# Selection of repair methods for rendered façades

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ABSTRACT: The repair methods of rendered facades are selected primarily on the basis of the technical condition of the structure. The information on the deterioration level of structures from a condition investigation allows the selection of appropriate repair methods and an assessment of related risks and the service life of the repair.The content of a condition investigation is to be such that set goals are achieved. Usually the aim is to determine the repair need and safety of structures. To achieve that, the deterioration and performance defects of structures need to be established. Rendered facades can be subject to several types of deterioration. This requires establishing the existence, scope, location, degree, impacts and future progress of deterioration in each case.The large variation in the level of deterioration between different buildings, and the fact that the most significant damage is not visible until it has progressed quite far, make a thorough condition investigation necessary in most facade repair projects.

## 1 INTRODUCTION

Prestigious and durability are the attributes commonly associated with rendered facades. The appearance requirements specified for the architectural design of buildings and facades of this type are usually high. The original facade makes demands also for the final result of facade repair. For the selection of repair method appears primarily damages and technical condition of the structure among the appearance requirements of facades.

Rendering was popular in the Finnish buildings facades until 1960s, when concrete structures and pre-cast concrete facades replaced rendering in new buildings facade. A small stock of older buildings with rendered facades consists mainly of churches, castles and other public buildings. The best known rendered buildings in Finland are probably those around the Senate Square in Helsinki including the Senate Building, Helsinki Cathedral and buildings of the University of Helsinki.

Rendering has been popular again during last ten years. Especially in the repair of those pre-cast concrete facades, which were made during 1960's and –70's. Also new buildings has now been build with rendered facade, but the construction technique and materials are different than old days. Insulating rendering is the main rendering system in these days in Finland.

Despite the young age of most of the building stock, some facades have had to be repaired after only 10 years' service life. Structures are damaged by various degradation phenomena whose progress is influenced by many structural, exposure and material factors. Consequently, the service lives of different structures vary a lot in practice. In the Finnish climate, frost weathering is the major deteriorating factor for porous materials.

## 2 STRUCTURES AND MATERIALS

The substrates of old rendered facades are mainly of burnt brick and mortar. In new buildings there is quite lot variation on substrates, materials and structures. The foundations of the buildings have varied by construction site. A common feature is a plinth of natural stone laid under the bearing brickwork. An advantage of a high natural stone plinth is that it prevents capillary transfer of moisture from the ground to the brickwork.

### 2.1 *External wall structure*

In old rendered buildings the mortar was applied onto solid masonry walls. Such external wall structures were common in Finnish rendered buildings until the 1960's. The thickness of the walls have varied over time (Neuvonen et al. 2002).

In the beginning of the 19th century bricks were usually manufactured on or nearby the building site. The quality of bricks varied a lot because they were fired in temporary kilns (Lahti 1960). Many brick factories were founded in Finland in the middle of the 19th century. In 1900 there were still 173 small brick factories in Finland, and 85 % of the bricks were made manually Kuokkanen & Leiponen 1981).

At the turn of the century each factory produced bricks of non-standard sizes with the moulds it had. An agreement on standard brick sizes was reached already in 1897, but standardised brick production was not started until the 1920's. Only those external walls that were faced with natural stone or rendering were built of domestic brick. Imported bricks were used for fair-faced external walls due to their higher quality. The dimensions and rates of firing of domestic bricks varied significantly which directly affected their durability (Lahti 1960).

The properties of bricks made a hundred years ago depended mainly on two things: the quality of the clay used and the firing. The temperature was not uniform throughout the kiln but fluctuated above and below 1,000 °C. The range in firing temperature, therefore, resulted in over-burnt to under-burnt bricks. Over-burnt bricks are dark, almost black, durable and impermeable. Under-burnt bricks are typically light in colour, weak, highly porous and partly stratified.

From 1980's in small houses rendered external wall structure has consist on blocks of autoclave aerated concrete (AAC) or breeze-blocks which has an insulation layer between two breeze-block. These kind of wall structure is still quite popular in rendered small houses in Finland.

In the beginning of this century insulation rendering has taken a big part of rendering market in Finland. Traditionally (1980's) insulation rendering has been made on mineral wool with lime- or lime-cement mortars and the tree coat rendering has been fasten with mechanical anchor to buildings framework.

