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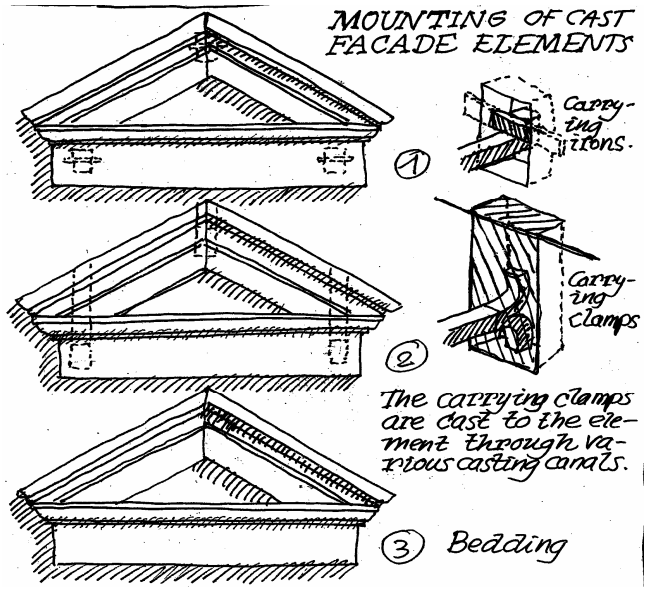
Centre for Building Preservation
RAADVAD, Denmark

CONSERVATION of PLASTER ARCHITECTURE ON FACADES - Working Techniques and Repair Methods

by Søren Vadstrup, architect MAA

Date: January 2008



European Research Project on
Plaster Architecture from the XIX and XX Century 1999-2001

In the year 1999-2000 the RAADVAD-Centre in Denmark participated in an European research project about Conservation of Plaster Architecture from the XIX and XX Century in Europe. The project was organised and co-ordinated by the 'Istituto per l'arte e il restauro' in Florence (Plazzo Spinelli) and the Partners were from Italy, Malta, England, Poland and Denmark.

The main goal of the project was to create and develop a multilingual online database of good practices for the conservation of these artefacts, both for the architectonic aspects (survey of exempla, bibliographic research on contemporary manuals periodicals archive materials, building techniques etc.) and for the conservation methods (distinguish original materials, techniques of intervention, repair methods etc.).

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The RAADVAD-Centre had the task to work especially with the working methods, crafts techniques and repair methods for the Plaster Architecture. A part of this was to produce working descriptions and drawings based on the research on the traditional materials, traditional constructions and the traditional crafts techniques – among this also the tools, helping tools and utensils for the work.

In November 2000 the results of the project were presented at a public Seminar in Palazzo Pitti in Firenze and shortly after, the Database was launched by Palazzo Spinelli at the web-site: www.plasterarc.net.

Unfortunately this Database was closed by 'Istituto per l'arte e il restauro', Palazzo Spinelli in 2008, but Centre for Building Preservation in RAADVAD in Denmark intend to continue to have it own contribution to the project at its own website: www.bygningsbevaring.dk

This is also due to the fact, that there has been great interest and use of this materials, as the Plaster Architecture are placed on a lot of buildings all over Europe from about 1840 to 1940, and a lot of these buildings and decorations, need to be repaired these years.

We hope in this way to achieve, that the exchange of knowledge and experiences in this field of architectural conservation will continue, with the RAADVAD-Centre as co-ordinating institution.

The Center has specialized in the restoration of buildings with traditional crafts, traditional materials and traditional constructions. The activities of the Center are: Research, information, education and training courses, consultants work and practical restoration work.

The research carried out for this project has implied analysis of written sources, gathering of practice experiences from concrete restoration works on plaster decorations on facades, technical experiments with materials and methods, tools and utensils.

The working descriptions aim to be a practical tool for concrete restoration- and renewal work on plaster architecture all over Europe.

The author, architect Søren Vadstrup, has been in charge of the Danish research project, and has for this purpose worked closely together with crafts firms, restoration architects, other researchers and historians.

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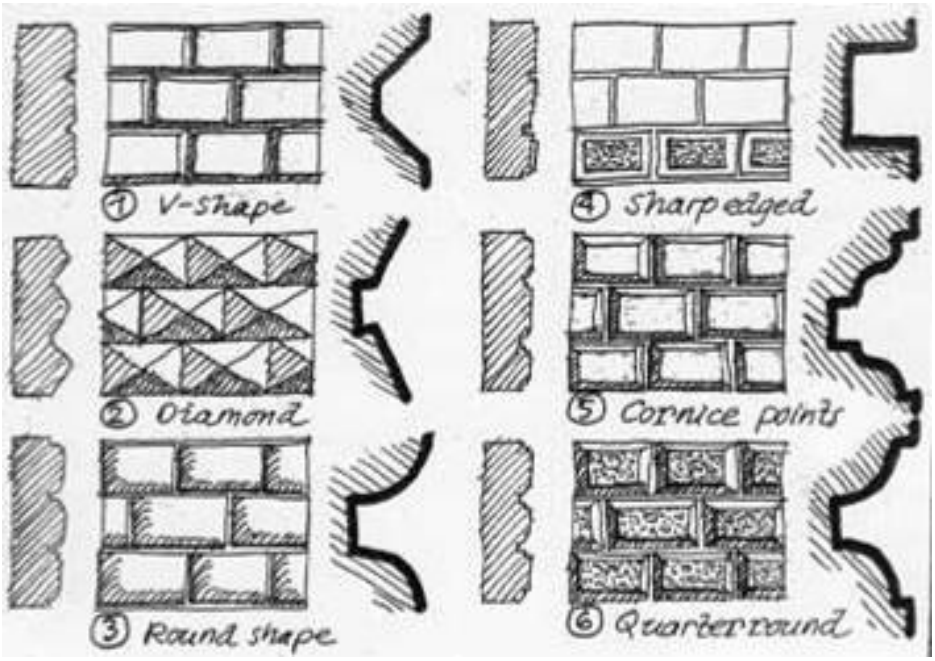

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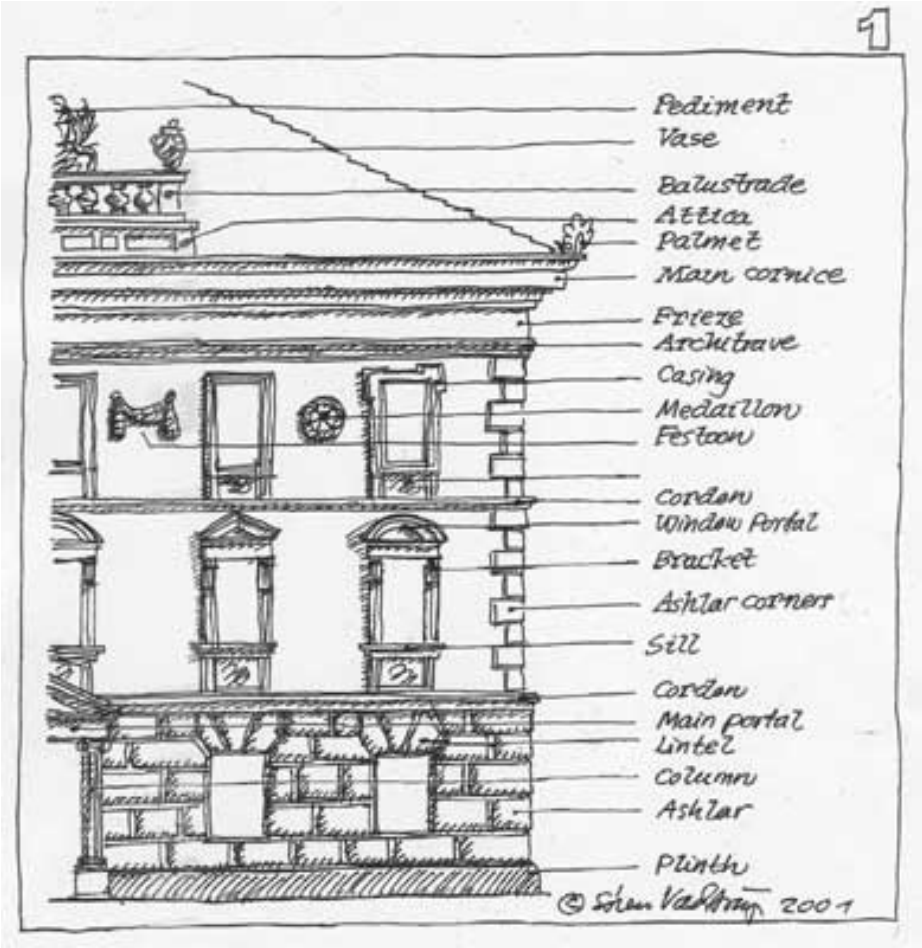
1.
Plaster decorations on facades in lime-, gypsum- and cement-mortar

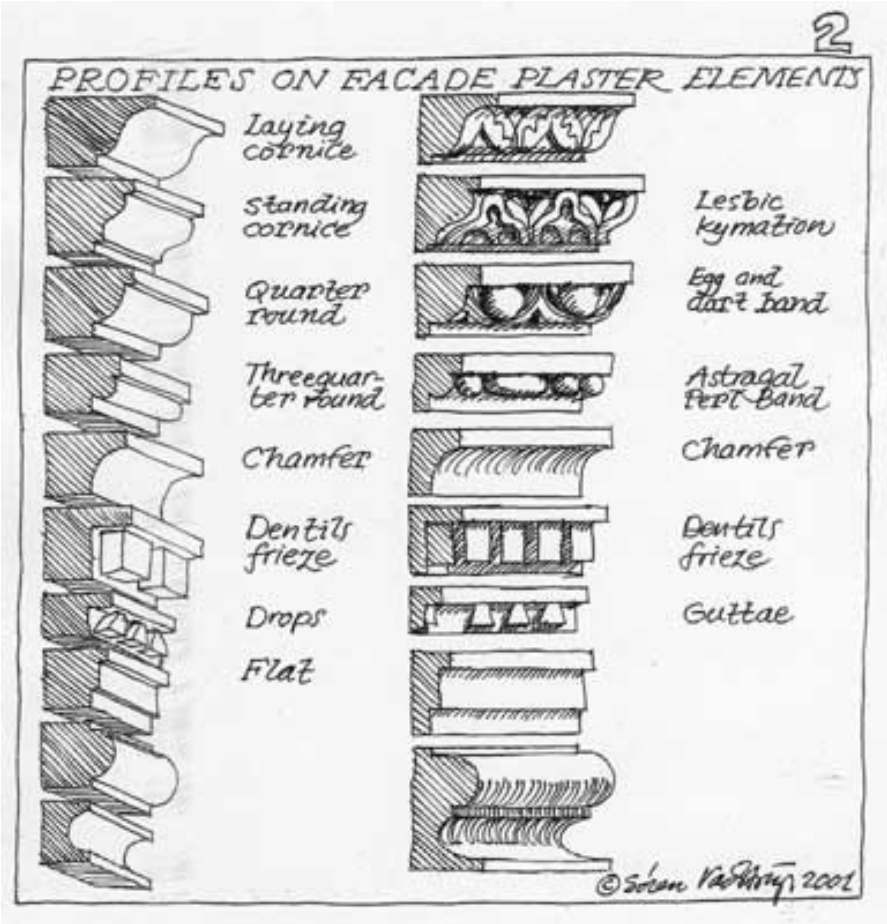
Typical elements of plaster decorations on facades



In the XIX and XX Century, it was very common to set up plaster decorations on building facades. The plaster decorations might look exactly like decorations in natural stones, but was much cheaper to produce. The primary purpose and effect of the plaster decorations is therefore to imitate and look like natural stone decorations. Drawing no. 1 shows some of these typical elements: Pediments, vases, balustrades, main cornices, friezes, casings, festoons, ashlars and stucco decorations.

