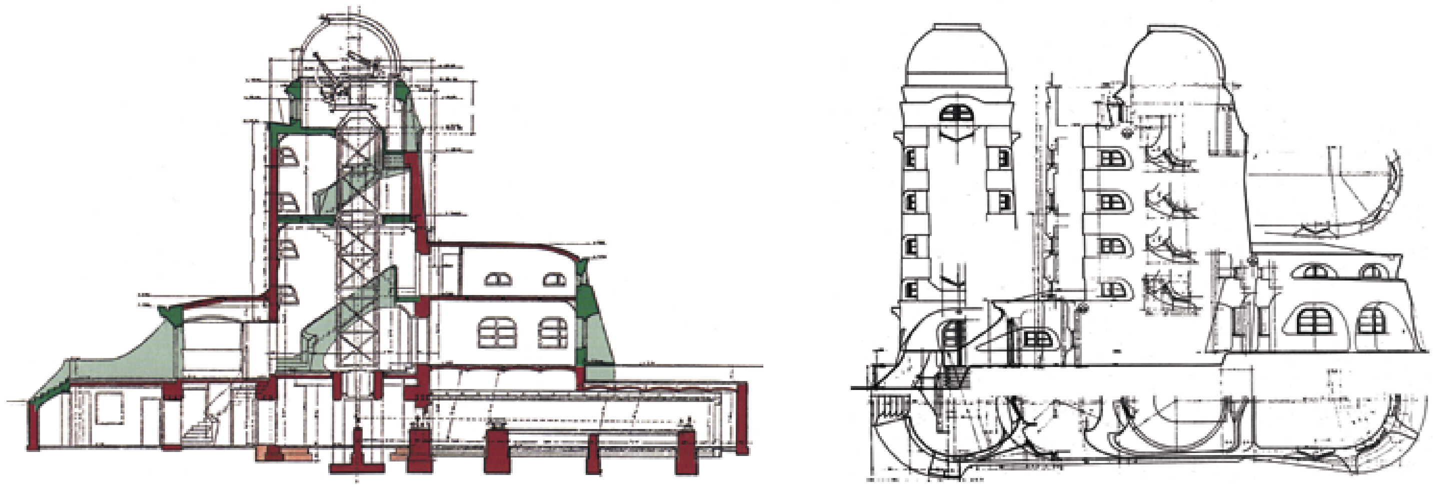
Then facing concrete was processed by stonemasons, and presented by the pointed chisel as a rustic surface, or by scratching and edge chipping as a noble natural stone. In utilitarian parts of buildings such as stairs, the concrete was occasionally worked by a stone cutter directly after the formwork had been removed, if the sand in the concrete was sufficiently fine-grained.[12] After processing by the stonemason, the different aggregates, i.e. the stone clasts and the selected sands became visible; they corrected the monotonous gray cement and created a material effect close to natural stone. It should be noted that in the early days of concrete technology sand was not yet industrially washed. These unwashed sands thus had a large number of fine particles in terms of granulometry, which accordingly also had a pigmenting effect on the cement mortar.

Working on the design for an office building in 1923, Ludwig Mies van der Rohe wrote *"about the vision of the Modern Movement: Architecture is the will of the age conceived in spatial terms. [...] The materials are concrete, iron, glass. Reinforced concrete buildings are by nature skeletal buildings. [...] A construction of girders that carry the weight, and walls that carry no weight. That is to say, buildings consisting of skin and bones [...] The creative architects want nothing, absolutely nothing to do with the aesthetic traditions of past centuries."*[13]

Despite these resolutely revolutionary words, many elements of Mies' built architecture are traditionally crafted. The tension between aesthetic, technical innovation and traditional construction methods literally leads to cracks.[14]

Prefabricated concrete coatings
In a pioneering achievement, Thomas Danzl wrote an overview of the almost infinite variety of colored material designs for plastered cement facades on different carriers: natural stone, bricks or concrete. Danzl drew attention to the wide variety of plasters produced industrially as dry mortar, both in terms of the types of cement, the colorants, the additives and the surface structure produced during

8. Hillig 1914. S. 65-68; see Rübel et. al. 2005, p. 70-74.
9. Hillig may be thinking of potash water glass painting after Adolf Keim; see ETH Zurich 1998.
10. Heim 1908.
11. Petry 1913, S. 176.
12. Petry 1913, Abb. 202, 203: Treppe am Hippodrom in Frankfurt/ Main, 1898.
13. MoMA, Mies v.d. Rohe Archiv, folder 3, quoted according to: Neumeyer, 20162, p. S.300.
14. Remember the problems of thermal expansion of the external wall of the Guggenheim Museum by F.L. Wright.



(left) Potsdam, Telegrafenberg, Einstein Tower 1920-1922, Architect Erich Mendelsohn. Mapping of the mixed construction. Red: brickwork, green: reinforced concrete. Graphics, Huse 2000, p.93, Gerhard Pichler.

(right) New York, Solomon R. Guggenheim Museum, 1959, Frank Lloyd Wright. As-built imperfections and concealed repairs, most recently completed in 2008.[26] Photo: Ivo Hammer 2012.

processing. In the 19th century, industrial air pollution, especially sulphur pollution, led to problems with the durability of traditional facades plastered with lime mortar. The standardization of products, increasing independence from transport problems by rail traffic and automobiles, and building materials with organic additives that could be processed quickly for *remuneration* led to the acceleration of the construction process, but at the same time, to problems in the durability of hydraulic plasters due to their high density and associated lower tolerance to thermal expansion. The finished products also led to a tendency to downgrade traditional handicrafts.[15]

Exposed concrete

Even in the interwar period, with the exception of industrial buildings and military installations, there were few buildings that exposed rough concrete. The derisive, popular term *soul silo* for the Antonius Church in Basel, consecrated in 1931, with its rough facade surfaces, apparently refers to the surface aesthetics common in industrial buildings.

Due to precast concrete elements, which were increasingly used in residential construction, and certainly also due to the influence of Le Corbusier (Charles-Édouard Jeanneret, 1887-1965), exposed concrete, béton brut, became a hallmark of modern architecture in the 1950s.