In new insulation rendering systems insulation is mineral wool or expanded polystyrene (EPS), mortars are cement-based and usually polymer modificated mortars. And rendering is fixed to insulation only with mortar, there is usually no mechanical anchor.

## 2.2 *Foundations*

Brick-buildings are brittle compared, for instance, to concrete ones and are easily damaged due to uneven settling of foundations and frost heave. The heavy weight of masonry buildings and their brittleness place demands on items such as, soil bearing capacity and type of foundation.

The type of foundation has naturally depended on the construction site and its soil composition. There have been three main foundation systems: rock-based, soil-based and pile-based.

Until the 1890's the typical foundation walls were made of dry set boulders (no mortar). At the beginning of the 20th century mortar or sand was normally placed between the boulders (Tawast 1993). The internal surface of the foundation, which formed the cellar wall, was generally lined with brick and later cast concrete. In the 1910's concrete foundation walls began to be used. The foundations were wider at the bottom in order to distribute the loads over a larger area. Bitumen or coal tar was used as waterproofing between the stacked boulders and the interior brickwork lining. Asphalt was used instead of mortar for tanking as well as in laying the brickwork of the interior surface (Neuvonen et al. 2002).

## 2.3 *Mortars and rendering methods*

Slaked lime has been used as an ingredient of mortar worldwide for thousands of years, and for hundreds of years also in Finland. The skill of mortar making was brought to Finland around 1100 by Swedish, Central European and Eastern Baltic masters representing the Germanic school. As late as the early 1900's Finnish builders used primarily pure lime mortars for masonry work and rendering – cement was added only occasionally (Perander et al. 1985).

In the 19th century most Finnish cement was imported, although the first cement factory already started operating in Savio in 1869 (Hurme et al. 1991).

The appearance, structure and colouring of rendered facades has varied quite extensively over time according to architectural trends. In the 16th and 17th centuries rendering was used to imitate natural stone surfaces being a cheaper alternative. Sandstone was imitated by pale yellow rendering, marble slabs by white rendering, and granite by grey rendering. A rendered surface was easy to colour and had no joints which allowed drawing lines on it to imitate stone slabs. Mortar was also used for mouldings. (Anon. 1999). The rendering jobs of old involved the application of three coats across the entire substrate.

Modern substrates like AAC or breeze-blocks demands different mortars for rendering than those old bricks. That because the strength and the suction of substrates are very much different than in burned bricks. In modern renderings there are used usually two coat renderings. It means that we use two different mortar. Base mortar can be sprayed in two layers with one mortar and surface also sprayed in two layers (Anon. 2005). Mortars are cement-based polymer modificated mortars.

In insulation renderings mortars are developed especially for this use. Mortars should have very good adhesion to insulation material and it must be still workable. Those mortars are usually cement-based but they includes a lot of polymers.

## 3 LOADS AND DETERIORATION MECHANISMS RELATED TO RENDERED FACADES

The damage to rendered facades as structures age is mainly due to weathering. Deterioration may be fast enough to be harmful if used materials or the quality of work have been poor or structural solutions have been defective or perform unsatisfactorily. Weathering sets off several parallel deterioration phenomena which means that usually more than one cause contributes to the degradation of the facade. Initially deterioration phenomena proceed slowly, but as the damage increases the rate of deterioration also normally accelerates.

Deterioration of rendered facades can be divided into three basic categories:

- structure-induced deterioration of rendering
- deterioration of materials
- damage resulting from moisture.

### 3.1 *Structure-induced deterioration*

The damage caused by structures to rendered facades typically consists of cracks. Harmful cracks in masonry are generally the result of uneven settling of foundations. A crack in the masonry substrate also always leads to cracking of the rendering layer. In brick walls the cracks normally run along the interfaces between mortar and masonry units. A condition investigation must be carried out to determine the causes of cracks and their movement. The cause can often be determined from the direction and location of cracks. Repair of active cracks without first determining the cause will usually lead to renewed cracking.

Drying of structure and mortar leads to shrinkage. Shrinkage is characteristic value for each material. In mortars a plastic shrinkage can be avoid by careful after-care, but characteristic shrinkage happens when rendering dries during time. Both of these shrinkage mechanisms can cause cracking on rendering. In most cases these cracks are quite narrow and they are usually only aesthetical problems. I cases, when rendering will be coated with organic paints or coatings which form an impermeable skin over the rendering, it might be very harmful.