Later on, from about 1870, the facades became more and more decorated and over elaborated, which lead to the original, innovative and vigorous Art Nouveau Style about 1900 - 1916. Also the successors of this style, Art Deco and Functionalism imply facades with more limited plaster decorations.

Typical mould elements



The plaster decorations very often have their ideal from antique Greek and Roman temples and architecture. Therefore they imply a number of typical mould elements from these models, elements which are also repeated in joinery, masonry, wood- and stone carving as well as interior stucco work.

The mould elements have both a simple and a more detailed shaping. The names for the elements on the antique Greek temples are often used for these common facade details.

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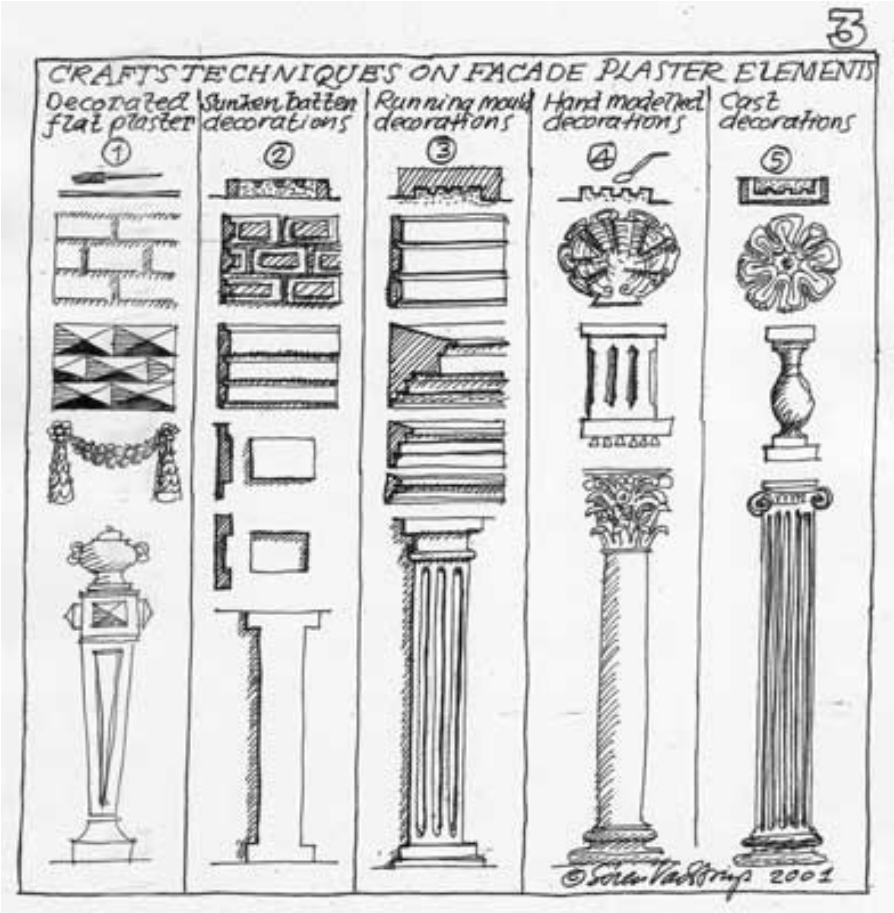
Working techniques



In the authentic plaster works on facades it is possible to distinguish between 5 various working techniques, which are further described in the next chapters.

1. Ornamented flat plaster on facades
2. Sunken batten decorations in plaster on facades
3. Running mould decorations in plaster on facades
4. In-situ modelled decorations in plaster on facades
5. Cast decorations in plaster, gypsum or cement on facades

These working methods have their own special elements and characteristics, but in certain cases the various techniques may produce the same element, for instance a half column.

2.
Materials

Air Lime

Lime is made by the burning of natural *limestone* (calcium carbonate CaCO3) in a kiln at 900-1000 Celsius. After the burning (calcining), the so called "quicklime" (CaO) is *slaked* with water to produce *lime putty* (Calcium hydroxide Ca(OH)2). The putty is then sieved to remove any unslaked lumps or extraneous materials and running into a *pit* to mature.

This *wet slaked lime putty* can be mixed with sand of different roughness/size of corns to produce *lime mortar* or -plaster, which actually is the same, but used differently. The *lime putty* can also be mixed with water 1:5 to a thin surface treatment: *Lime-wash.*
Normal lime-wash will always be white as the lime and the putty, and is therefore also called *whitewash*. If certain colours (pigments soaked in water) are added to this, you get *coloured lime-wash*, or *lime-colours*.

The hardening of the lime, both in lime-wash and in lime mortar, always is obtained through carbonation, a chemical process involving the atmospheric carbon dioxide, but also with water as an important solvent. The process forms calcium carbonate - the original limestone, firmly integrated in the building construction.

Air-lime mortar

The name *air-lime*, is due to the hardening process by the carbon dioxide from the air.
To make mortar or plaster, which actually is the same, but used differently, the above mentioned *lime putty* may be mixed with sand of different roughness/size of corns to produce *coarse mortar* or *fine mortar.*

The traditional mixing of lime mortar is *lime putty* and *sand* 1: 3 (volumes).The mixing must be done by a machine for 20-30 minutes, while adding an adequate volume of water.

The air-lime plaster has the best water-draining properties, if the stratified layers of *coarse mortar* and the *fine mortar* are added correctly. Compared with the Portland Cement (OPC), the air-lime mortar has a higher plasticity and workability. The released hydration heat is lower and develops more slowly, giving origin to less water evaporation and retraction. After having stiffened, the air-lime mortar keeps an auto-regeneration capacity for filling cracks since its carbonation by the air occurs slowly along the time.

The air-lime plaster may be used as a sacrificed layer to remove/draw out salts from the masonry. Therefore the air-lime mortar/plaster must be preferred on most repairs on old buildings - also because it's relatively weak material properties.

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Hydraulic lime

Not all limestones are "clean" calcium carbonate. Certain limestones contain "impurities", mostly clay and silica. When this "impure" limestone is burned, the clay decomposes at between 400 - 600 Celsius and combines at 950 - 1250 Celsius (the top of the burning temperatures for hydraulic lime) with some of the lime, forming silicates and aluminates, especially tricalcium silicate and dicalcium aluminates.

When the burned lime is slaked, and water is added, it immediately, and very quickly, depending of the strongness of the hydraulic effect, carbonates to a mixture of calcium carbonate and very hard cementitious materials and some clay.

This hard lime, already known and used by the Romans, and therefore later called *Roman Cement*, was also called *water lime*, according to its ability to harden only by water, and even under water. Today this lime is known as Hydraulic lime.

Hydraulic lime mortar

The hydraulic lime hardens faster and the plaster becomes often harder and stronger than the air-lime-plaster. But the water and moisture from rain or snow will remain for longer time in the masonry and plaster, which may be fatal. On certain extreme places, chimneys, plinths, windy west-gables etc., it may be appropriate to use hydraulic lime mortar/plaster.

The "classic" hydraulic lime mortar for exterior plaster is made of wet-slaked lime, hydraulic lime and gravel/sand in proportion 1:1:6 (volume measures). The hydraulic additive can be natural hydraulic lime, volcanic ash (pozzolans, trass) or finely powdered brick/roof tile dust. For more exposed areas or purposes, for instance plinths, ashlars surfaces and friezes, or repair works on 100 years old Portland Cement plaster or plaster details, a slightly harder and more resistant 1:2:9 hydraulic lime mortar is recommended.

Making hydraulic mortar by putting brick dust in air lime mortar.

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Portland cement (OPC)

The "impurities", which make the hydraulic lime carbonate very quickly can also be added in the form of *clay* to the chalk or limestone before or under the burning. This was invented in 1811 in England and, to distinguish this product from the often reddish Roman Cement, it was named "Portland Cement", from its supposed appearance and similarity to the white limestone of that name.

Not until in the late 1850s was the process for the industrial production of Portland Cement ready. The ground limestone and the clay are mixed into fine slurry with water. The mixture is fired in temperatures of 1300 - 1500 C, which is a lot higher than air lime and hydraulic lime, and the burnt lime (quicklime) and the clay unites chemically to form a clinker. After regrinding and firing, the white hot clinker powder is allowed to cool and a small amount of gypsum is added to lengthen the setting time of the Portland Cement.

From the 1860s the Portland Cement turns to be the dominant material for plaster and plaster decorations on facades. In 1891 a Danish firm, F.L.Smidth, bought the British patent and managed to spread Portland Cement plants all over the world.

Ordinary Portland Cement mortar

The Portland Cement (OPC) mortar is even stronger and harder than the hydraulic mortar - in most cases too strong and moisture absorbing for the old weakened and vulnerable masonry materials on old buildings. Even if the plaster is originally made of Portland Cement, it is recommended to use air lime mortar or hydraulic lime mortar to repair, because also the cement materials have been weakened during the years.

Most of the Plaster decorations on facades are made of Ordinary Portland Cement mortar (OPC), either as cast decorations or ashlars or etc.

Ashlars decoration made of Portland Cement mortar. The colour is light grey and the durability is very high.

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Gypsum.

Once mined from large gypsum quarries near Paris (thus the name plaster of Paris), gypsum in its natural form is calcium sulphate. When calcined (or heated), one-and-a-half water molecules are driven off, leaving a hemi-hydrate of calcium sulphate. When mixed with water, it becomes calcium sulphate again. Gypsum begins to cure as soon as it is mixed with water. It sets in minutes and completely dries in two to three weeks.

Gypsum was primary used as interior plaster, as finish coat and decorative plaster. For finish coats, gauging plaster was added to lime putty; it causes the lime to harden. Historically, gypsum made a more rigid plaster and did not require a fibrous binder.

