The external renders of the early 20th century architecture

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Abstract. External renders are an essential part of the architecture of the first half of the 20th century. The aesthetic effect of such plasterwork was achieved by surface treatment, colouring or by using various filler components that acted with their colour or structure. The binder of the plasters was most often Portland cement which played an important role in the processing of plasters or surface finishes, and in addition, formed the functional properties of the plasters (hardness, durability, resistance to external conditions).

This paper summarizes the results of a survey focused on the characterization of components used for the creation of external rendering taken from several architecturally significant buildings in the city of Brno dating back to the first half of the 20th century (villas, apartment buildings, public apartment houses). The survey into the collected samples performed by means of petrographic (light polarizing microscopy) and phase (powder X-ray diffraction) analysis revealed interesting information concerning the wide range of materials (components) used and the craftsmanship involved in their processing, all of which fundamentally influence the art-craft and utility properties of the buildings. The information gathered can serve as an important source of information for the renovation of early 20th century architecture.

1. External renders of the first half of the 20th century - introduction

In civil engineering, renders have always been the element of the façade that, to a certain extent dictates the aesthetics of the building itself as a whole. Throughout history, a wide range of materials have been used for renders, with the traditional binder being lime right up to the end of the 19th century. However, towards the end of the 19th century, the Secession period brought an unbelievable array of renders. The colourfulness and structure of the plasters were dictated not only by the pigments but also by the aggregates used and, above all, by the surface finishing technique. Plasters of varying compositions and surface structures could be applied on one building, with stucco framing geometrically unifying divergent surfaces. The demand for a unique expression motivated builders to experiment in developing plasters which would appear in a certain region and within a short period of construction. Successful experiments were further copied and adopted by other workshops, sometimes however, without knowledge of the original technique, thus increasing the number of varieties. The diversity of materials was further enriched by the use of Roman or Sorel cement and modified gypsum plaster binders, used mainly for making mortars and renders or for the creation of cast decoration elements integrated into the façades [1, 2, 4]. The variability of façade surfaces was not even affected by the dramatic increase in the production of Portland cement in the early 1900s and
its increased use throughout the whole world as, among other applications, a binder in plasters. Cement binders therefore, can be found in all European centres on buildings in the style of Late-Classicism through individualist Modernism to Functionalism. The introduction of Portland cement into the making of plaster did not however force out lime. On buildings from the first half of the 20th century it is common to find “hard” cement-based renders alongside “soft” lime-based renders.

Various renders can coexist also as multi-strata layers; period instruction manuals of the period for masons generally recommend applying the render on exterior walls in two layers – the rough bottom (core) layer with a cement binder and sand mixed in a high ratio of from 1:3 to 1:5, followed by the second layer with its increased cement content because, as some manuals state, the aggregate lowers the binding properties of cement. Only some of the manuals recommend adding lime in order to slow the setting and improve the workability, but on the other hand the reason being the resulting poor resistance to moisture in exterior conditions [3–6].

Cement-based renders were carried out using an exceptionally wide range of technologies and craft techniques. Renders were created in such a way as to create an effect with their own distinct colour and inner structure (pigments, coloured aggregates, limestone, mica, other crushed rocks, coloured glass) and with its outer structure (washing out the surface, surface scrubbing with a scraper, bush hammer or other masonry tools). [6–8].

From a heritage care point of view, the issue of research into and repairs of hard renders is one of great urgency. Thanks to the marked durability of cement material, a large number of early 20th-century renders have been preserved. However, these facades are nearing the end of their lifespan and require urgent renovation. The structure and colouring of widely applied substitutes today do not correspond to the original material. In order to achieve an optical match of a façade surface, which combines the original material with modern additions, an overall paint layer is usually applied. However, in the case of cement renders this is to the detriment of the original aesthetic concept as the colouring of the façade was achieved through the use of selected aggregates or pigments colouring the plaster throughout its entire mass.

Whereas the issue of other building construction binders has been addressed in this country and abroad, there is a lack of literature dealing with the issue of historical cement-based renders. Much space has been dedicated to lime-based technologies1 through a whole range of seminars and conferences2. Research into Roman cement and its applications has been published in detail within the framework of the outcomes of the international ROCARE project3. Some information concerning hard renders can be found in old literature, in masonry textbooks and brochures of the period, which are, however, focused on the issue from a limited point of view of recommendations for craftsmen. Compared with the situation in the Czech Republic, considerably more research is carried out in Belgium, concentrating on hard renders and issues concerning the restoration of architecture of the first half of the 20th century. Some of that research, cited in this article, can serve as comparative material for the study presented here.