Rainwater can penetrate into the rendering and the wall structure through cracks in facades resulting in moisture and frost-weathering damage.

### 3.2 *Deterioration of materials*

Frost weathering due to a high moisture load is the most common reason for the deterioration of the rendering layer, especially with weak, old lime mortars. Rendering mortar is a porous material whose pore system may, depending on the conditions, hold varying amounts of water. As the water in the pore system freezes, it expands about 9 % by volume which creates hydraulic pressure in the system (Pigeon and Pleau 1995). If the level of water saturation of the system is high, the overpressure cannot escape into air-filled pores and thus damages the internal structure of the concrete resulting in its degradation.

Probably the most widely known frost damage theory is the hydraulic pressure theory by Powers published in 1948. Accordingly, damage occurs as freezing water expands creating hydraulic pressure within the pore structure of a porous material. The pressure is created when part of the water in a capillary pore freezes and expands forcing thereby the unfrozen water out of the pore. The migration of water causes localised internal tensions in the material whereby its strength may fail resulting in cracking (Powers and Brownyard 1949).

The cause of the rapid weathering is generally a damaged or non-performing structural detail or a structure connected to the rendering surface. Frost weathering is manifested as reduction in strength of the rendering, loss of adhesion, or crazing or chipping off of the surface. In Finnish climatic conditions frost weathering is the most common cause of damage.

The degree of frost weathering may vary in different parts of the wall surface - depending on, for instance, the load and variation in material properties - as well as thorough the thickness of the rendering. Weathering due to high local moisture load may affect only a very limited area. On the other hand, an improper surface treatment may result in deterioration across most of the wall surface.

### 3.3 *Defects in moisture performance*

Rendered surfaces have traditionally been painted with inorganic lime paints. These coatings are porous, allowing water and water vapour to pass through in both directions.

Organic paints form a uniform, almost impermeable skin over the rendering. In principle, impermeable surface treatment prevents rainwater from penetrating into the rendering layer. However, in practice water always migrates into the rendering layer through permeable points in the coat of paint, structural cracks, etc. The wall structure cannot dry out fast enough as a result of the impermeable coating which can lead to frost weathering. The deteriorating effect of organic facade has been widely recognised.

One function of flashings, eaves, etc. is to prevent rainwater from entering structures through seams and joints and to allow them to dry to avoid any detrimental effects of moisture within. The performance of seams and joints play a major role in the durability of the overall structure. Moreover, the performance of flashings has a major impact on how dirty the rendering gets.

## 4 REPAIR ALTERNATIVES

Selection of suitable repair alternative for each case has several demands:

- the repair must be cost effective
- aesthetic requirements
- degree of different deterioration mechanisms
- service life requirements of repair
- requirements concerning the reliability of the repair.

The following repair methods are used based on the degree and extent of the deterioration:

- light coating repair
- patching and coating repair
- rendering removal and re-rendering
- repair of entire facade, for instance, with an insulating rendering.

All the requirements of selection of repair method has not the same value. The repair methods are selected primarily on the basis of the technical condition of the structure. The one that best meets the architectural and financial criteria of the project is then selected from among those that meet the technical requirements. In figure 1 it has been shown the principles of selection of repair method.

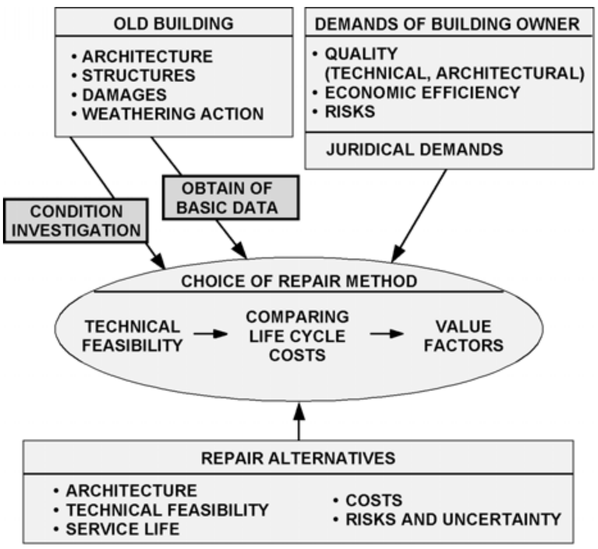


Figure 1. Different factors which has influence on decision of repair method.