Gypsum can also be used for cast decorations on exterior facades. For instance for bas-relief friezes, for "teeth" on dentils cornices or for other decorations. For this purpose it is necessary to paint the gypsum with linseed oil paint, as the gypsum decorations on facades needs protection from water.

Sand

The sand used in lime mortar must be totally clean from organic materials, humus, clay and salts. The two types of sand are "hill-sand" and "sea-sand" - carefully washed, dried and sieved. The grains in the sand have furthermore to be sharp and of various size - from maximum 8-10 mm to very fine sand-dust.

In order to minimize the retraction effect of new mortar, the sand should have a continuous granulometric curve, with both thin and thick grains. As mentioned above, it is also very important that the different layers/coatings of the plaster have different grain-sizes, which is decisive for the size of the pores in the mortar. The pores have to be finer and finer from the ground and out, which will lead the water in the plaster *out*. If the opposite is the case, the water will soak straight into the masonry.

Lime-water

If the well-mixed lime-putty and water (1:5) is stored for 24 hours, the undissolved lime is sinking to the ground as white sediment with some clear water above. This clear water is water saturated with lime (pure Calcium hydroxide Ca(OH)2), visible by a light shine of blue. This so called *lime-water* can be tapped and used for preparation of the ground before lime-washing or to a finishing and fixing coat on the lime-wash.

Lime-water can be coloured with lime-resistant pigments, in a ratio of 7 % vol. pigment-pasta (se beneath). This is called *lime-water-glazing*, as the colour will be slightly transparent.

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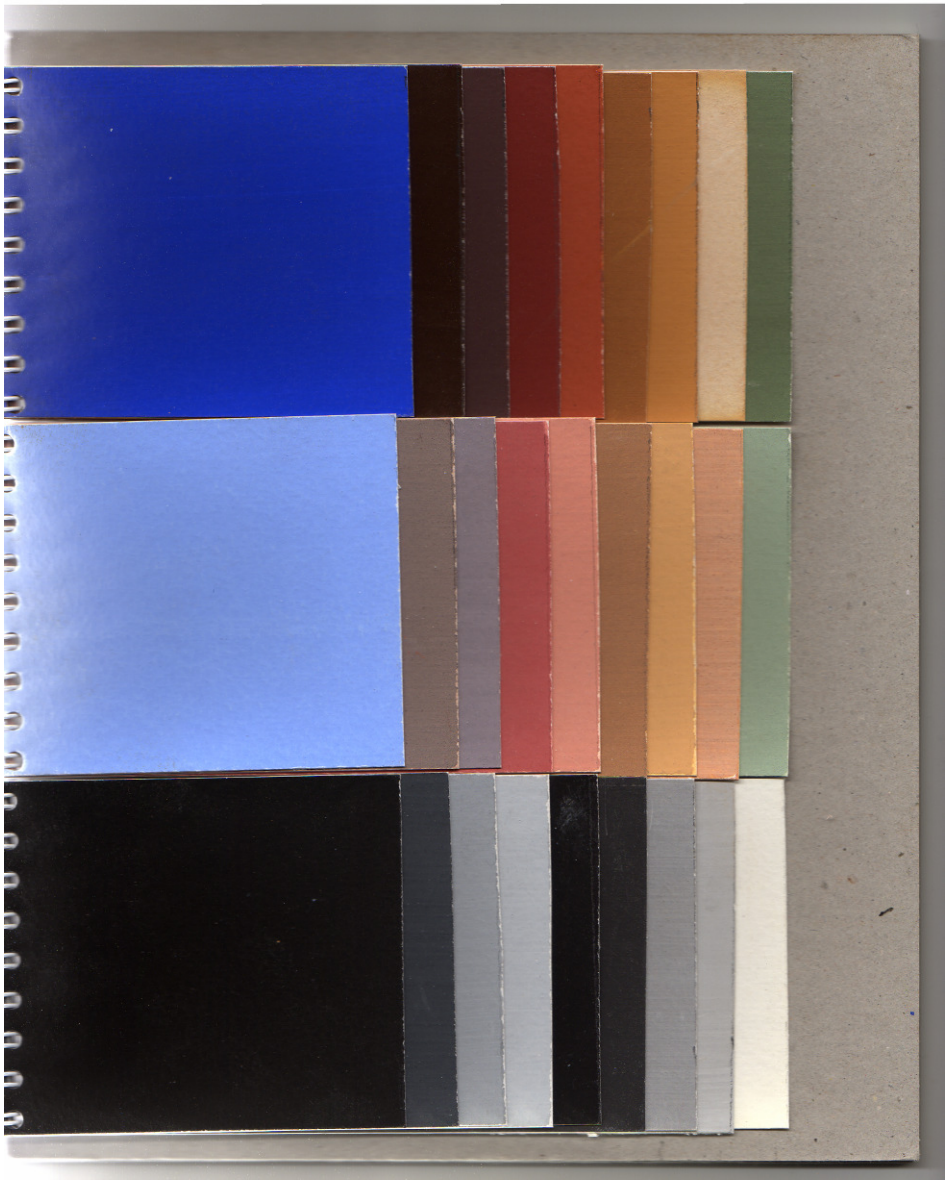
Pigments for coloured lime-wash/ lime-colours

Pigments for coloured lime-wash, also called lime-colours, shall be *lime-resistant*, which means resistant to basic/alkaline exposition. The "classic" lime-colours are therefore oxide-red, yellow-ochre, raw or burnt Terra di Siena, lampblack, raw or burnt umbra, earth-green or azurit-blue, Egyptian-blue etc. - always beautifully "whitened" by the white colour of the white-wash.



The classic pigments for façade colours.
The RAADVAD-Centre has made a sample of 27 hand painted colours in lime wash technique, which shows the correct nuance and textural effect of the colours and furthermore has a dimension of 7 x 12 cm, which makes it possible to use in practice. The samples are collected in a folder, which can be purchased at the Centre.

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Laths

Laths provided a means of holding the plaster in place if the background is very deteriorated, brittle or weak. Wooden laths are nailed at right angles directly to the structural members of the buildings (the joists and studs), or are fastened to non-structural spaced strips known as furring strips. Three types of lath can be found on historic buildings.

Wooden Laths are usually made up of narrow, strips of split willow twigs or branches with spaces in between. The plasterer applies a slight pressure to push the wet plaster through the spaces. The plaster slumps down on the inside of the wall, forming plaster "keys." These keys hold the plaster in place.

Metal laths, in form of steel net (galvanized chicken wire), need less space than wooden laths, and are often better able to hold the plaster.

Brick laths are made of steel nets with lumps of burnt clay.

The laths will often have to be combined with additional key-arrangements into the wall, small iron nails, carved holes in the backing. Furthermore the backing coat mortar can be reinforced and the adhesion improved with fibrous materials such as cow hair, sisal fibres etc.

General use of the materials on plasterworks on facades

The materials used for the plaster decorations are, as mentioned above lime-materials: Air lime mortar and hydraulic lime mortar (Roman cement). Further gypsum and lime-gypsum mortar. From about *1850*, when the Portland Cement was industrially produced, the "cement-mortar" became the dominant material.

The appearance of the Portland Cement enabled among other things the introduction of the small or larger cast *balcony* at the facade, which was a very popular element. As balcony balustrade, wrought or cast iron was very often used. The general rule is that:

Decorated flat plaster is made of air lime mortar or natural hydraulic lime mortar.

Sunken batten decorations are made of natural hydraulic lime mortar or Portland cement mortar. Present repairs must use hydraulic lime mortar.

Running mould decorations are mainly made of air lime mortar or hydraulic lime mortar, more seldom Portland cement mortar.

In-situ modelled decorations are always made of air lime mortar or hydraulic lime mortar.

Cast decorations on facades are either made of gypsum or Portland cement mortar.

The gypsum decorations are mainly made as quite flat relief, or placed protected from water under large a main cornice. It is very important that the cast gypsum decorations on facades are surface treated and protected by a layer of linseed oil paint.

The plaster decorations on facades are furthermore very often combined with other materials, bronze, cupper, wrought or cast iron, tile, wood or natural stone.

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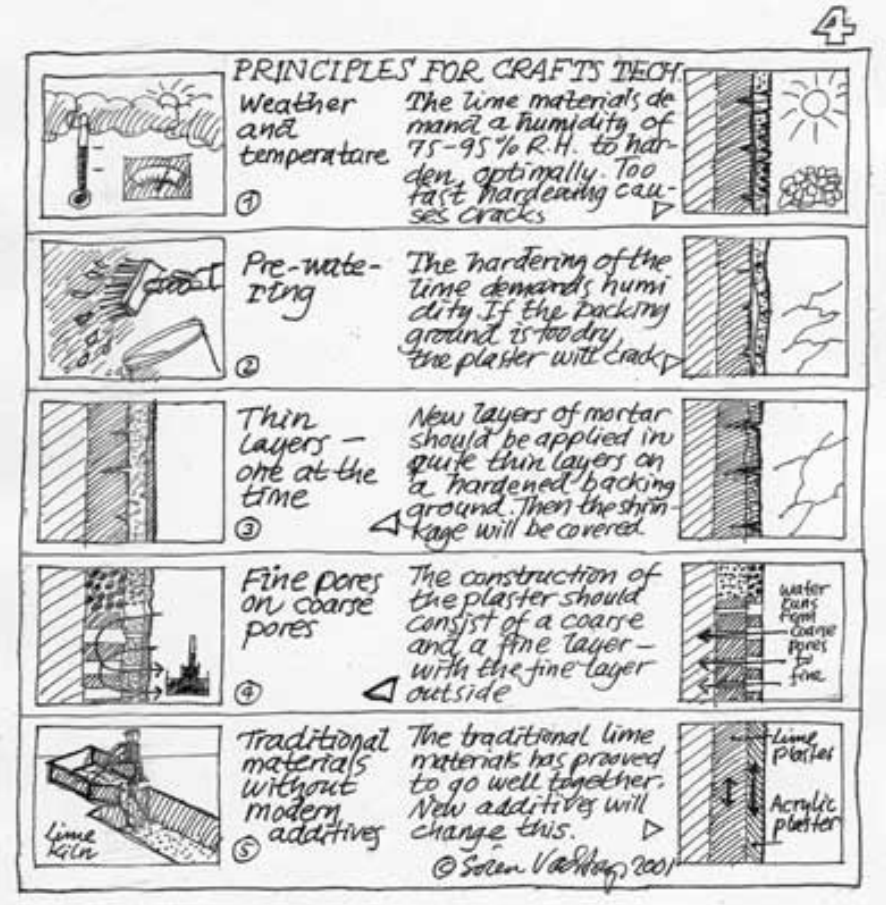
3.
General principles for the crafts techniques



Demands on weather and temperature
Lime mortar-repairs must under ideal circumstances take place during a relative humidity in the air at 75-95 %. The temperature should be minimum +5 Celsius and maximum +18-20 Celsius. A total absence of sun and wind is also recommendable. These circumstances, moisture, low temperature and no sun, promote a slow-acting carbonating and hardening of the mortar, which is necessary for an optimal binding of the mortar to the ground and prevention of small (crocodile-skin) shrink cracks of the surface.