On the opening of the Unité d'Habitation in Marseille in 1952, Le Corbusier wrote: *"The construction of the Unité in Marseille gave the new architecture the certainty that reinforced concrete, used as a raw material, is just as beautiful as stone, wood or brick. This experience is extremely important. It now seems possible to show concrete as like stone in its raw state. It used to be the opinion that the cement looked sad because it was a sad color. This opinion is just as wrong as claiming that a color is inherently sad. A color only gets its value from its surroundings."*[16]

It is significant that after pouring the concrete and stripping the form work, Le Corbusier had the concrete surface reworked by a specialized cement worker *"... whom I could trust and who was able to work according to my direct instructions and understand them. I showed him certain parts of the building where he had to work with his trowel like a sculptor with his chisel. And so the miracle took place. The contrasts worked. With the use of paint and the help of the trowel, the beauty of the raw concrete has become visible."*[17]

Conservation and repair: who is doing what?

The objects of conservation, historic monuments, are substrates of historical processes that have historical, artistic or other cultural significance by virtue of scientific and political determination, and by a mostly legally regulated procedure and in some cases also by international agreement as a World Heritage by UNESCO.[18] The Venice Charter of 1964 is still valid today as the basis for the theory and practice of preserving listed historic architecture.[19] The preamble to the Charter of Venice defines historic monuments as "messages from the past" while emphasizing the obligation of people to hand *them* [the ancient monuments] *on in the full richness of their authenticity.* Maintaining the authenticity of a monument only makes sense if the cultural attributions of a monument are not seen as metaphysical categories transcending materiality, but as element of materiality. The idea is inseparably linked to the object. Hartwig Schmidt, a pioneer in the preservation of the architecture of the Modern Movement, summarized the problems of preserving the authenticity of architectural concrete buildings in 2010 under the following key aspects: [20]

1. The industrial norms of renewal are mostly not applicable for the preservation of listed architecture.[21]
2. The success of conservation measures does not only depend on a careful preliminary investigation, which hardly anyone disputes, but also depends on careful execution and competent supervision of the work.
3. The owner of the property must be prepared to take the risks of a conservation and repair that does not meet industrial standards.
4. The execution of the repair work must not be left to a construction company, but rather be carried out by specialized conservators-restorers for stone objects or wall paintings / architectural surfaces.

What is meant with the, admittedly rather clumsy, term *conservator-restorer*? The professional title of conservator-restorer was internationally agreed in 1984. The term is used to distinguish it from other professions that deal in various functions with the preservation of cultural heritage.[22]
Gone are the days when artists *restored* paintings. For nearly a hundred years it has been generally accepted that in order to preserve the more authentic materiality of a painting, a separate profession is necessary, which is able to understand the complex dialectics of cultural attribution and technology and to intervene with suitable methods. Why should it be any different for listed buildings? Architects with artistic and engineering training often excessively instruct construction companies or specialized craftsmen. Conservation-restoration is not just a technical problem that can be left to architects and technical conservation specialists.[23] The profession requires artistic sensitivity, manual dexterity and in-depth knowledge of historical technology, art history, sciences such as chemistry, physics, microbiology, and thus a specialized university education.
I propose to expand the existing university courses for conservation-restoration of wall paintings and stone objects wherever possible so that architectural surfaces are included, regardless of material and time period. I propose to supplement the existing university courses for the preservation of historical architecture, which were usually set up for architects, by a special course for conservators-restorers for architectural surfaces.

In the sense of the modern concept of culture and the consistent conservation of listed monuments aimed at the preservation of authentic materiality, the field of work of the profession not only includes decorative

15. Hammer 2003. Since 1931, a white Portland cement has also been available in Germany under the product name Dyckerhof Weiss, which is still produced today. www.dyckerhoff.com.
16. Le Corbusier 1952, quoted according to Rübel et al. 2005, p. 82.
17. Rübel et al. 2005, p. 83 f.; Klinkhammer 2011 (Matroil and Matone, Peintures Berger) ; Translation Ivo Hammer.
18. Hammer 2019.
19. Charter of Venice, https://www.icomos.org/charters/venice_e.pdf (accessed 20.5.2021).
20. Schmidt 2010, p. 117. Schmidt doubts the effectiveness of corrosion inhibitors and does not consider electrochemical re-alkalization to be recommended.
21. See also Croft et. al. 2018. The editors state: The concrete industry continues to push standardized repair approaches.
22. ICOM CC, Copenhagen, see: Hammer 2020, p. 246.
23. Macdonald, Arato Goncalves 2020, p. 14 present a narrow and outdated idea of the field of work of a conservator-restorer that is often encountered to this day. They state: Conservators … can provide a useful link between architects/engineers and craftspersons. Their contribution is particularly valuable where the appearance of the repair is of importance… See also Pedroni et. a.. 2020, p.42. The authors define the conservator-restorer as follows: … profession entailing technical (sic!) examination, preservation, and conservation-restoration of cultural property. The lack of awareness of the conservator-restorer's profession is evident e.g. in the fact that the two universities in Austria that train conservators-restorers for architectural surfaces and stone objects are not mentioned in this publication.
24. The most important question is: what is well preserved and why? An interdisciplinary based evaluation of the causes of damage is an essential basis for a successful conservation intervention. Often physical parameters such as porosity, hydrophilic capillarity, the condensation of water under the surface, which happens almost every night on a facade, the drying speed, and thermal expansion are not given sufficient consideration; see Hammer 1996.
25. Hammer 2003.
26. Thomas Trienens et al. 2008.

(left) Peine, Lessing Lodge: Historical picture of the building from the time it was built, approx. 1927. The building was free-standing in a newly developed construction area for a long period of time. Photo: Lessing Lodge.

(right) Peine, Lessing Lodge, east facade. Photo: HAWK / Götz, 2007.