The technical condition of rendering and the service life which facade has left can be found by systematic condition investigation. The information on the deterioration level of structures from a condition investigation allows the selection of appropriate repair methods and an assessment of related risks and the service life of the repair. Thus, the investigator must be highly knowledgeable about the repair methods for rendered facades and the demands on them.

## 5 SYSTEMATIC CONDITION INVESTIGATION

The object of the condition investigations of facades is to produce information for building owners and designers which can be used to evaluate the need for repair. They will also help select the most suitable repair methods.

The content of a condition investigation should be such as to allow reaching the set aims. Usually the goal is to determine the repair needs and safety of structures. This requires establishing the damage to structures as well as their performance defects. For that, the existence, extent, location, degree, cause, impacts and future progress of damage must be determined (Anon. 2002).

The content of a condition investigation is determined by the type of structure and materials used, the climatic conditions and visible deterioration as well as the set goals. Thus, the investigator should be highly knowledgeable about the performance of structures and the deterioration phenomena which affect both structures and materials.

## 6 SYSTEMATIC CONDITION INVESTIGATION

Investigation of the rendering itself is only a part of the condition investigation of facade rendering. The focuses are:

- the substrate and deterioration of the substrate
- type, strength and deterioration of rendering
- deformation, movements and cracking
- coatings
- moisture behaviour
- thermal performance
- condition and attachment of ornaments
- special issues, such as earlier repairs.

### 6.1 *Substrate and its deterioration*

The structural performance of the rendering substrate is determined during the condition investigation. Construction drawings are very helpful in determining structural performance. The materials of the substrate, their strength and attachments are also determined.

The substrate may have been damaged by, for instance, weathering and steel corrosion in addition to cracking. The condition investigation should determine the reason for, extent and degree of the deterioration. Moreover, renovation planning must also consider any possible impacts on bearing capacity, slenderness of the building structure and bending of beams from deterioration or corrosion.

### 6.2 *Type, strength and deterioration of rendering*

Determination of the strength and adhesion of rendering is an essential part of the condition investigation. The investigation of facades involves assessment of the adhesion of rendering and deterioration of different mortar layers, the degree of deterioration, and the extent and location of various types of deterioration on the facades. Large, uniform areas of loose rendering influence the selection of the type of repair. Small, solid loosened areas can in some cases be left unrepaired.

The strength of the rendering layer is more significant when coated with organic substances. Removal of the coatings requires higher strength of the rendered surface than cleaning and re-coating of facades with permeable coatings.

The condition investigation should also determine the type, materials and thicknesses of rendering layers.

### 6.3 *Deformation, movements and cracking*

The cracks visible on facades have most often been caused by uneven settling of the building foundations, loading of the building frame, or restraint actions or rendering deformations. The condition investigation must determine the reason for cracking before the type of repair is selected.


Figure 2. This kind of cracks in facade are usually a sign for uneven settling of the building foundations.

The condition investigation must also determine the extent of cracking and its impact on the selection of the type of repair and the useful life of the repairs.

### 6.4 *Coatings*

The coatings of rendered facades can be divided roughly into two groups:

- organic paints and coatings which form an impermeable skin over the rendering
- inorganic paints and coatings which do not substantially alter the moisture performance of the rendering surface.

The condition inspection determines the type and condition of the coating. As a rule, impermeable organic coatings should be removed during repairs. Certain organic coatings have contained, for instance, asbestos which means that the asbestos-content of the coating must be established.

### 6.5 *Moisture behaviour*

Old rendered facades subjected to local moisture loads will deteriorate prematurely. The moisture load on facades and their various sections are assessed in the condition investigation.

The moisture behaviour of a facade is affected by, for instance, eaves, effectiveness of rainwater drainage, joints with various structural elements, and the condition of flashings. The condition investigation evaluates the visible impacts of defects in moisture performance.

Defects in moisture performance are the most important factor causing local deterioration of rendering.

### 6.6 *Thermal performance*

The thermal performance of an external wall structure generally needs to be assessed in buildings made of thin LECA blocks or aerated concrete masonry units. It is possible to improve the energy performance of the building by, for instance, applying an insulating rendering should the existing rendering be in bad enough condition to require re-rendering to the substrate.

Old buildings with solid brick walls do not meet today's thermal insulation standards. Yet, they are not generally required to have additional insulation installed because of architectural considerations.