Watering the ground
Before adding new plaster, the masonry has to be watered carefully with plain tap-water. The carbonating and hardening of the mortar needs, besides CO2 from the air, also water. If the ground is too dry, the binding of the mortar to the ground will take place too fast, which will cause a poor fixing of the mortar and often larger shrink cracks of the surface.

Thin layers on hardened ground
Layers of mortar should always be applied in a fairly thin layer - and always on a backing layer which has had time to carbonate. By this procedure, the inevitable shrinking cracks in all lime- and cement mortars will be covered by a new thin layer of mortar, with less

shrinkage. If the layers are too thick or the ground is not fully carbonated before new layers are added, this on the contrary will cause large shrinking cracks in the surface.

That is why the running moulds in the drawings and descriptions in this material are prescribed made in two sizes - a smaller mould size for the backing coats, to allow these layers to harden, including shrinkage, and a larger and true size mould, for the last coat.

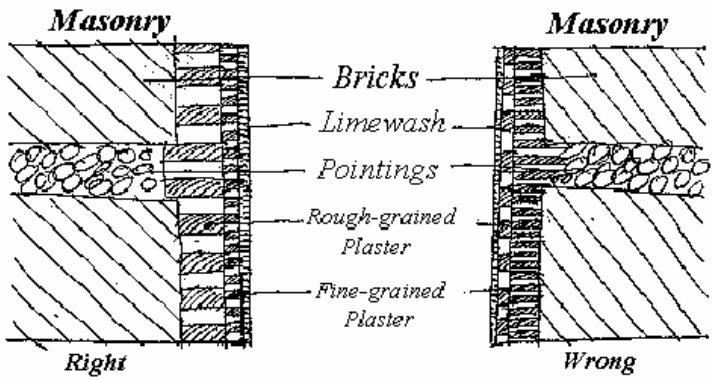
Fine pores on larger pores

Layers of mortar shall always be made in three coatings or layers:

1 A thin, rough backing coat of hydraulic lime-mortar with quite coarse sand, *thrown* on the masonry, keeping a fairly rough surface. This layer should harden 2-3 days.
2 A 2-3 cm thick second coat of coarse mortar, drawn to an even layer and after that allowed hardening for one week.
3 A 1 cm thick finishing layer with fine grained sand, thrown on and scoured to an even coating.

As water inevitably moves from larger pores to smaller, a construction with fine pores on larger pores from the inside and out ensures that intruding water will move out again relatively fast.

The thickness of the rough, first layer must not be more than 2 cm, as thicker layers will cause internal pressure between the interior areas and the area more exposed to the weather conditions, where the water evaporation and the quick cooling of the mortar occurs. This effect favours the retraction effect which often causes cracks in the surface.



An example of this physical balance on traditional building-constructions is the micro-construction of plaster on masonry, which, due to the capillarity of the water, must have increasingly finer pores from the inside and out, just like the lime mortar correctly prepared by the experienced craftsman has - often furthermore finished by the fine-grained lime wash. If you change this clever and natural micro-construction of lime mortar, for instance by adding a tight layer of plastic paint, the natural balance will disappear and damages break out.

Traditional materials - without modern additives

It is important to use the traditional materials as original and pure as possible. Remember, that the now deteriorated old lime materials have often lasted for 200-250 years. No modern additives, such as acrylates, casein, resins have yet proved to last more than 25 years.

4.
Decorated flat plaster on facades

Variations - surfaces and decorations

Flat plaster surface on facades is seldom just flat plaster. The deliberate choice of gravel and sand for the mortar influences on the colour and texture of the finished plaster. This "natural coloured" plaster can be brown, grey, brown-grey, brownish, yellowish, reddish - as the gravel material itself.

The next decorating step is to colour the mortar with pigments. This enables the plaster to be yellow, red, red-brown, green, black-grey and white.

The third step is to give the plaster a surface treatment of colours, made by paint or lime wash all over the surface. But this material can also manifest itself in artistic decorations in lime technique (al secco) or in linseed oil technique.

More sophisticated decorations can however be achieved by decorating the flat /plaster itself, by 5 various techniques:

1 Scratched stucco-decoration
2 Protruding pointings
3 Inlay/intarsia plasters decorations
4 Sgrafitto decorations
5 Al fresco decorations

Materials

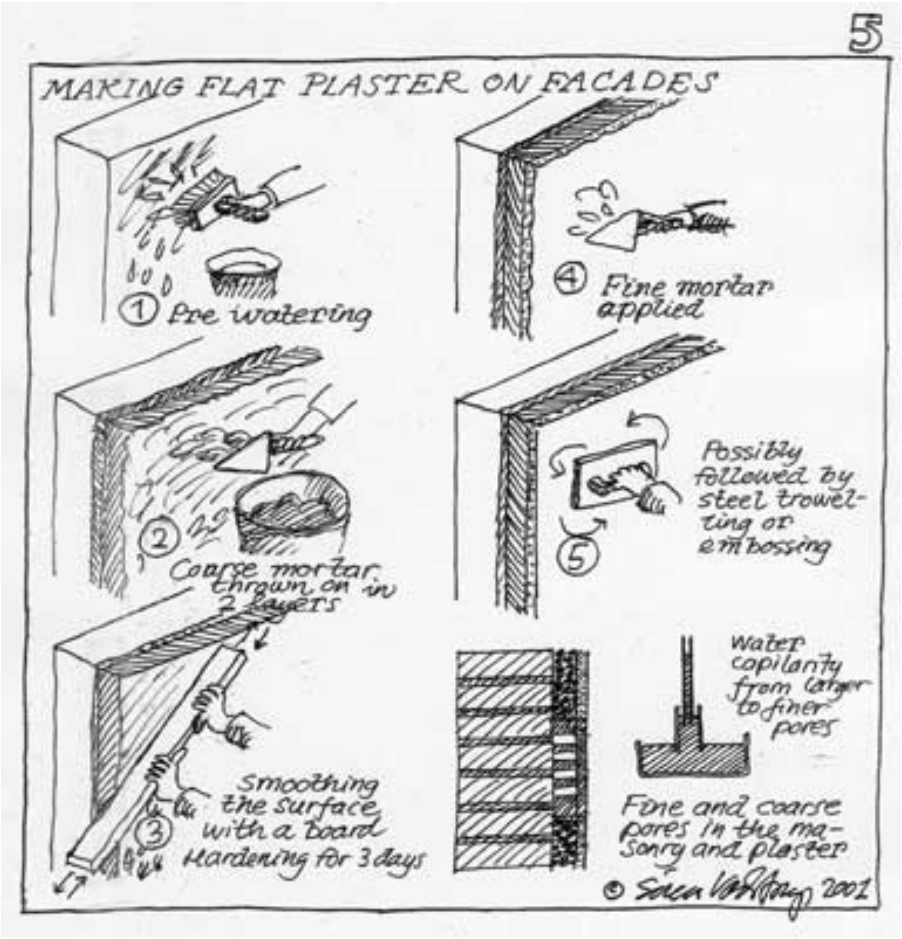
The materials for these techniques are mainly wet slaked air lime mortar (air lime and gravel 1:3) or hydraulic mortar (air lime, hydraulic lime and gravel 1:1:6). Portland Cement mortar will tend be a too hard and stiff material for this purpose.

To obtain and ensure a sufficient flexible and workable mortar, the wet slaked lime has to be matured for at least 3 years in a frost free lime kiln, very fine grained and without any sort of dirt or impurity.

Also the gravel and sand has to be carefully selected, sieved, washed and without any impurities.

Even the water must be very clean and without any salts etc. Best is distilled water, so in previous times, the masons gathered rainwater in special wooden barrels. The same is recommended to day. Air lime mortar, made with use of rain water, carbonate even more slowly, and could therefore be worked in with sgrafitto, intarsia and alfresco for a longer period.

Making flat plaster



Flat plaster has to be made in three coatings or layers as shown on drawing no. 5:

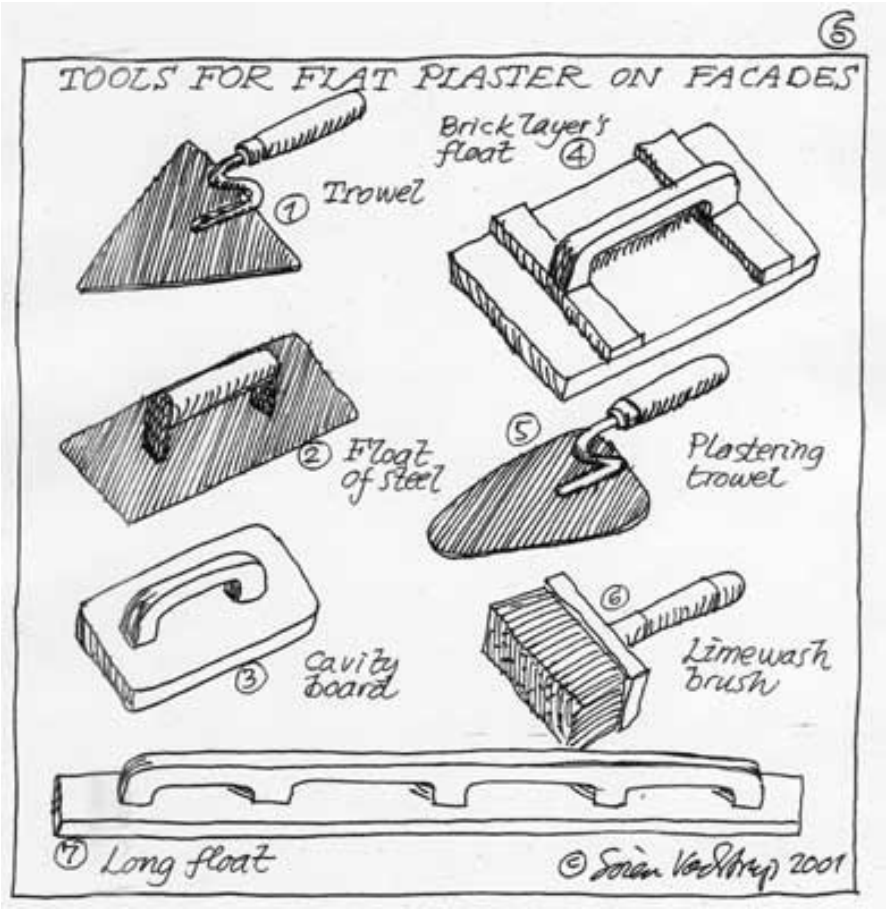
1 A thin, rough backing coat of hydraulic lime-mortar with quite coarse sand, *thrown* on the masonry, keeping a fairly rough surface. This layer should harden 2-3 days.