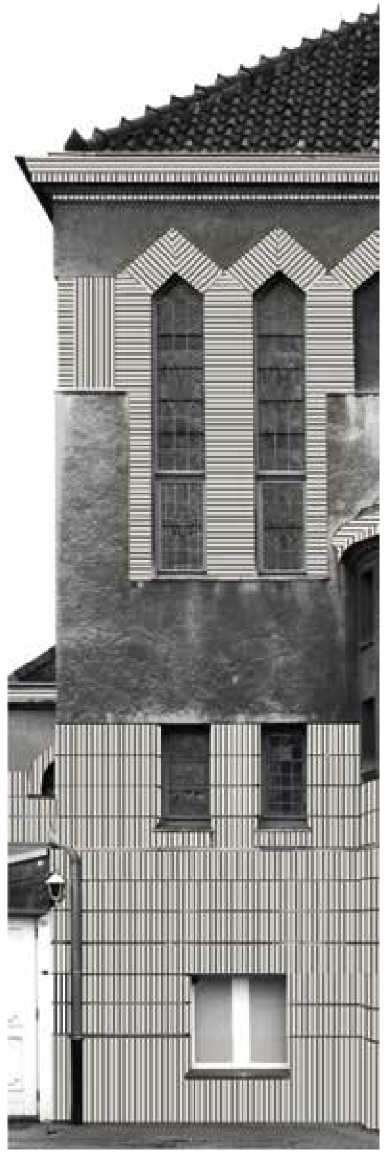
elements and coatings, but also the entire wealth of architectural surfaces made by craftpersons, including natural stone, brick and structural exposed concrete
The conservator-restorers should
a. carry out preliminary investigations in interdisciplinary cooperation with architects, construction engineers, structural engineers, art historians, construction researchers and scientists,
b. develop and propose measures of conservation and repair[24]
c. carry out conservation work and
d. supervise the repair work of the construction company. [25]

In the practice of preserving architectural surfaces, it has proven useful to carry out all the conservation and repair steps that result from the proposed measures on a limited, self-contained area. We call this first step, 'pilot work'. The pilot serves as the basis for further project design by architects, establishes cooperation between craftpersons and conservation-restoraters, and sets a benchmark for the further implementation of the conservation and repair. Small sample areas disappear during work and cannot serve as a reference.

Case study
The subject matter is the material-colored external facade of the Lessing Loge (Lessing Lodge), owned by the *Druidenorden e.V.* in Peine/Germany from 1926. We present the Lessing Lodge as an example of a conservation-scientific investigation carried out by conservator-restorers. It is an example for the study of materials and techniques, the damage phenomena, the evaluation of the damage processes and the methods and techniques of conservation and repair.
The building was designed by Alwin Genschel[27] in historicist forms. It is a solid brick building coated with scratched cement plaster *Edelputz*, stone plaster and cast stone, a particularly high-quality example of the use of Portland cement for the incrustation of facades in terms of design, material quality and precision of execution[28]. Even if the facade appeared to be in good condition at first glance, a closer look revealed significant deterioration. The plastered surfaces are very dirty, and the binding medium, calcium carbonate, has been converted to calcium sulphate due to pollution. Despite the high density of the materials, the surface was, in some parts, considerably weathered. Another problem was the corrosion of building steel reinforcement. Following a thorough conservation-science study, we developed a concept for the preservation of the entire facade as part of the HAWK University of Applied Sciences and Arts in Hildesheim study program in cooperation with the Lower Saxony State Office for the Preservation of Monuments in Hanover and the Peine Monument Authority. The concept included the cleaning and reconversion of calcium carbonate, and the repair the concrete-steel composite. The methodological premises of the concept were not only the treatment of the causes of the damage, but also the economic efficiency of the measures.

27. City Councilor Alwin Genschel, Hanover, see Götz 2007.
28. For terminology, see Danzl 2003.

Peine, Lessing Lodge, east facade. Representative design of the facade by changing the surface arrangement; (blue): scratched plaster; yellow: cast concrete plaster, dressed by a stone mason using a charring chisel; (green): dressed concrete, partly prefabricated before transferring it to site. Photo / graphic: HAWK / Götz, 2007.

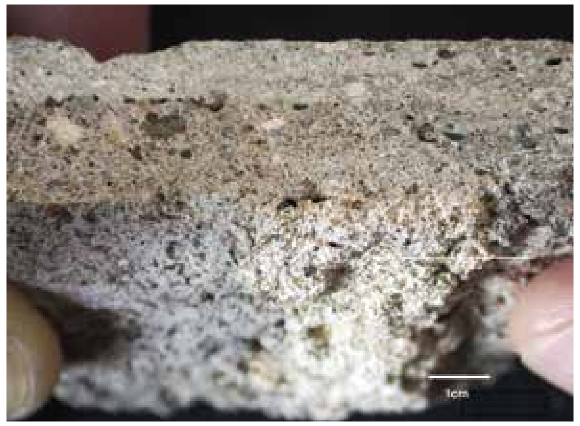


Peine, Lessing Lodge, west façade, detailed view; the scratched plaster surface, before conservation. Photo: HAWK / Götz, 2007.

Peine, Lessing Lodge, east façade, base, detailed view: cast concrete plaster with horizontal joins and dressed treatment by chisel. Photo: HAWK / Götz 2007.

Peine, Lessing Lodge, east facade: alternating dressing on the concrete stone of the window frame with a well preserved surface.
Photo: HAWK / Götz, 2007.

Peine, Lessing Lodge, west facade: concrete stone with weathered and sanding surface.
Photo: HAWK / Götz, 2007.



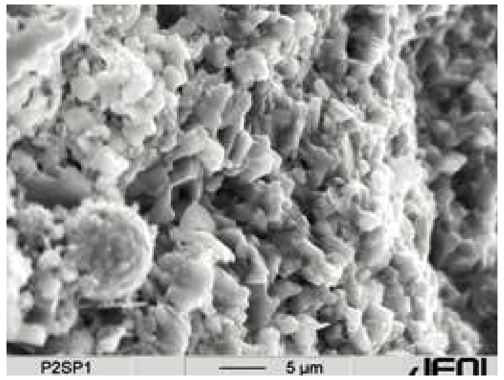
Peine, Lessing Lodge, cast stone plaster: sample / transversal layer in angled light / daylight with flush-mounted and adhering plaster.
Photo: HAWK / Götz, 2007.