A condition investigation of insulating renderings should determine its the type, moisture content, the attachment method and the quality of the bond to the substrate.

### 6.7 *Condition and attachment of possible ornaments*

Sometimes a rendered facade is adorned with numerous plaster ornaments. The bonding reliability of plaster ornaments is determined during the condition investigation. Small and flat decorations usually adhere to the plaster with the help of plaster mortar. Large ornaments which protrude from the facade are mechanically fastened by, for instance, wrought iron nails and laths.

The condition investigation of plaster ornamentation should generally be conducted by an expert. Actual breakage of an ornament can easily be noticed during a general condition investigation.

### 6.8 *Special issues including earlier repairs*

Areas of earlier patch repairs of rendering are often distinguishable from the rest of the facade. Different mortars have often been used for the repair. The condition investigation should determine deterioration and adhesion to the substrate of the patching.

The timing of rendering repairs must also take into account the repair of adjoining building elements. Repairs that affect rendering repairs include window replacement and repair of balconies and eaves.

The condition investigation of a rendered facade should also evaluate the need for repair of adjoining structures – at least visually.

## 7 SAMPLE SIZE AFFECTS RELIABILITY

The condition investigation of an old structure always involves a degree of uncertainty, because it is not usually possible to investigate all facades and all structures. The information describing the condition of structures is collected as samples and the condition and properties of structures vary in different sections of the facade. Systematic condition investigation attempts to collect parallel information from as many sources as possible. This makes the evaluation of results easier and increases the reliability of conclusions.

Information on the potential problems occurring in structures and the state and progress of deterioration can be collected, for example, from the building's design documents, through visual observations on site, by various field research methods and by sampling and laboratory tests.

The deterioration mechanisms of rendered facades are generally such that a sufficiently reliable view of the condition of the facade can generally be formed by careful visual inspection and simple field research methods. Measurements requiring special equipment and laboratory testing of material samples are mainly needed in special cases.

## 8 CONCLUSIONS

The repair methods are selected primarily on the basis of the technical condition of the structure. The information on the deterioration level of structures from a condition investigation allows the selection of appropriate repair methods and an assessment of related risks and the service life of the repair. Thus, the investigator must be highly knowledgeable about the repair methods for rendered facades and the demands on them.

The large variation in the level of deterioration between different buildings, and the fact that the most significant damage is not visible until it has progressed quite far, make a thorough condition investigation necessary in most facade repair projects.

## REFERENCES


Anon. 1999: *Rendering book. Helsinki*. BY 46. 90 p. (in Finnish)

Anon. 2002: *Condition Investigation Manual for Concrete Facade Panels*. Helsinki. Concrete Association of Finland BY 42 178 p. (In Finnish)

Anon. 2005: *Rendering book 2005*. Helsinki. BY 46. 158 p. (in Finnish)

Hurme Riitta, Häyrynen Maunu, Penttala Vesa, Putkonen Lauri, Soini Eero 1991: *Concrete in Finland 1860-1960*. Jyväskylä, Suomen Betonitieto Oy. 195 p. (in Finnish)

Kuokkanen Rauno, Leiponen Kauko 1981: *History of Finnish Brick Industry*. Helsinki, Suomen Tiiliteollisuusliitto r.y. and Tiilikeskus Oy. 553 p. (in Finnish)

Lahti Matti J. 1960: *How Helsinki has been Built*. Rakentajain Kustannus Oy. 336 p. (in Finnish)

Neuvonen Petri, Mäkiö Erkki, Malinen Maarit 2002: *Multistore Apartment Buildings 1880-1940*. Helsinki, Rakennustietosäätiö RTS. 192 p. (in Finnish)

Tawast Ismo 1993: *Underpinning*. Tampere, Tampere University of Technology, Institute of Geotechnics Publication 26, Institute of Structural Engineering Publication 59. 199 p. (in Finnish)

Perander Thorborg et. al. 1985: *Mortars in Historic Buildings*. Espoo, VTT Research Reports 341. 148 p. (in Finnish)

Pigeon M. and Pleau R. 1995: *Durability of Concrete in Cold Climates*. Suffolk. E & FN Spon. 244 p.

Powers T.C. and Brownyard T.L. 1948: *Studies of the Physical Properties of Hardened Portland Cement Paste*. Bulletin 22. Portland Cement Assosiation Bulletin. Chicago. IL.