2 A 2-3 cm thick second coat of coarse mortar, drawn to an even layer and after that allowed hardening for one week.

3 A 1cm thick finishing layer with fine grained sand, thrown on and scoured to an even coating.

As water inevitably moves from larger pores to smaller, a construction with fine pores on larger pores from the inside and out ensures that intruding water will move out again relatively fast.

Tools and utensils



The tools and utensils for the flat plaster are shown on *drawing no. 6* and for the flat plaster decorations on *drawing no. 7*. The latter are various scraping irons, special spoons and awls etc. It is important to be very choosey and specialized in selecting the tools - not just to choose the first you come across.

To the utensils belong various fillets, a drawing, impregnated with shell-lacquer, and provided with a lot of holes along the lines of the figures. A so called *ponse*, which is used for transferring the drawing to the plaster-ground.

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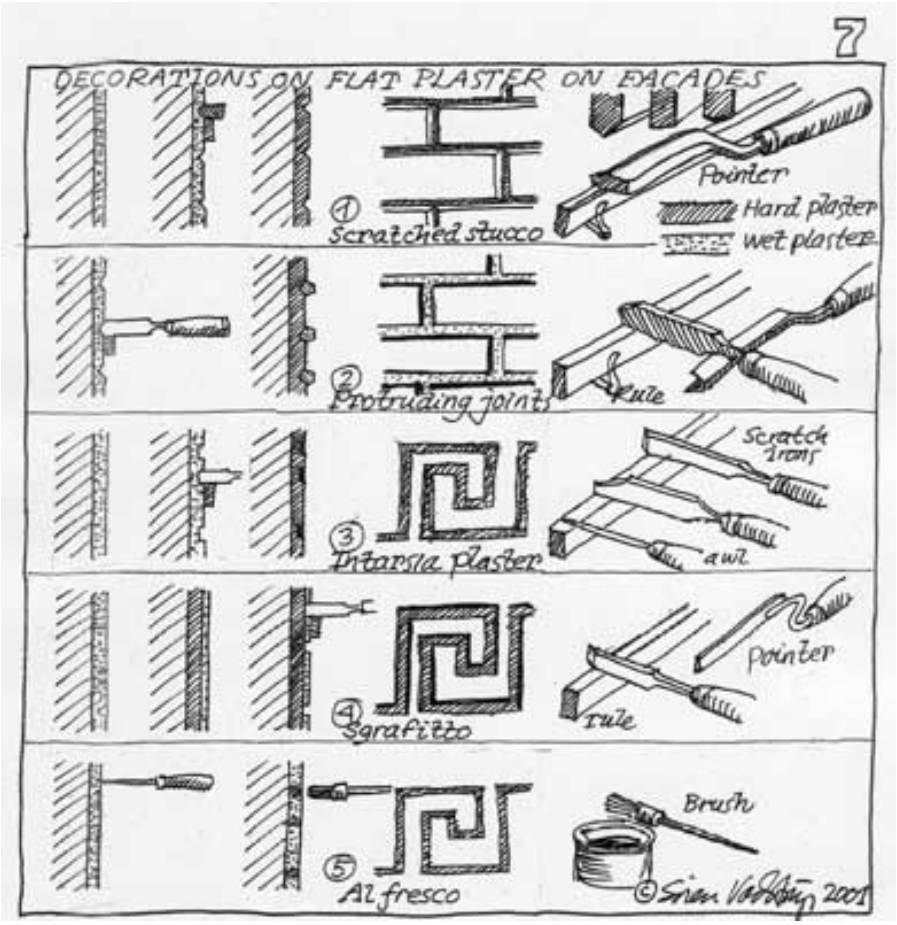
Making scratched stucco-decorations



Scratched stucco pointing, also called "the poor mans ashlars" is made in the still wet third layer - after the scouring of the surface. The geometry of the decoration is drawn with an awl by "light hand". Resting on a wooden list or lath, held by one hand, a special mason's drag forms a sharp "pointing" imprint in the wet mortar. The pointing is usually a V-shape, but can also have a square cross section.

Making protruding pointings

Protruding pointings are also made in the still wet third layer of a flat plaster coat. Here the geometry figures are scratched with a special iron, held perpendicularly to the surface and making a slight uneven V-trace, 5- 6 millimetres deep.

After the plaster has hardened for a week, the protruding joints are added in hydraulic lime mortar (1:2:9) with a special shaped pointing-iron/jointer. The tool is mainly drawn by hand, resting on a horizontal wooden float, where a pile of mortar is placed. The consistency of the mortar has to be very precise, both to achieve straight, precise and sharp-angled pointing and to avoid stains or patches from the mortar on the rest of the plaster surfaces.

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Making inlay/intarsia plaster decorations

Inlay/intarsia plaster decorations are also made in the still wet third layer of a flat plaster coat. The name means "inlay" in Italian, and in this technique specially coloured mortar is inlayed, in scratched grooves in the fresh mortar.

The decoration is drawn on the surface in free hand with an awl or the decoration is transferred to the surface from a drawing via a *ponse* - a shell lacquer impregnated cardboard, provided with a lot of awl holes along the outlines of the drawing. With a little un-tight linen bag (*ponse bag)*, filled with charcoal-dust, the black powder is sprinkled over the *ponse* to mark the outline of the decoration at the wall through the pricked holes in the paper (See drawing no. 21).

Another method to transfer the decoration to the wall is to make an overlay drawing, a so called *calque,* on a piece of paper, from which it is possible to scratch or trace the contours of the ornament with a metal pin, through the paper.

After this the composition is scratched in the wet mortar with a special iron, held perpendicular on the surface, but this time making an even and square groove, 5- 6 millimetres in the surface.

Still while the mortar is wet - that means during the same day, the groove is filled carefully with a specially prepared coloured air lime mortar, quite "dry" in the consistency, but applied "wet-in-wet". The mortar must be prepared of wet slaked air lime and very fine sand (0-4 mm) 1:3. The tool for this work is a spatula or a palette knife.

After filling the groove with coloured mortar, the surplus mortar is cut away with a knife, so that the surface is exactly at the same level as the plaster-surface. The surface is furthermore smoothed and straightened with a spatula.

Making sgrafitto decorations

Sgrafitto means scratching or scraping in Italian - and that is what the process is about. In sgrafitto the hardened but well pre-watered second layer of rough plaster surface is applied a 2 cm thick layer of a strongly dark coloured lime mortar. The colours can be charcoal or lampblack, used directly as filler-material in the 1:3 air lime mortar.

While this layer, which is smoothened with a wooden float, is still wet, a new 3-8 millimetres thick layer of white or bright coloured air lime mortar is added. The pigments can be ground chalk, whiting or zinc-dioxide. The sand and the chalk have to be delicately fine grained, to ensure that the surface can be glazed very smooth and even.

Again the geometry or composition of the decoration can be transferred to the still wet surface by free hand, with a *ponse-drawing,* or with a *calque.*

Still while the mortar is wet, all the edges of the figure are cut free with a knife or a spatula. It is important, that the cutting edge forms an oblique angle, both to obtain the sharpest possible outlines and to keep the rain water from intruding the mortar layers. After this the rest of the mortar between the lines is scratched away with special tools.

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By this process the dark/black under-mortar is detached and visible as black/dark drawings or figures in the white surface-layer, with a slightly relief-effect as an additional decoration.

More advanced sgrafitto-decorations can be made of up till 4-5 thin layers of mortar in various colours, but the main technique is made of one dark and one light layer.

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Making al fresco plaster decorations

The last decoration technique on flat plaster to be mentioned here is al fresco plaster. Again the name is Italian and means "In the fresh (wet) mortar". Even on exterior facades, al fresco decorations has a quite good durability, but will often be placed under a large eaves or half roof for protecting reasons.

The construction of the backing ground for the al fresco is made as described under flat plaster (Drawing no. 5). But instead of three layers, the ground is built up with 5 to 6 very thin layers (3-4 millimetres), with finer and finer sand - ending with fine grained marble dust in the last layer. In this decoration technique the layers must not carbonate, but on the contrary have to be applied "wet-in-wet", in one continuous process. To prevent shrinkage cracks, the layers are beaten hard with a wooden board or the like, to make the plaster as tight and firm as possible. Even though it is necessary to scratch the surface slightly with a comb, before applying the next layer, to improve the adherence.

The colours for the mural paintings are made of lime water, mixed with fast pigments and stored for 24 hours, to be totally soaked.

Again the figure or geometry of the decoration has to be drawn on the wall or transferred very quickly to the finishing coat of very fine mortar, with a *ponse* or a *calque,* and then, continuously at this point, the fresco painting is made as quickly as possible on the still wet mortar. Here no mistakes or regrets are allowed, as the lime colours intrude into the mortar surface and fix immediately.

It is only possible to make a painting as large as the prepared mortar ground - a so called "day's work", but on the other hand it is not possible to continue the next day on the "old" mortar layers from the day before. They have to be pulled down and new ones constructed again all from the very start.