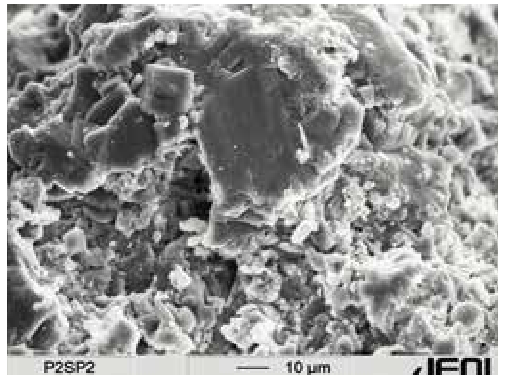
Cast stone plaster: sample / transverse layer in angled light / daylight.
Photo: HAWK / Götz 2007.

Cast stone: sample / transversal view under angled light / daylight with core (1) and facing concrete (2).
Photo: HAWK / Götz, 2007.

Scratched plaster: sample / transversal view under angled light / daylight. The white, greyish crystal clasts are travertine. The gray aggregates presumably show Osnabrück shell limestone with enclosed iron oxide-containing anchorite components, which are typical of yellowish surface weathering.
Photo: HAWK / Götz, 2007.

Peine, Lessing Loge, east facade, stone plaster / sample: Both pictures show large paneled gypsum crystals.
Photo: Meinhard-Degen, 2007.





Materials / Technology

The original surface of the building, which is made of non-coated materials, has been preserved to this day. A cement-containing preparation mortar and a cement-containing basic plaster lie on the brick masonry. The plinth on all sides of the building is designed with cast stone plaster with horizontal rectangular joints, and then precisely dressed in the manner of stone. The slightly protruding and spacious area between the base and the row of windows on the 1st floor and on the gable ends of the north part is coated with a very coarse-grained scratched plaster. The pillars, pilasters and stucco were partially reinforced with structural steel, prefabricated in individual molded parts from cast stone, facing and core concrete, and put together in situ. The individual fittings were already dressed using wide chisels before being transferred to site.

The analysis of the original plasters revealed a mortar mixture for the cast stone (facing concrete), the cast stone plaster and for the scratched plaster, the majority of which consist of Portland cement, stone powder, limestone clasts (travertine, Osnabrück shell limestone), some quartz sand as well as isolated pieces of wood and brick chips.[29]
Thanks to the addition of stone powder, the surfaces of the concrete stone have an almost full-surface dense matrix and hardly any capillary water absorption capacity. The scratched plaster is somewhat more porous, since lime hydrate predominates as a binder. The plastering systems can be viewed as natural stone conglomerates of different grain sizes.

Condition / damage phenomena / damage factors

Weathering due to physical and chemical processes can be seen in approx. 80% of the entire facade surface in the form of sanding and trickling. Where driving rain and eaves water could directly attack the plaster matrix, the surface is more damaged.
Most of the design on the west facade, especially the dressing of the cast stone plaster on the base of and other exposed parts of the building, was irretrievably destroyed. Here, the surface is very lacunal and the individual aggregate parts stand out clearly. The original surface has only been preserved in protected areas (e.g. window reveals). Here the surface is very firm and looks compact. Due to the rough and irregular surface properties, the damage to the scratch plaster is not as clear as that of the stone plaster. The loss of substance did not lead to a significant change in the surface structure, but yellowish discoloration also occurred here.

In 1980 the cornices were covered with zinc sheet. This has restricted infiltration from the outside, but thermal condensation is still active. Thermal condensation occurs on a facade, as we know, almost every night and after every precipitation.[30] Due to the low ability to absorb capillary water, the surface of the cement plaster dries quite slowly. This favors the damage cause by pollution and the conversion of the calcareous binder to gypsum. Due to water retention in the gypsum crystals and as a result of the hydrophilic properties of the pollution, moisture is increasingly absorbed on the surface, and thus weathering is accelerated Exhaust gases from a factory near the south-west, which had been in operation until recently, made the facade surface particularly

29. Thin section evaluation by Dr. Henrik Visser (ZMK, Hanover), Dr. Jeannine Meinhard-Degen (Institute for Diagnostics and Conservation, Halle), plaster analysis: Dipl. Lab. Chemist Rolf Niemeyer (NLD, Hanover), mineralogical and petrographic investigation: Prof. Dr. Roland Vinx, Mineralogical and Petrographic Institute, University of Hamburg.
30. See Hammer 1995.

contaminated with sulphurous substances. The conversion of the calcareous binder to gypsum acts to compact the surface as crust and thus blocks drying. Thermal expansion leads to shear stresses compared to the non-converted plaster matrix.

Electrochemical corrosion processes and carbonation of the concrete led to cracks and spalling of the reinforced construction, especially on the stucco edging of the entrance area. The aesthetic appearance of the facades based on the materials and their surface design are heavily falsified and impaired by marks of rain drainage, washouts and discoloration. The damage processes and their dynamics and the change in the appearance of the facade since the construction period can be seen in the comparison of photos. On the construction photo (ca.1927) traces of rain drainage and washouts are already recognizable. In 1973, the north and east façades were already in a state of preservation comparable to the current state, particularly with regard to the areas with clearly noticeable watercourses. The harmful damage processes essentially concern three intertwined factors:

- Pollution (sulphate)
- Conversion of calcareous binding media to gypsum
- Partial loss of the surface due to sanding

Conservation conception

Based on the damage phenomena and their causes, we have developed a sustainable conservation concept for the treatment of the facade surfaces.

Cleaning. Reconversion of gypsum

By means of cleaning and conversion of gypsum the physical properties of the surface should be restored as far as possible, and thus further loss of the original plaster surface should be prevented. At the same time, the aesthetic appearance of the facade should be improved and the disturbing damage phenomena eliminated. Various methods of cleaning were tested in advance: steam cleaning, applied poultices (with and without the addition of surfactants[31]), cleaning with a microfine jet device[32], cleaning with pure ammonium carbonate and with deer horn salt, *Hirschhornsalz.*[33]

The tests with steam cleaning and water poultices (with and without the addition of surfactants), were unsuccessful. The surfaces were cleaned well with the microfine blasting device, albeit with the restriction that the unstable ochre-coloured components were attacked very quickly. It turned out to be difficult to make sufficient capillary contact with the surface, especially on the rough scratch plaster surface, with the poultice material that had been worked on until then.