2. Selected examples of Modern architecture

All samples were taken on the territory of the city of Brno. The reasons were logistical, but Brno was also extremely suitable thanks to the large representation of modern architecture. The buildings selected for the basis of this study, and from which samples were taken for the analysis of the historical renders, are listed in table 1. This selection reflects several aspects; the aim was to cover as many different types of rendering as possible, include a cross-section of buildings typical of the period, and take samples of authentic materials, but not of those on renovated buildings, as this

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1 To cite just one of the dozens of local publications: Girsa V. and Michoinová D. 2015 Tradiční vápenné omítky: poznání a praktické postupy (Praha: IC ČKAIT)
2 Just one of many seminars: „Vápenné omítky pro památkovou péči“ (Lime renders in heritage care) organized by WTA CZ in cooperation with the Klokner Institute of ČVUT and the Faculty of Civil Engineering VUT in Brno, 9. December 2009.
3 For details see: www.rocare.eu.
would necessitate the inclusion of facades that had previously undergone overall repairs into the survey. However, it was impossible to achieve this aim in full. During the first two decades of the 20th century, lime-based rendering technologies were the norm and acquiring an authentic sample was simply not possible. Not many buildings were constructed during WWII, and on most of those surviving, the renders had been renewed. This was also apparent when taking samples from the buildings of the 1920s and 1930s – the authentic renders were not always found, even though the relevant documentation suggested that they should have been, and in some other cases there are serious doubts as to their actual existence. In spite of these obstacles, samples were taken from significant buildings, documenting the development of modern architecture and building engineering before WWII.

The list of buildings is presented according to a chronological key dating the construction of the building in order to compare the technologies and material composition of the samples taken. Along with the basic information concerning the construction of the building, the table contains a brief description of the render samples and their basic characteristics.

![Figure 1](image1.jpg)

**Figure 1.** (a) Nemocenská pokladna soukromých úředníků a zřizenců (Treasury for social care of private clerks), Kounicova 299/42, Zahradníkova 299/10, Brno (architect: Jaroslav Syřiště, 1923–24), (b) Městské lázně (Municipal Spa), Zábrdovická 158/13, Brno (architect: Bohuslav Fuchs, 1929–1932).

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4 Full use was made of research, specialist opinions, photographs and further documentation of the National Heritage Institute, Regional Specialist Department in Brno.
Figure 2. (a) Nádražní poštovní úřad (Railway Station Post Office), Nádražní 118/7, Brno (architect: Bohuslav Fuchs, 1937–1938), (b) sampling place, the front (west) façade.

Table 1. Description of the sampling sites.

| Object | Location (district, street) | Architect | Sampling site/position |
|--------|-----------------------------|-----------|------------------------|
| Nemocenská pokladna soukromých úředníků a zřízenců (Treasury for social care of private clerks) | Kounicova 42/Zahradníkova 10, Brno | Jaroslav Syřiště | A-terazzo of the plinth, B/plain surface finishes |
| Městské lázně (Municipal Spa) | Zábrdovická 12, Brno | Bohuslav Fuchs | Plain surface finishes |
| Nádražní poštovní úřad, západní fasáda (Railway Station Post Office, west facade) | Nádražní 118/7 | Bohuslav Fuchs | Plain surface finishes |
| Nádražní poštovní úřad, jižní fasáda (Railway Station Post Office, south facade) | | | Plain surface finishes |
| Odborná škola pro ženská povolání Vesna (Secondary School for Female Occupations Vesna) | Lipová 232/1, Brno | Bohuslav Fuchs, Josef Polášek | terrazzo of the plinth |
| Zemský dům III / činžovní dům (National House III/Apartment block) | Kounicova 944/1-944/7, Brno | Karel Náhůnek | terrazzo of the plinth |
| Bytový dům (Apartment block) | Botanická 825-828/37-45, Brno | Vítězslav Unzeitig | terrazzo of the plinth |