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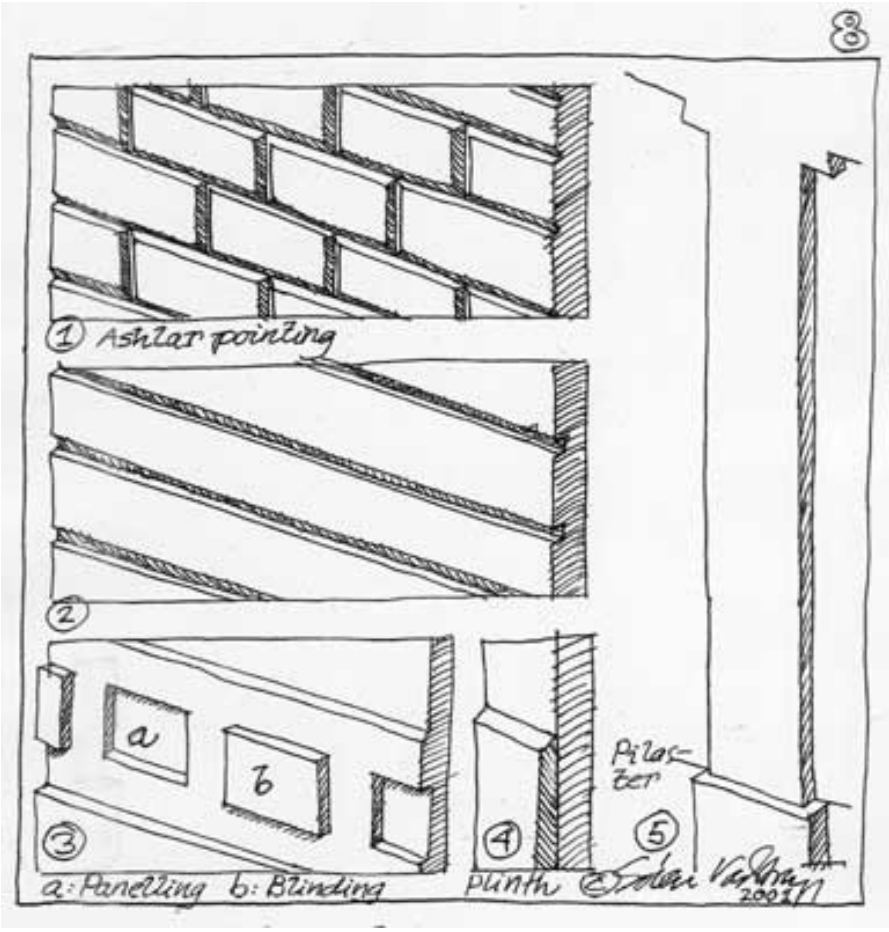
5.
Sunken batten decorations in plaster on facades

Stucco, ashlars and imitated/artificial stone on facades can be made in several ways, but the sunken batten technique, which is described here, is definitely the masons' work, while the technique of making ashlars with running moulds is mainly carried out by the stucco workers - sometimes by the masons.

Sunken batten decorations is made of specially formed battens, which make a reverse imprint in the wet mortar, and by this, when the battens are removed again, imitating pointings or forming edges of natural stone work.



Drawing no.8 shows the different varieties of sunken batten decorations. Most common are ashlars decorations, but also other possibilities are indicated. Ashlars can have various appearances, as shown on *drawing no.11*, both regarding the relief in the pointing grooves and the character and structure of the surface.

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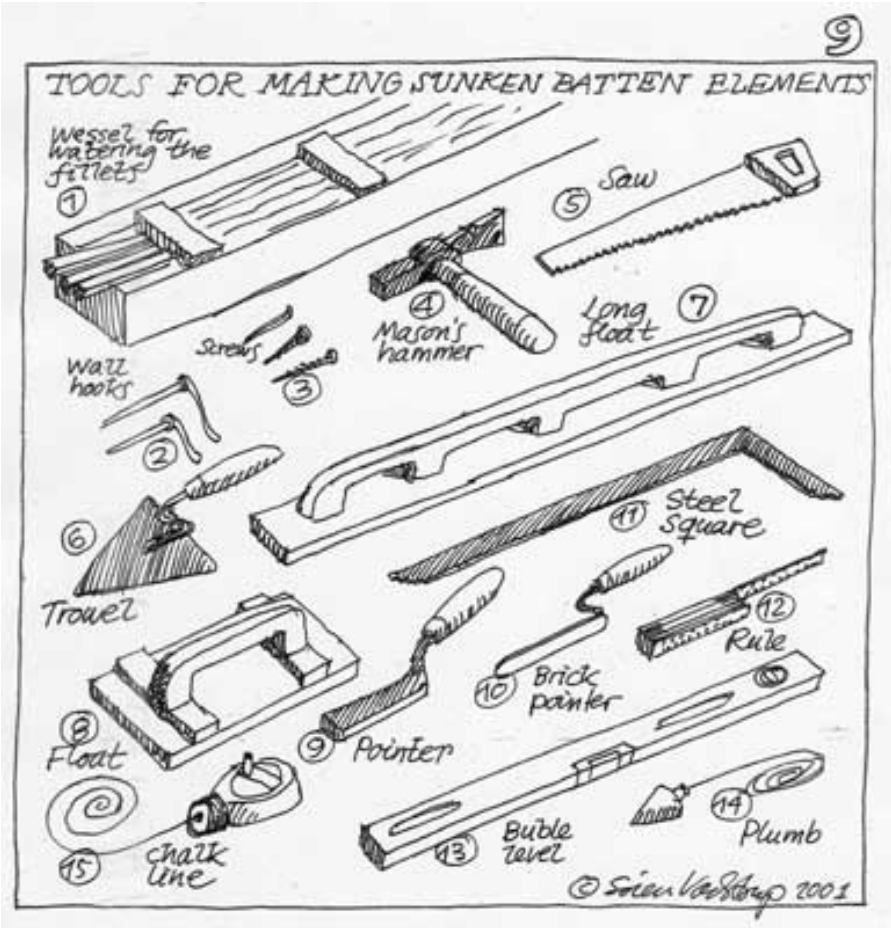
Tools and utensils

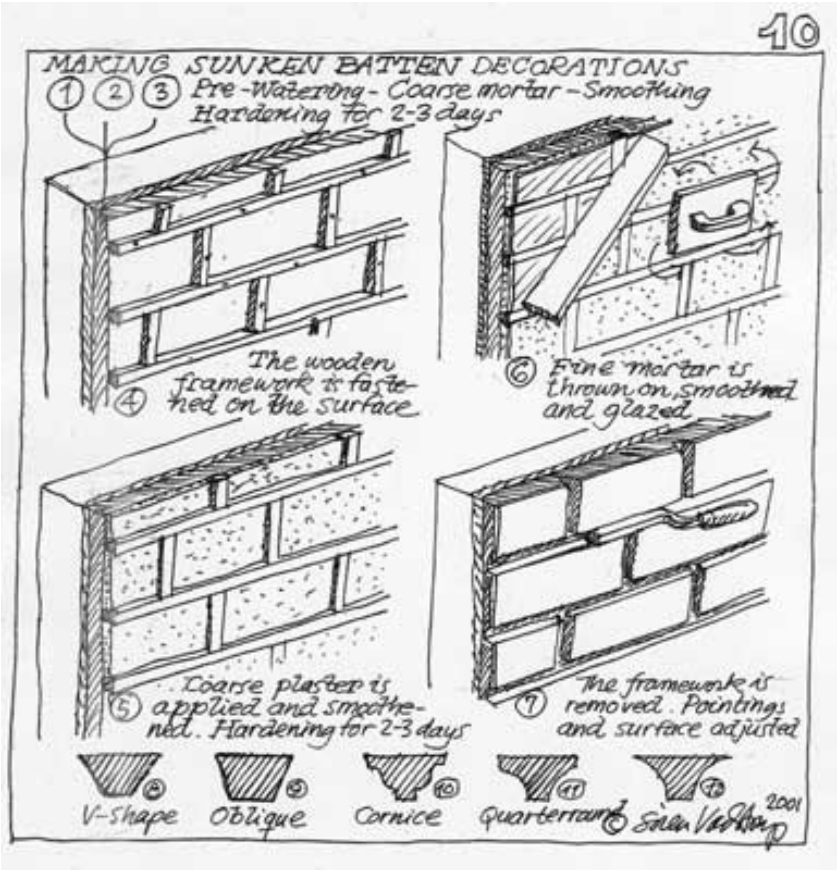


The various tools, both for carrying out the ashlars and for the surface treatment, are shown on *drawings no. 9 and 10*.

Materials

The materials are hydraulic lime mortar and on buildings after 1860 often Portland Cement mortar. To day we recommend hydraulic lime mortar (1:2:9) both for making new ashlars and for the repair of old decorations, because the old remaining cement materials are now so weakened that insertions with new, modern cement mortar will cause problems.

Making sunken batten decorations



The backing coat for the sunken batten plaster decoration has to be 2 layers of rough mortar, thrown on the well watered masonry, smoothened and after this hardened for 2-3 days or a whole week.

A lot of battens are planed to obtain the right shape for the reverse imprint of the pointing grooves. After this the battens are soaked, totally sunken in water, for a couple of days. The shrinkage of the wooden battens after the hardening of the mortar and the drying of the wood makes it possible to remove the battens again without spoiling the edges of the pointing. In addition the battens must have a conical and chamfer shape.

When the backing is ready, the battens are placed and fixed to the facade, in the wished pattern (*Drawing no. 10)*. After a thorough watering of the backing coat, a layer of rough hydraulic lime mortar is thrown on the surface and smoothened, approximately 1 cm under the outer level of the battens.

After hardening a week the ground is thoroughly watered and a finishing layer of fine grained (0-4 mm sand) hydraulic lime mortar is thrown on. Now the surface is smoothened and glazed very carefully, to the same level as the outer level of the battens.

While the mortar still is wet, and the battens still at their place, the desired surface structure is carried out, except the stone carved surface (Drawing no.12, figure 5).

After a week hardening the wooden skeleton is removed very carefully, in order not to destroy the edges of the pointing profiles. The screw holes, possible missing parts or air holes are repaired immediately, if necessary with a special shaped jointer.