Peine, Lessing Lodge: The two pictures from 1973 show the north and west (left) and east façade (right). The surfaces are very dirty. Signs of weathering can be clearly seen on the scratch plaster and plinth surfaces.
Photo: Unrein, 1991.

1	l	water	or	100	pbv
40	g	ethyl methyl hydroxy cellulose (Tylose MH 1000 ®)	or	4	pbv
200	g	ammonium carbonate (deer horn salt)	or	20	pbv

Table: Recipe for cleaning paste according to Ivo Hammer34

31. Implementation: We applied the poultice material consisting of breech cellulose powder approx. 1 cm thick without an intermediate layer and covered it with foil to prevent it from drying out prematurely. The contact time of the poultice was 3 hours on average.
32. We tested the relatively hard blasting agent made of high-grade corundum with a grain size of 10 mm.
33. See Ivo Hammer 2003, Fig. 14 (Krems, Ursula Chapel around 1300, Hirschhornsalzkompressen 1991). Performing the test areas in Peine: Bordered with a 5 cm wide neutral poultice made of cellulose and demineralized water, and the strong suction effect of the surface can be counteracted. The poultice was left on the surface for about 4 hours.
After removing the poultice, a 4-layer salt reduction poultice made of beech pulp was applied. The name *Hirschhornsalz* comes from an earlier period in which the salt was extracted from animal raw materials by means of "dry distillation" (dry heating). Today it is produced by sublimation (conversion of gaseous substances by skipping the aqueous state into the solid final state) of a mixture of ammonium chloride, calcium carbonate and charcoal. The salt corresponds approximately to the formula NH_4 HCO_3 x H_2N-COO-NH_4 with an ammonia content between 21 - 23% (see Römpp-Chemical Lexikon). Hirschhornsalz is used as a raising agent and can be obtained inexpensively (approx. € 1.50 / kg) from the bakery wholesale.
34. Hammer 1995.
35. Kärcher® company.
36. The beech cellulose, Arbocel BC 200® acted as an absorber for water storage and as a solid medium. The 80 pbw of water were mixed with 10 pbw of tylose and the 20 pbw of deer horn salt with 20 pbw of water. After sufficient swelling of the tylose, the salt solution was added. Then 5 GT beech pulp was added. We mixed the components mechanically with a bar stirrer until a filler-like consistency was reached.
37. See Matteini 1991.

As a result, the poultice materials were refined. A cleaning paste consisting of deer horn salt and methyl cellulose, Tylose MH 1000 ® as a carrier material was tested and then used to clean a pilot area.

The surface areas defined at the beginning of the work were quickly brushed in with the cleaning paste. The thickness of the paste was approximately 5 mm. The paste was reapplied daily because the consistency of the Tylose MH 30000 ® became too firm after one day. After the exposure time of 15 minutes, the paste was removed with a high-pressure water cleaner35, in which the pressure of the water jet could be adjusted to the sensitivity of the surface. However, the paste could not be removed with the water jet alone. After about 20 minutes the Tylose® was apparently dry and mechanical foaming of the Tylose® with the help of brushes became inevitable. It turned out that at least three repeated attempts (foaming and rinsing) were necessary in order to be able to remove the paste without residue. The cellulose residues could be checked optically by examining the surface for sparkles in the raking light. It should be noted that the cleaning process could be carried out much more effectively and with less manual effort by using suitable machines with appropriate brushes. In view of isolated dirt pockets in the recesses of the scratched plaster surfaces,
a second cleaning cycle was carried out to completely remove the dirt.

On the cornice, in the area of the lintel and in the joints on the base, very severe blackening

1	l	water	or	100	pbv
40	g	ethyl-methyl-hydroxy cellulose (Tylose MH 1000 ®)	or	4	pbv
200	g	ammonium carbonate	or	20	pbv
50	g	beech cellulose (Arbocel BC 200®)	or	5	pbv

Table: Recipe of the modified cleaning paste (HAWK / Götz)

Peine, Lessing Lodge, east facade, position, dimensions and condition of the pilot area before conservation.
Photo: HAWK / Götz, 2007.

Peine, Lessing Lodge, east facade, base: cleaned surface.
Photo: HAWK / Götz, 2007.

and incrustations could not be removed even in a second cleaning cycle. In order to be able to clean these areas, the cleaning paste was modified. A 20% pure ammonium carbonate solution replaced deer horn salt, mixed with 4% Tylose® and 50 g beech cellulose Arbocel BC 200®.[36]

We achieved good and uniform cleaning of the surfaces using this cleaning paste. Compared to the exclusive use of beech cellulose poutices with ammonium carbonate, this method is much more economical, being 1/10th cheaper to buy. In addition, the paste can be processed quickly and guarantees good and sufficient capillary contact with the surface. We could restore the physical properties of the plaster surface to a substantial degree by eliminating the superimposed layers of dirt and re-converting the gypsum into calcium carbonate. The cleaning effect was checked scientifically (proof of gypsum reduction, sulphate detection according to Matteini).[37]

The treatment of corroded reinforcement relates to a few areas of the stucco edging of the entrance area and the cast stone columns

Corrosion protection. Coating with red lead?

Coating with red lead was the standard corrosion agent for many years. Because of its toxicity, it has been banned, or its use severely restricted. Red lead as a corrosion protection coating works very well on metal surfaces outdoors. In alkaline compounds, however, there is a risk of saponification of the organic binder (oil paint). We have no research results or long-term studies on the hydrolysis resistance of red lead as oil or alkyd resin paint. Another disadvantage is the potential difference - the alternating voltage between lead and iron. Due to the electrochemical potential, the steel starts to rust again under the paint. The application of red lead is restricted compared to mineral systems, because only the steel may be coated, and longer drying times between the coats have to be planned.

Industrial corrosion inhibitors?

Concrete renovation systems were developed in the 1970s when massive damage to concrete structures occurred. In recent years, polymer CEMENT CONKRET

Peine, Lessing Lodge, east facade, scratched plaster: cleaned surface. Photo: HAWK / Götz, 2007.

Peine, Lessing Lodge, east facade, scratched plaster, detail of the cleaned surface. Through the cleaning, the weathered structure and yellowish discoloration of the surface became apparent. Photo: HAWK / Götz, 2007.