The principal method of material investigation was light microscopy (LM). The samples were impregnated with epoxy resin under vacuum and, subsequently, thin sections of 30 μm thickness were produced from their cross sections. The thin sections were examined in transmitted polarized light using an Olympus BX 51 microscope and scanned using a Canon 9000F Mark II film scanner equipped with polarizing foils. One sample was examined also by powder X-ray diffraction with a Rigaku Smartlab diffractometer with Bragg-Brentano Θ-Θ reflection geometry. Ni-filtered Cu radiation ($\lambda_{K\alpha} = 0.15418$ nm) was used. The tube was powered at 40 kV and 30 mA. Divergence slit width: 0.5°, Soller slits: 5°
receiving slit: 0.1°. Measured angular range: 5-80°2Θ, step size: 0.02°2Θ, time per step: 1 s. The gained data was evaluated with the help of Panalytical High Score 3 Plus and Bruker AXS Topas 4 software. The quantitative phase analysis was done by the Rietveld method. Crystal structure models from the Bruker AXS database were used. The analysis of pigments were performed by scanning electron microscopy and X-ray microanalysis (SEM/EDS) using a Tescan Vega TS 5136 LM instruments powered at 30 kV. The samples were carbon coated.

3. Composition of hard renders
Pokladna soukromých úředníků a zřízenců (Treasury for social care of private clerks), Kounicova 299/42, Zahradníkova 299/10, Brno (Jaroslav Syřiště, 1923-24)

Sample A – reddish terrazzo of the plinth sections
The sample is composed of one layer of reddish render (applied to a light ochre, hard, rough-grained core render on the building) containing dark green and white clusters of filler (figure 3a, b). The binder is of a mixture based on aerial lime and Portland cement. There is a dark red oxide pigment quite homogenously dispersed in the binder, locally forming clusters (figure 3d). The pigment is most likely a secondary industrial material containing hematite, e.g. metallurgical dust. The filler is primarily composed of macroscopic white, crushed limestone and dark green serpentinite (figure 4c) mixed to a volume ratio of 3:2. Alongside these rock clusters there are sporadic traces of quartz, metaquartzite and minute fragments of metabasites. The filler is granulometrically well sorted with two separate particle sizes: 5.0–3.0 mm and 1.0–0.1 mm. With the help of image analysis, the filler to binder volume ratio was determined to be 2:1.

![Figure 3. Treasury for social care of private clerks, Kounicova 299/42, Zahradníkova 299/10a, terrazzo of the plinth sections: a) Macro photographs of the fractured sample, b) thin-section photomicrographs of the sample, XPL, c) the detail of the clusters of the aggregate, thin-section photomicrograph, XPL, d) the fragments of the Portland cement clinker particles and hematite pigment, PPL.]

Sample B – plain surface finishes
The strata of the renders are made up of a light grey-ochre core layer (1) and a greenish surface renders (2) (figure 4a, b). The binder of the core layer is of Portland cement most probably with an admixture of lime whose presence can be surmised from the optical character of the matrix, which
displays an increased porosity and low presence of cement clinkers. The top layer only contains a lime binder (the content of unfired clusters of lime is significant). The core mortar was made by mixing the aggregate and binder to the approximate ratio of 3:1, with the same “recipe” used in the top render layers containing lime binder. The aggregate is almost exclusively made up of clusters of serpentinite (figure 4c). Only on the base of the sample are there quartz and metaquartzite clusters, which are not however, part of a separate layer. The granulometric sorting of the aggregate is relatively poor. The size variation in the fragments of filler is <0.1–4.0 mm with relatively uniform particle size distribution. The colour shade of the top render layer was achieved through the addition of a green pigment, which is dispersed throughout the binder (figure 4d). The sporadic presence of glauconite was optically identified within the pigment. The composition of the pigment was analysed by means of EDS which confirms that majority of the green pigment was composed of elements lighter than sodium, which in turn points to the use of an organic dye. The size of the largest pigment grains is up to 0.1 mm, with the majority of the grains however, significantly smaller. The pigment has even penetrated into some of the filler fragments where it has created a relatively extensive light-green tinted area.

Figure 4. Treasury for social care of private clerks, Kounicova 299/42, Zahradnikova 299/10a, plain surface finishes: a) Macro photographs of the fractured sample, b) thin-section photomicrographs of the sample, XPL, c) the detail of the clusters of aggregate – serpentinite, d) the detail of the Portland cement clinker particles and green pigment, PPL.