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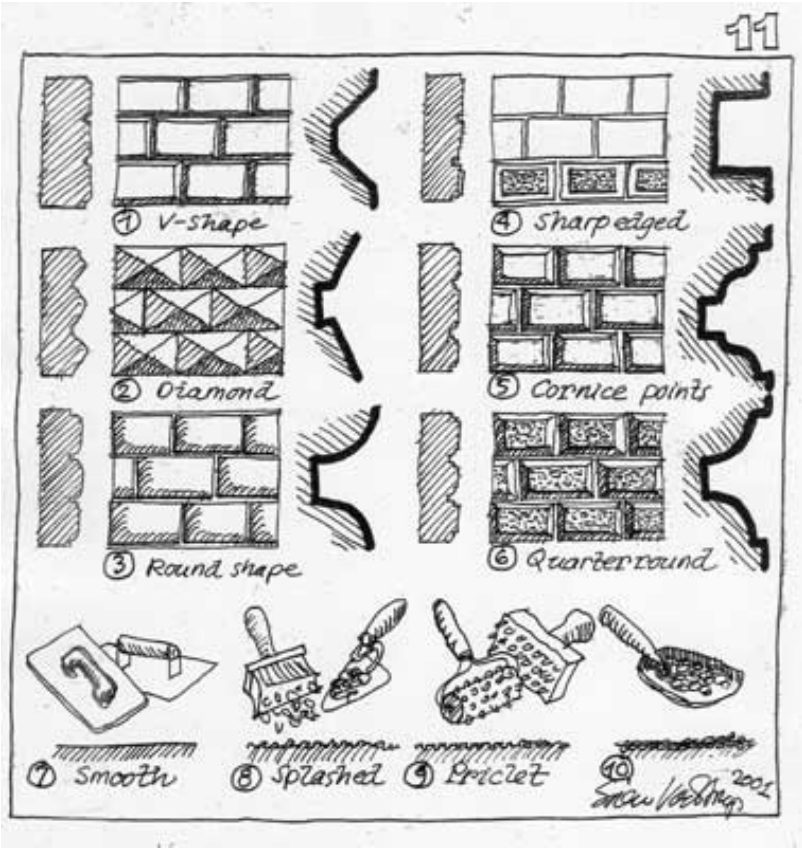
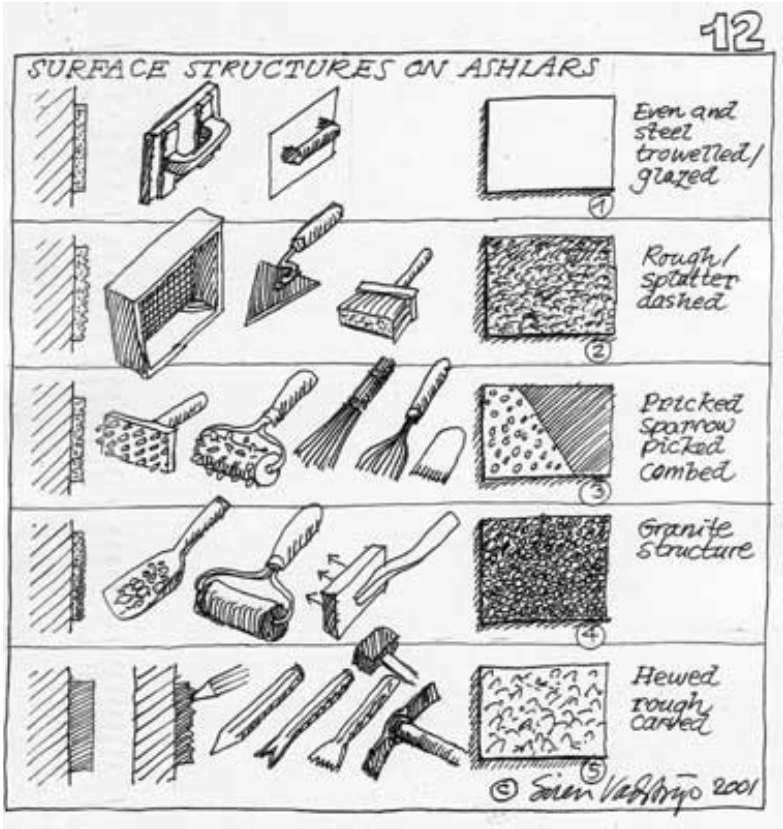
Surfaces structures on ashlars





Surfaces structures on ashlars:

1 ***Glazed or polished surfaces*** are made by a smooth wooden float and a metal board.
2 ***Splatter dashed surfaces*** are made of a relatively rough lime mortar, thrown on the surface through a rough sieve. In order to appear as natural as possible, the mortar ought not be adjusted after the application.
3 ***Sparrow picked or combed/brushed surfaces*** are made with special tools as shown on the drawing, while the surface mortar is still wet. The comb or besom is often drawn slantingly.
4 ***Granite gravel surfaces*** are made of selected granite gravel, either rough cut and sharp rubble or small round gravel, which is thrown at the wet mortar or pressed or pushed in place. To fix the gravel, it is furthermore pressed in the ground by a roll or a wooden beater.
5 ***Rough carved surfaces*** are made by leaving the surface 2-3 cm higher than normal. After one week of hardening the surface is carved with stone carving tools: Flat chisel, tooth chisel, point chisel, flat hoe and tooth hoe, for different surfaces.

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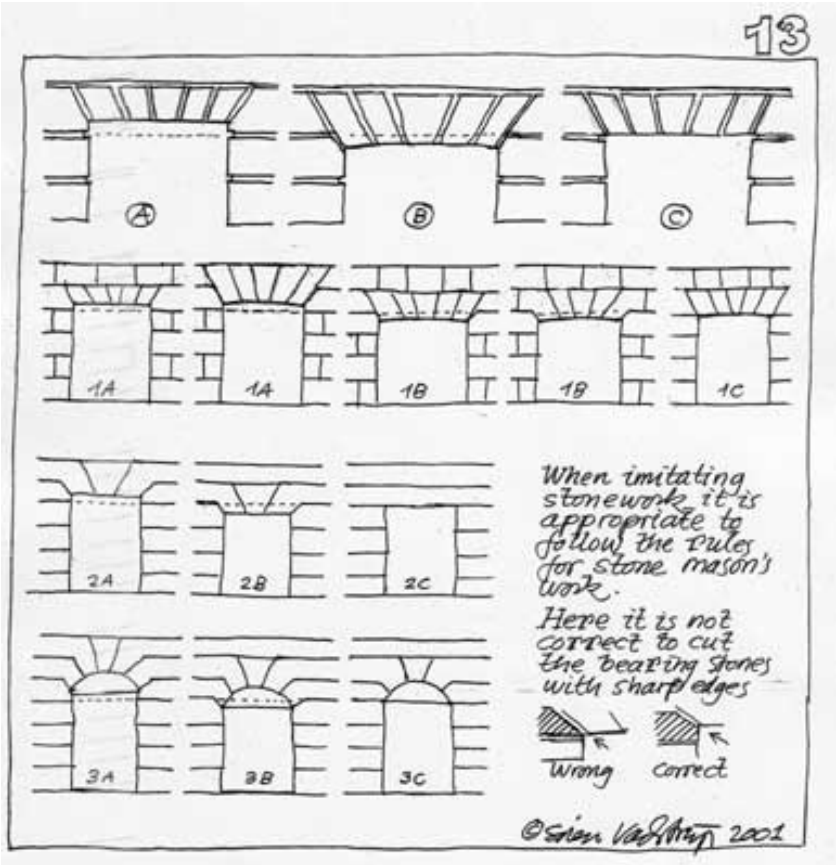
Lintel-constructions

The lintel-constructions are an important element of ashlars decorations on facades in connection with holes for windows and doors. The lintel can be horizontal or curved/bowed.

In the first place it is important that the horizontal lintels are not made totally straight, but constructed with a very small bow upwards, only 1 cm, because if not, they will seem to be "hanging".

Secondly, when imitating stone work, it is necessary to think and to "copy" how a stone mason would construct the same detail in real stone. To be able to receive the pressure from the load, the corner stones are cut without sharp edges, which tend to break off. Therefore the upper edges of the window- and door holes are often raised or lowered approximately 5 cm in proportion to the horizontal joints - to prevent sharp and therefore weak edges at the particularly loaded bedding stones in the upper corners.

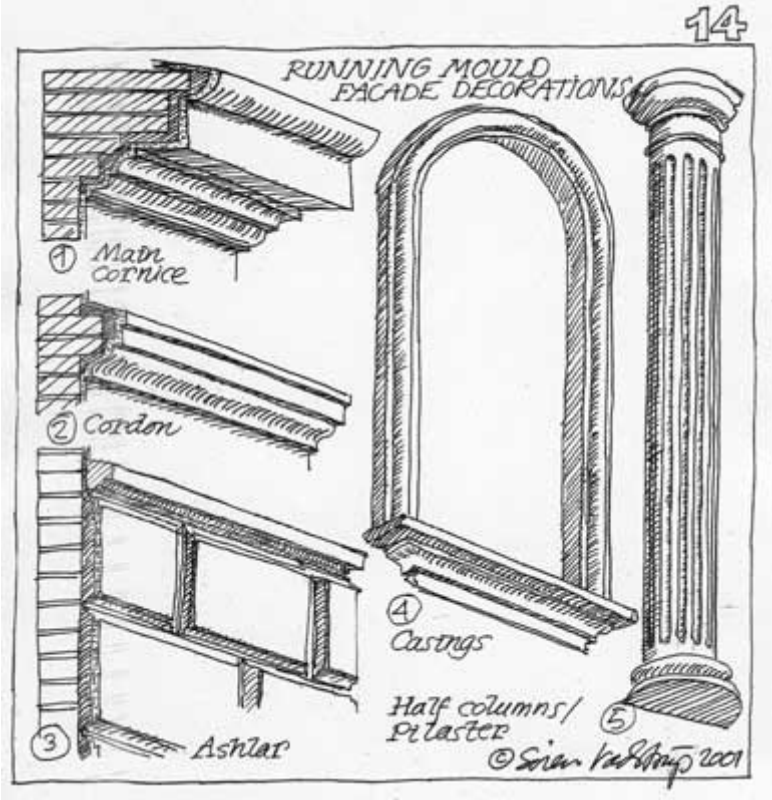


This gives some varieties in the design, depending of the highs of the lintel stones as shown on *drawing no. 13*.

If existing ashlars does not have these details, it must not be changed, but kept exactly as it is now. Many lintels on existing old buildings are made in level with the horizontal joints. But the right way to construct this detail is to imitate, not only the external likeness, but also the stonemasons craftsmanship and natural and functional constructions.

6.
Running mould decorations in plaster on facades

The main cornices, the architrave and horizontal friezes, the window- and door casings and possible half columns are typically made by running mould. But also ashlars can be constructed this way.



Materials
Running mould decorations on facades are constructed of air lime mortar or hydraulic lime mortar. After 1860 also Portland cement mortar is used.

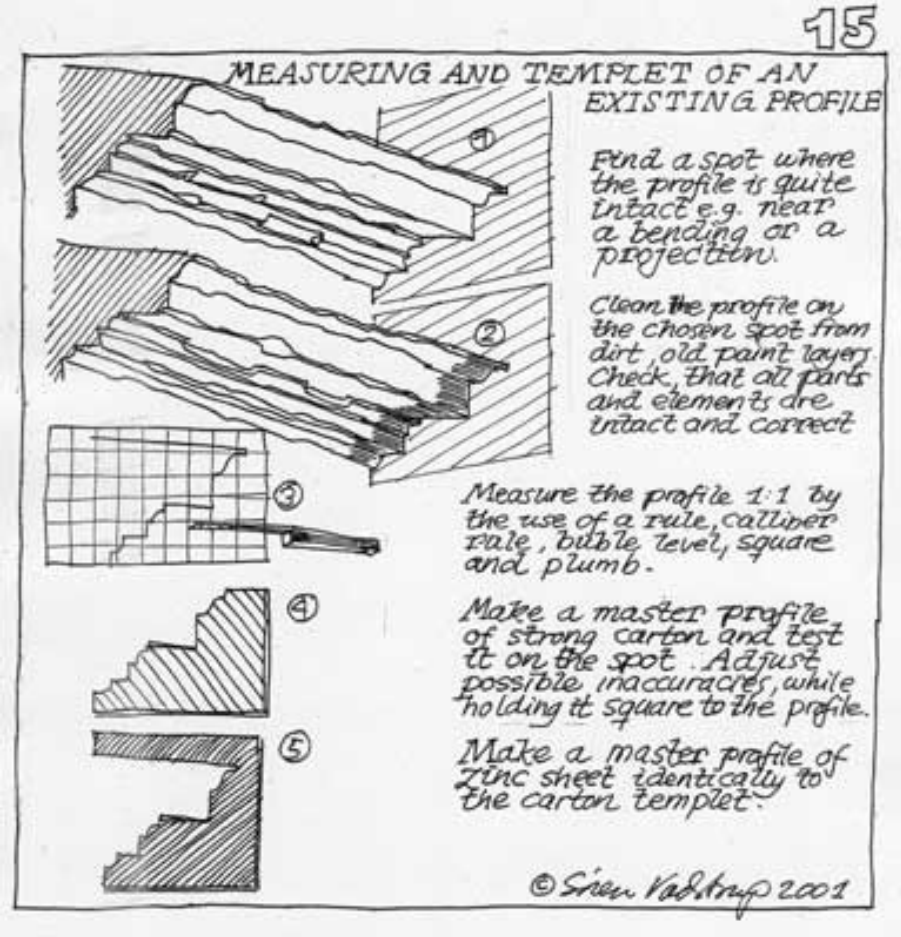
To day we recommend the use of air lime mortar (1:3) or hydraulic lime mortar (1:1:6 or 2:1:9) both for making new Running mould decorations and for the repair of old decorations, even if they are originally made of cement. The old remaining cement materials are right now so weakened that insertions with new, modern cement mortar is not appropriate.