Peine, Lessing Lodge, east facade, basement, detail, surface of the lintel. Crusting and blackening in the edge areas despite cleaning twice. Photo: HAWK / Götz, 2007.

Systems® (PCC) have been increasingly used in concrete renovation. The concrete renovation systems are called 'mineral corrosion protection'. This consists of a polymer-modified dry mortar based on cement. Zinc dust particles are added to the mortar as a corrosion blocker.
The concrete renovation concept is a mixture of a corrosion protection coating and repassivation. These systems were used among others for the renovation of the Einstein Tower in Potsdam (1997-1999), built by the architect Erich Mendelsohn in 1920-1921.[38]

The passivation, the protection of the structural steel in the mineral composite, is guaranteed by natural alkalinity (pH 12-13). The passivation continues until the carbonation process is complete. Carbonation of concrete takes up to 50 years or longer if the concrete is optimally manufactured.[39] The lowering of the alkalinity into the neutral range (pH 9) is called depassivation. If the alkaline steel protection is removed, corrosion occurs as a result.[40] The advantage of an industrial corrosion inhibitor compared to red lead is the better and faster application and easier handling of the material, since the prescribed two- coat material can be applied to the entire damaged area, i.e., steel and flanking plastered areas. The corrosion protection works in two ways: firstly, through the zinc dust and secondly through the natural alkalinity of the cement slurry and cement mortar.[41] The disadvantages of the system are that the manufacturers do not specify the ingredients exactly. And, secondly, due to the synthetic resin content and the associated limitation of the hydrophilic porosity, there is no material compatibility with the original concrete plaster; the saponification and hydrolysis resistance of the polymer additives has not yet been adequately checked.

Re-alkalization using cement mortar

Experience has shown that adequate cement plaster coverage is able to prevent corrosion processes to the structural steel over a long period of time. The denser the concrete or cement plaster and the higher the water retention capacity, the longer the period of carbonation with simultaneous passivation protection. The structural steel is inserted into the concrete without any rust protection, and often rusty. Without natural passivation, the structural steel would have to be pre-treated with a rust protection system. Using a cement-based repair mortar, developed on site, we can achieve the re-alkalization of the steel-concrete composite without introducing incompatible materials into the composite material.

We can achieve a long-term alkaline protection due to the high pH value of the cement mortar, and Portland-cement corresponds to the construction period. The limitation of cement can be seen in the fact that damaging substances (soluble alkalis, gypsum) can be introduced into the system. However, this is mostly irrelevant on the outer facade, since soluble building salts are likely to be washed off the surface.

Assembling a repair mortar

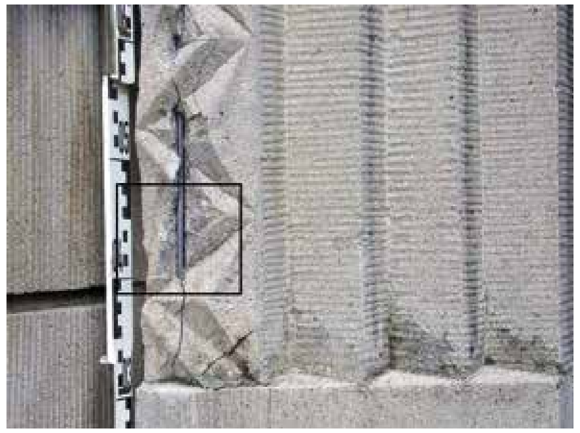
The starting point for the development of a repair mortar was the knowledge that we gained through our conservation-science study. We assembled a repair mortar that corresponded to the original concrete in terms of materials and techniques, surfaces, color and grain size of the binders and aggregates, and that protects the reinforcing steel through alkaline passivation. The selection of the binding agent and the aggregate was based on the original materials in the damaged areas. The repair mortar could be adapted to local conditions using colored sands.

Trial and Mock-up works

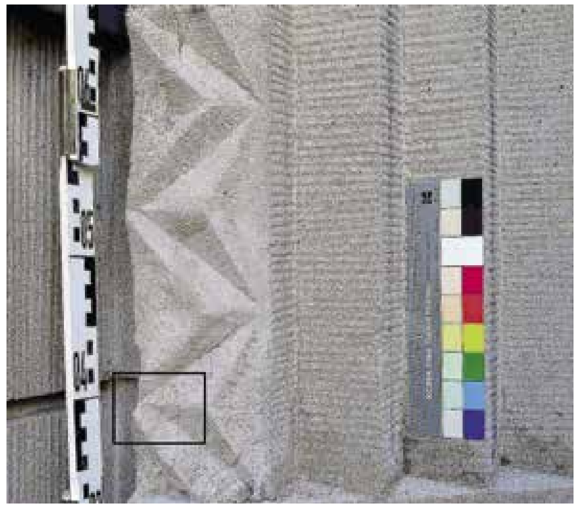
For the sample material, we chose a slightly finer grain size than that of the original material in order to be able to create a good connection to the old material at the edge of the repair. The plaster was applied to highly porous 15 x 15 cm brick slabs. The tile slabs had previously been sufficiently soaked in a water bath. The base plaster consisted of cement and sand in a ratio of 1:3 and was applied so that the porous brick substrate did not absorb too much water. After the base plaster had hardened sufficiently, the finishing plaster followed. By tapping lightly with the spatula, the limestone clasts with the more even or flatter sides were deposited parallel to the surface. To simulate the weathered condition, parts of the binder and the fine aggregates were removed from the plaster surface with a slightly dampened natural sponge. After evaluating the various test samples, the mortar formulation

38. Pichler 2000, p. 100.
39. Hilsdorf 2010, p. 67
40. Effect of aggressive anions (chlorides, sulphates). Displacement of the passivating hydroxide ions of the cement paste on the structural steel reinforcement.

Repair mortar we assembled in comparison with the construction concrete block at the stucco border of the entrance area.
Photo: HAWK / Götz, 2007.