Městské lázně (Municipal Spa), Zábrdovická 158/13, Brno (Bohuslav Fuchs, 1929-1932)
Plain surface finishes
The sample consists of a grey sample of render with a surface features macroscopically visible, characteristic protruding aggregate fragments (figure 5a). The strata of the sample are composed of four layers (figure 5b) including the medium-grained glauconitic sandstone as a ground material (layer 0) and 3-layered render with the strata: under-layer (1), core render (2) and stucco render (3). Whilst the under-layer is a lime-cement one, the other render layers feature binders predominantly with containing Portland cement components (figure 5c). The estimated volumetric binder to aggregate ratio of the under-layer is approximately 3:1, with the core and stucco ratios both reaching an identical 1:1. The filler of the core layer (2) is a rich mixture of rock fragments (quartzite, metaquartzite, metamorphic slate, granitoid rock, aplite, sandstone, etc.) and minerals (quartz, alkali feldspar, plagioclase, muscovite, biotite) with an admixture of (probably) blast furnace slag.
The structure and coloured mosaic of the surface layer is made up of a mixture of macroscopic white crushed limestone and black serpentinite mixed to a volume ratio of 1:3, sorted to a grain size of 1–3 mm (figure 5d).

**Nádražní poštovní úřad (Railway Station Post Office), Nádražní 118/7, Brno (Bohuslav Fuchs, 1937-1938)**

**Plain surface finishes (west façade)**

The sample of the render features a distinctive surface structure as a result of large, projecting fragments of the aggregate, visible even under the covering layer of whitewash (figure 6a). The sample taken on site is composed of three layers in total (figure 6b): the core mortar with a fine filler (1) which base has not been captured in the sample, an upper layer 10–14 mm thick with large fragments of filler projecting from the layer of the sample (2). On top, there is a thin, discontinuous, extremely porous, surface layer (3) with thickness varying from 0.4–0.7 mm, which is probably a secondary modification. The binder of layer 1 is Portland-cement compared to layers 2 and 3 which contain lime as a binder. The binder/aggregate ratio of layer 1 was established to be roughly 2:3, with the filler made up of a mixture of crushed limestone of 0.2–2.5 mm particles and finer sand with the gain size distribution of some 0.05–1.5 mm. The aggregate composed of fragments of minerals and rocks - quartz, plagioclase, mica, garnet gneiss, metamorphic slate, flints, granitoid rock and others.

![Figure 5](image)

**Figure 5.** Municipal Spa, Zábrdovická 158/13, plain surface finishes: a) Macro photographs of the fractured sample, b) thin-section photomicrographs of the sample, XPL, c) the detail of the stratigraphy (0-glauconitic sandstone, 1-lime-cement render and 2-cement finish (with the details of the Portland cement clinker particles), PPL, d) the detail of the third layer containing crushed limestone and black serpentinite, XPL.

The limestone to sand ratio was estimated to be approximately 1:1. In comparison, the binder to aggregate ratio of layer two is around. The aggregate contains two distinctive grain size regions – a finer one with a prevailing particle size in the region of some 0.05–0.25 mm, composed of marble dust with, sporadically, fragments of sand (figure 6c) and rough clusters of aggregate with particle size 4–16 mm containing sub-rounded to sub-angular fragments of metaquartzite to quartz cataclasites having low sphericity. Finally, layer 3 was formulated by mixing binder and aggregate to the ratio of 3:1 in volume parts. The porosity of layer 3 is over 30%, probably a result of the addition
of an unidentified non-foaming substance (figure 6d). The aggregate is composed of very fine-grained particles of crushed marble dust with particle size distribution 0.02–0.04 mm.

**Plain surface finishes (south façade)**

The sample taken from external wall render consists of one single layer of highly porous render with macroscopic signs of fragments and open porosity onto which a coat of white paint has been applied (figure 7a). Most of the volume of the sample is composed of a layer with a cement-lime binder with a predominance of Portland cement (1). On the surface there is a thin (0.1–0.7), probably secondary, discontinuous paint layer (2) with a lime as a binder and with porosity of over 50% (figure 7b, d). Both the microstructure and composition of the aggregate of the layer (2) are identical to those of layer 3 of the west façade of the building. The render was formulated in volumetric binder to aggregate ratio being about 1:3. The aggregate underwent well sorting; two particle size region can be identified in the filler one being less than 1 mm and the second 3–3.8 mm. The mineralogical composition of the aggregate shows a prevailing mixture of quartz and crushed marble mixed in rough volume ratio of 1:1. There were also sporadic traces of minor inert components identified in the sample (probably blast-furnace slag) and opaque minerals (figure 7c).

![Figure 6](image-url)

**Figure 6.** Railway Station Post Office, Nádražní 118/7, plain surface finishes (west façade): a) Macro photographs of the fractured sample, b) thin-section photomicrographs of the sample, PPL, c) thin-section photomicrographs, the detail of the marble aggregate, XPL d) the interface between the ground layer (1) and highly porous surface paint layer (2), PPL.
Figure 7. Railway Station Post Office, Nádražní 118/7, plain surface finish (south façade): a) Macrophotographs of the fractured sample, b) thin-section photomicrographs of the sample, XPL, c) the detail of the slag particle, XPL, d) the interface between the ground layer (1) and highly porous paint layer (2), PPL.

Secondary School for Female Occupations Vesna, Lipová 232/1, Brno (Bohuslav Fuchs, Josef Polášek, 1929-1930)

Terrazzo of plinth

The render strata consist of ochre core render followed by the upper layer made up of a macroscopically visible red colour and featuring an inhomogenous texture (figure 8a). Under close microscopic inspection, the render strata is actually composed of three layers (figure 8b): two macroscopically visible, light yellow layers of core plaster (1) and its pigmented surface layers (2) and the upper render with red pigment (figure 8c). The base of layer 1 is not captured in the sample, the thickness of layer 2 varied from 1-11 mm. The thickness of the red surface layer (3) is from 9–12 mm. The binder of all three layers is Portland cement, in layer 1 probably with an addition of lime. The binder to aggregate ratio in layers 1 and 2 is identical at approximately 2:3, with the ratio in layer 3 at approximately 1:3. The filler in layers 1 and 2 are identical and is approximately 2:3 and the binder/aggregate at 1:3 in layer 3. The aggregate of layers 1 and 2 are identically composed of sand with a particle size distribution 0.05–3 mm. The sand grains are composed of varied mineral rock fragments (quartz, plagioclase, sporadically muscovite, biotite, glauconite, garnet, sandstone, greywacke, siltstone, metaquartzite, cataclasite, granitoid rock, and vestiges of limestone). The aggregate of top layer is composed of marble dust and sand mixed to a volume ratio of approximately 2:1. The aggregate of the layer is rather medium sorted with grain size distribution 0.1–1.3 mm. The red pigment of layer 3 is hematite, according to the morphology probably a calcined ochre pigment. Within all layers, some of the pores are partially or completely filled with ettringite, probably due to the alteration of the cement binder through exposure to the aggressive atmospheric environment (figure 8d).
Figure 8. Secondary School for Female Occupations Vesna, Lipová 232/1, terrazzo of the plinth: a) Macro photographs of the fractured sample, b) thin-section photomicrographs of the sample, PPL, c) the interface between layer the layer the ground layer (2) and red finish (3) (containing crushed marble and sand as an aggregate), d) the detail of the pore filled with ettringite.

National House III / Apartment block, Kounicova 944/1-944/7, Brno (Karel Náhůnek, 1924)

Terrazzo of the plinth
The macroscopic composition of the sample is of two layers: a grey core render (1) and a surface layer (2) with a greyish-yellow binder, white clusters of filler and a grooved texture (figure 9a). Only layer 2 has been studied microscopically. The binder of the terrazzo layer is Portland-cement based, with the binder matrix containing abundant fragments of Portland clinkers of up to 0.3 mm in size. The binder to filler volume ratio is approximately 1:3. Most of the filler fragments fall into two particle size regions, < 1 mm and 2.5–6 mm, both particle sizes were mixed in an approximately 2:3 volume ratio.

Figure 9. National House III/Apartment block, Kounicova 944/1-944/7, terrazzo of the plinth: a) Macro photographs of the fractured sample, b) thin-section photomicrographs of the surface layer (2), XPL.
The prevailing aggregate component is crushed limestone with the rare occurrence of quartz (figure 9b). The sample contains an ochre pigment composed of iron oxide-hydroxide, most likely of natural origin. The argument for the natural origin is supported by the fact that some clusters of iron oxide-hydroxides occur in the original position – surrounding the minute grains of quartz.