Peine, Lessing Lodge, west facade, entrance area / stucco edging. Damage in the cast stone. The corrosion products on the iron reinforcement were removed with the sandblaster.
Photo: HAWK / Götz, 2007



Peine, Lessing Lodge, west facade, entrance area / stucco edging. Condition after the repair. The repair plaster adapted very well in color and structure to the original material.
Photo: HAWK / Götz, 2007.

below proved to be the most suitable for a matching repair and for the re-alkalization of the concrete system. The mortar had good processing properties and the materials could easily be obtained from retailers.

Corrosion treatment

The corrosion products (rust) were removed by sandblasting with the blasting material Edelkorund ®, 110 mm (Al Six). The edge areas of the flanking plaster mortar were also worked on to ensure that no corrosion products adhered to the iron or plaster. The area was then thoroughly cleaned with compressed air to remove dust and sandblasting particles.

Anti-Corrosion treatment of cracks

Through alkaline repassivation, crack grouting with a cement-based injection mortar can gently create a new bond and secondary rust protection.
We used the crack injection according to SYSTEM KAISER ® (plaster fixation - secondary corrosion protection).[42] The

1,5	VT	Portland cement	or	15	pbv
0,5	VT	Travertine clasts	or	5	pbv
2	VT	Yellow sand B, 0-0,125 mm	or	20	pbv
0,5	VT	Sand, Nordstemmen plant near Hildesheim, 0-0,125 mm	or	5	pbv
0,2	VT	Water (approx..)	or	2	pbv

Table: Recipe for the repair mortar, HAWK / Götz

SYSTEM KAISER is specially developed for injection applications.

The system provides that grout packer is glued to the cracks and sealed in a subsequent operation. This is followed by the injection process, in which the mortar is injected by means of sealed syringes through optimal use of pressure via the packers. The repair should be adapted to the steel-

2	VT	Portland cement	or	20	pbv
1	VT	Travertine powder	or	10	pbv
1	VT	Quartz sand 0-0, 063 mm	or	10	pbv
1	VT	Quartz powder	or	10	pbv
3	VT	Water	or	30	pbv
2	VT	Sand, Nordstemmen plant near Hildesheim, 0-0,125 mm	or	20	pbv

Table: Formula of the injection mass, HAWK / Götz

concrete composite. The repair material should be as identical as possible to the original material system in terms of physical and technical parameters. Various cement-based suspensions were tested. The cement was obtained regionally from the TEUTONIA CEMENT WORKS HÖFER (Lower Saxony). Travertine powder, quartz powder and quartz sand, 0-063 mm, Millisill® in various proportions by volume were used as fillers. The individual suspensions were thoroughly dispersed.[43] After checking the physical and optical parameters, the following recipe was selected.

Traditional limewash as sustainable care

For millennia, whitewash based on lime has been applied for repair, embellishment, sustainable maintenance and protection of facade plasters.

The craft tradition of repairing and renewing the surface is part of the technological principle of a mineral architectural surface. It is only through this traditional, sustainable maintenance that historical architectural surfaces have been preserved to this day. "Every new coating with lime as a repair of the facade surface also repairs the previous layers."[44] With normal weathering, the lime repairs itself through the known sintering process. Sustainability results from the periodic maintenance of the surfaces: the ease of maintenance, which can be repeated at any time, the aesthetic integrity and the long-term favorable maintenance cost balance.

In the course of newly developed technologies in the first third of the 20th century historical facade surfaces were only rarely maintained according to the traditional craftsmanship. In practice, the plasters were often knocked off and completely renewed or they were maintained with the wrong materials that are incompatible with the historical system of porous building materials. The reasons for this are complex; the essential factors include short-term calculations for repairs without taking into account the follow-up costs, the prevailing aesthetic norms, unsuitable building standards, shortened, if not misleading, ideas on building physics and a lack of technical training. The stone plaster industry developed economical and "hygienic" plaster systems, which - as the manufacturers intended - no longer needed to be cared for by additional coatings. These surfaces were also prone to weathering and were and still are often painted with incompatible paint systems. The result was renewed damage. Against the background of this experience, methods of preservation and repair of plastered facades have been developed in monument conservation since 1980, which combine material-compatible methods of preserving wall painting with the traditional craftsmanship for the care and protection of historical surfaces.[45]

Comparison with buildings dating from the first third of the 20th century in Peine
The facade surfaces of buildings in Peine, dating from the early Twenties, are badly weathered after 80 years. There are hardly any areas left of the originally smoothed surfaces. The aggregate materials stand out

41. Friendly communication from Dipl. Rest. Heiko Brandner: "To protect against corrosion, freshly delivered structural steel was immediately coated with a cement slurry on construction sites. Lade, Winkler 1952, p. 121 state: "The best rust protection for iron in an alkaline composite is obtained by painting with a cement slurry or by embedding it in a fine cement mortar."
42. www.system-kaiser.de (Ralf Czarnietzky)-
43. The effects of dispersion of lime were studied in a research project 2003-05 of the HAWK in Hildesheim / Ivo Hammer in cooperation with the University of Florence / CSGI Pietro Baglioni, Luigi Dei, with studies by Barbara Hentschel (www.hornemann-institut.de), Kathrin Jäger, Sigrid Engelmann, Damaris Venzlaff and Benno Vogler, see: Hammer 2017
44. Hammer1996.
45. Hammer 2010 (English and Polish).

clearly. For the most part, the surfaces are 'powdering' due to lack of cohesion. Due to cleaning with ammonium-carbonate (deer horn salt), (deer horn salt), the surface area and the porosity are increased, making the facade even more susceptible to weathering. A lime-based coating is therefore required to protect the surfaces and ensure long-term maintenance. A caring whitewash also always involves serious intervention and a visual change in the surface. However, the situation on site must be assessed in case the facade surfaces might weather unacceptably quickly without re-coating. The concept of the presentation of the natural color of the material and the color design of the surface would be further adulterated due to the associated damage and typical weathering properties of the mortar that is used. The caring limewash is therefore justified by the specific situation on the building, not as a general principle. Such massive damage cannot be observed in other buildings in Peine from the first third of the 20th century, where stone plaster and cast stone was used.[46] The structure of these surfaces is much better preserved. A protective coating would be out of the question here.

Lime whitewash for sustainable care: technology

By applying a fine lime whitewash as a wafer-thin membrane, the weathering zone is shifted into the lime whitewash, thus protecting the historical plaster surfaces.[47] The exposed clay-containing aggregate materials are covered and the high porosity of the lacunal surface is reduced. Even if the whitewash is partly weathered, there is still protection in the depressions of the tiny lacunae. From a conservation point of view, whitewash is an indispensable measure for the sustainable care of the facade surface, it serves as a protective and weathering layer.

Pilot work

Fine slurries of local sands were added to the lime as aggregates. Due to the fine silicates, i.e. the proportion of silt, in the range of approx. 2-63 mm, the sand also has a lime pigmenting effect. Depending on the type of sand, the lime takes on a yellowish or, more rarely, greyish tint. With the addition of shell lime powder and Rhenish trass lime, the lime was additionally greyish, i.e. tinted in the material color of the original cement plaster. The grain size of the aggregates of the whitewash was adjusted so that a very thin, subtle coating was possible, which only fills the weathered parts, but does not change the surface structure. The trass lime and the clayey components and fine silicates in the sand mean that the lime can also set and harden hydraulically. So that the whitewash can be applied better, about 1% linseed oil varnish has been added, which corresponds to the tradition of craft production.

The linseed oil, which is temporarily stored in fine molecules, is saponified relatively quickly by the strongly basic calcium hydroxide. For this reason the linseed oil only has a temporary blocking effect. The whitewash was brushed once onto the thoroughly pre-wetted surface like a wafer-thin membrane. The structure and the materiality of the whitewash came very close to the structure of the original surface. The weathered parts of the surface could be adapted well to the less weathered parts. The architectural structure was once again perceptible as an esthetic unity and the visual impression of the color was again determined by the different structure of the concrete stone plaster and the scratched concrete plaster surface.

10	VT	Lime putty	or	10	pbv
9	VT	Rhenish Trass	or	9	pbv
4	VT	Mussel lime powder	or	4	pbv
4	VT	gray sand, Nordstemmen plant (near Hildesheim), Silt slurry	or	4	pbv
6	VT	yellow sand, Berkum plant, Silt slurry	or	6	pbv
50	VT	Water (as needed)	or	50	pbv

Table: Recipe for whitewash.
(HAWK / Götz)

46 See Götz 2007.
47 Hammer 2003, p. 187.

Peine, Lessing Lodge, east facade, pilot area, whitewash A, B and C.
Photo: HAWK / Götz, 2007.

Acknowledgements
First to my student Marko Goetz, who did a wonderful job in his diploma work, which was awarded by the Lessing Lodge.
We would like to thank for the good cooperation: Univ. Prof. Dr. dott. Thomas Danzl, then BDA Vienna; Wittkop, Keith Stewart on behalf of the Lessing-Loge Peine; Dr. Hendrik Visser, ZMK Hanover; Dipl. Rest. Bettina Achhammer, Bernhard Recker, Dipl. Lab. Chem. Rolf Niemeyer, NLD Hanover; Univ. Prof. Dr. Roland Vinx, University of Hamburg; Dr. Jeannine Meinhard-Degen, IDK Halle; Dipl. Rest. Christel Meyer Wilmes and Dipl. Rest. Annelie Ellesat, HAWK Hildesheim.

Ivo Hammer
conservator, professor emeritus, Dr. Phil, Hildesheim, Wien
member of docomomo ISC/T Austria

Peine, Lessing Lodge, east facade, condition after the intervention layer was applied.
Photo: HAWK / Götz, 2007.

Litterature

Bauakte, Lessing – Loge (1926), Bahnhofstraße 27, Peine, archived in Hochbauamt Peine.
Danzl, Thomas (2003), *Kunstputz (Edelputz) – Kunststein (Betonwerkstein) – Kunststeinputz (Steinputz), Die Bedeutung und Erhaltungsproblematik materialfarbiger Gestaltungen an Putzfassaden des 19. und 20. Jahrhunderts*, in: Jürgen Pursche (Hrsg.), Historische Architekturoberflächen. Kalk – Putz – Farbe, ICOMOS Hefte des Deutschen Nationalkomitees 39, p. 146-159.
Götz, Marko (2007), *Die materialfarbigen Fassadenoberflächen der Lessing–Loge in Peine von 1926 mit Edelputz-Steinputz-Betonwerkstein Entwicklung eines Konservierungs- und Restaurierungskonzeptes zur Erhaltung und nachhaltigen Pflege mit einer praktischen Umsetzung in einer Pilotfläche und Überlegungen zur Erhaltungsperspektive*, unpublished thesis, examiner: Ivo Hammer and Thomas Danzl, HAWK Hildesheim.
Hammer, Ivo (1980), *Historische Verputze. Befunde und Erhaltung*, in, Österreichische Sektion des IIC (Hrsg.), Restauratorenblätter 4, Wien, p. 86-97.
Hammer, Ivo (1988), *Sinn und Methodik restauratorischer Befundsicherung. Zur Untersuchung und Dokumentation von Wandmalereien und Architekturoberfläche*, in: Österreichische Sektion des IIC (Hrsg.): Wandmalerei/Sgraffito/Stuck, Restauratorenblätter, Bd. 9, Wien, p. 34-58.
Hammer, Ivo (1996 a), *Salze und Salzbehandlung in der Konservierung von Wandmalerei und_Architekturoberfläche* (Bibliography created together with Christoph Tinzl), in: Salzschäden an Wandmalereien, Arbeitshefte des Bayerischen Landesamtes für Denkmalpflege, Band 78, München, p. 81-106.
Hammer, Ivo (1996 b), *Symptome und Ursachen. Methodische Überlegungen zur Erhaltung von Fassadenmalerei als Teil der Architekturoberfläche*, in: Zeitschrift für Kunsttechnologie und Konservierung, Jg. 10, p. 63-8.
Hammer, Ivo (2003), *Bedeutung historischer Fassadenputze und denkmalpflegerische Konsequenzen. Zur Erhaltung der Materialität von Architekturober fläche* (with bibliography and list of conservation works), in: Jürgen Pursche (Hrsg.), Historische Architekturoberflächen. Kalk – Putz – Farbe, ICOMOS Hefte des Deutschen Nationalkomitees 39, p. 183-214.