**Apartment block, Botanická 825-828/37-45, Brno (Vítězslav Unzeitig, 1955-1956)**

**Terrazzo of the plinth**

The macroscopically compact sample features a red binder with black and white clusters of aggregate and a rough surface texture (figure 10a). The sample is composed of two layers: the core mortar (1) and the top, approximately 10–13 mm thick (figure 10b) layer with red pigment (2). The binder to aggregate volume ratio in the core mortar is 1:3, with a lower ratio in the top layer (approximately 1:2). The binder of the core mortar is Portland-cement based with poorly sorted aggregate with the majority of the fragments smaller than 2 mm. The composition of the aggregate is of a mixture of sand composed of a rich mixture of mineral and rock fragments and a smaller portion of crushed limestone. On the basis of the PLM and XRD results, in the top layer is Portland-cement based with an addition of gypsum. Using XRD, the amount of gypsum in the whole sample (including the filler) was found to be 7.9 wt. %, therefore, it is unlikely that it would originate from hydrated cement. As a result of the presence of gypsum, ettringite has formed within the sample. The filler is composed of macroscopic white crushed limestone and dark crushed serpentinite. The limestone to serpentinite volume ratio is approximately 2:1. Fragments of other rocks and minerals, such as quartz, plagioclases, glauconite and occasional fragments of mica schist, appear only sporadically. The particle size distribution of the aggregate falls predominantly into two regions with most falling between 2–3 mm and less in particle size. The results of the XRD analysis of layer 2 are in listed in table 2.

![Figure 10](image)

**Figure 10.** Apartment block, Botanická 825-828/37-45, terrazzo of the plinth: a) Macro photographs of the fractured sample, b) thin-section photomicrographs of the sample, XPL.

**Table 2.** Mineral composition of red terrazzo layer (2) determined by means of XRD in wt.%. 

| Aggregate   | Binder +aggregate | Pigment  | Aggregate   | Serpentinite |
|-------------|-------------------|----------|-------------|--------------|
| Alite       | 0.4               | 0.9      | 7.9         | 70.0         |
| Ettringite  | 0.4               |          | 1.4         | 9.9          |
| Gypsum      |                   |          | 0.6         | 0.6          |
| Calcite     |                   |          |             | 1.4          |
| Hematite    |                   |          |             | 1.7          |
| Quartz      |                   |          |             | 2.2          |
| Lizardite   |                   |          |             | 3.0          |
| Antigorite  |                   |          |             |              |
| Olivine     |                   |          |             |              |
| Pyroxene    |                   |          |             |              |
| Amphibole   |                   |          |             |              |
| Chloreite   |                   |          |             |              |
4. Conclusions
The study discusses the detailed composition of several samples of renders taken from the façades of buildings constructed in the first half of the 20th century in Brno. The study is the first comprehensive study in this country concentrating on the issue of material composition of renders in modern architecture. The authors would like to continuously expand the topic through further research in order to broaden the spectrum of knowledge concerning the technologies and craft processes involved in preparing the renders on buildings of modern architecture. Although this study is based on a limited number of samples, several interesting assertions can be made, especially as regards the composition of the renders, which are only partially in agreement with those presented in specialist works of reference. Such works of a historic nature tend to address the issue from the point of view of the necessary crafts and skills, whilst overlooking the wide range and changeability of the material recipes. For several reasons therefore, the information acquired is crucial for gaining an insight into the issue at the current time. A subsequent benefit of the analyses of the samples is that they serve as a valuable record contributing to an understanding of the degree of skill of the craft, the materials used and the recipes at the time in question.

The components found in the samples of render can, for example, point to local sources of material that are no longer exploited or indicate the use of, from today's point of view, curious waste material (e.g. slag, pigments, and glass). And lastly, a detailed analysis of the render is crucial in providing a base for suggesting adequate supplementary materials for the restoration of architecturally important buildings of the first half of the 20th century, even in cases where the original material has not been preserved. In extreme restoration situations, the acquisition of knowledge of the techniques and the recipes for materials can be of assistance when devising replicas or allusions for architecture of the first half of the 20th century.

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