Tools and utensils
Running mould are made by a sheet zinc mould, mounted on a wooden sledge, which is able to "Running" or glide along the facade, via horizontal or vertical rails and guides, fixed to the facade. Furthermore special trowels and boards are necessary.

Making Running mould main cornices and friezes

At first it is necessary to make an exact drawing 1:1 of the profile or mould of the cornice or frieze. If an existing cornice is repaired or replaced, the old and original profile must be painstakingly measured and recorded - on a place, where the profile is best preserved and correct.

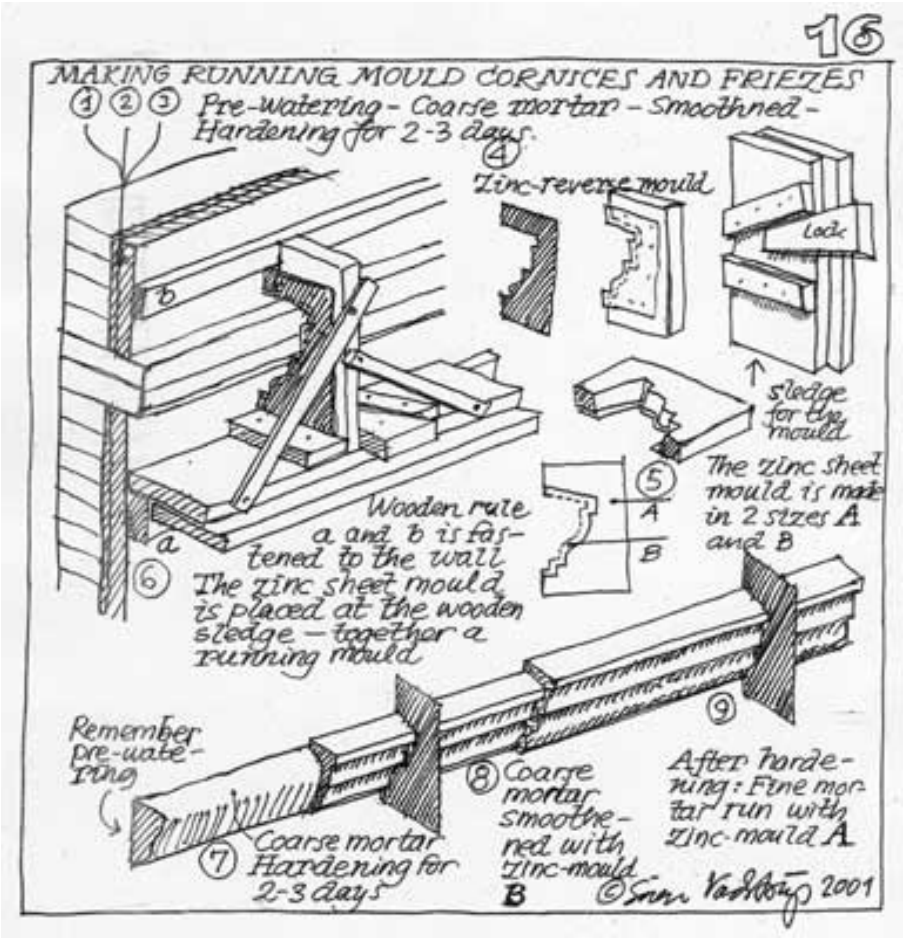
To verify the exact shape, an accurate template is made in paperboard, and tested and corrected at the spot. Note that the main cornice is often made with a little oblique drip (under carved) internally, to prevent water drops from "hanging". This must be carefully copied.



It is on the other hand quite important, that the running mould decorations, especially the main cornices, have good proportions, so in glaring cases, it is allowed to improve the shape.

The next step is to make a precise sheet zinc mould of the same shape as the cardboard template. After this a 1 cm smaller sheet zinc mould is made for the first, muffle running mould. Both sheet zinc moulds are nailed to a piece of board or plywood, cut out 2-3 mm smaller than the sheet zinc mould, and provided with a chamfer towards the profile.

The wooden piece with the sheet zinc mould is now firmly mounted to a wooden sledge with a special lock wedge and two shore lists, fixed with screws.



Now two wooden rules are mounted at the masonry, following the future lines of the cornice, frieze or casing, at the facade, and adjusted in proportion to the right height and course of the running mould sledge. As the mortar layer must not be more than 5 - 6 cm thick, all larger running mould decorations must have adequate corbellings of bricks or stone in the masonry. Therefore it is necessary to test the running mould sledge on the spot, in order to ensure, that the applied mortar layer everywhere will be 3 - 5 cm thick.

After plentiful pre-watering of the backing, coarse hydraulic mortar is thrown on, and the small sized reverse running mould drawn with the slanting edge pointing backwards. This is done several times, until the shape is complete, according to the small mould. If the surface is very smooth, it will be necessary to scratch small grooves in it.

After 2 - 3 days of hardening, preferably more, we are ready for the finishing coat. The mortar for this must be made with air lime, wet slaked for at least 3 years, mixed with very fine sand (0-4 mm), in proportion 1:3. Mixing time: 20 minutes.

The ground is pre-watered and the fine grained mortar thrown on and treated with the larger reverse running mould mounted at the sledge. When the shape is completed, a finish coat is applied, mixed in the proportion, lime sand 1:2, while at the same time, the running mould is drawn the opposite way - with the slanting edge pointing forward. This creates a particularly hard, smooth and weatherproof surface.

Making running mould friezes


C


F


G

A Setting up the wooden roles on the masonry
B Testing the reverse zinc mould for the space for the corbellings
C Coarse mortar is thrown on
D The running mould scrapes surplus mortar off
E Fine mortar is thrown on
F The running mould scrapes surplus mortar off and smoothens the surface
G Detail of the running mould
H Detail of the running mould

It will often be necessary to make the last 10 cm at the end of the running mould decoration "by hand", as the sledge has only a certain length. This is done with a collection of special wooden floats - never with a sponge, as this will damage the edges and spoil the lines.

The reason why the running mould decorations are made in two separate operations - with two sheet zinc reverse moulds of different size is to prevent the small shrinking cracks in the surface, which inevitably will occur if thicker layer of mortar is applied continuously "wet-in-wet". By laying a relatively thin finishing coat on a thicker, but hardened ground layer, the shrinking cracks in this will be filled, covered and minimized. As these cracks, even if they are quite small, often causes increase deterioration and approaching damages, especially on decorations exposed to rain, this more complicated procedure is absolute worth while.

Running mould decorations are sometimes pre-fabricated at the workshop, cut in suitable elements, transported to the building site and mounted here like the cast decorations.

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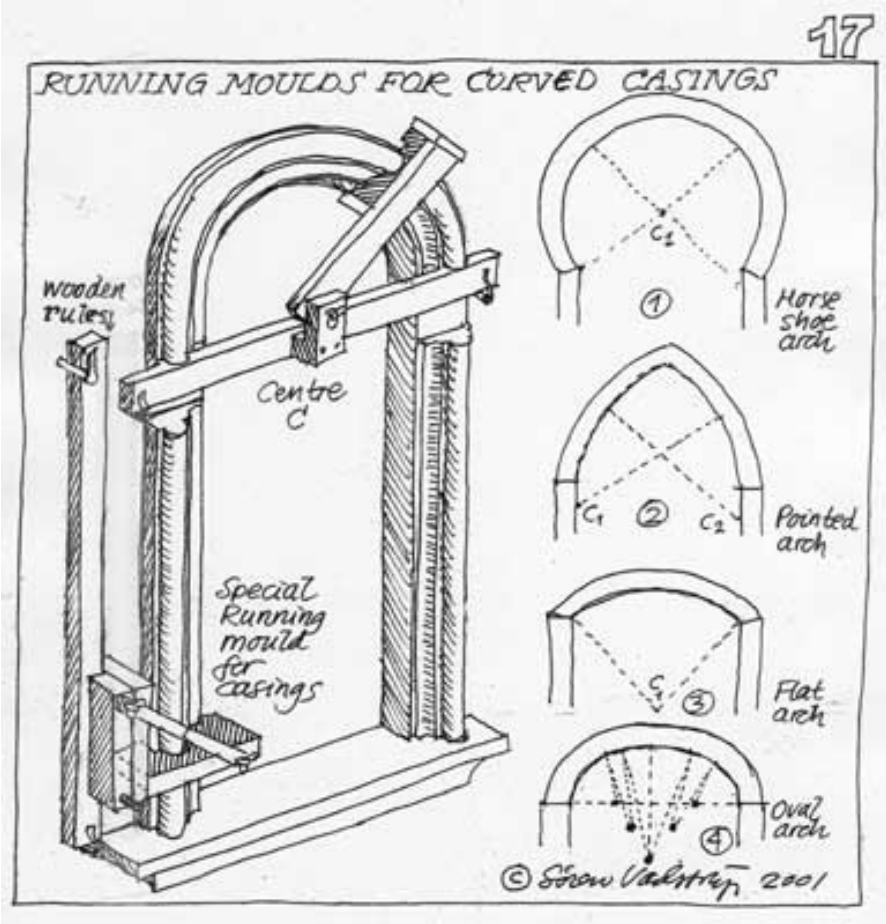
Making curved running mould decorations



Door- and window casings are sometimes curved, which is also possible to make with the running mould technique as shown on drawing no. 17.

The straight parts are made with a smaller running mould sledge, thus enabling the mould better to reach the often sharp bottoms. To make the curved parts, the sledge is mounted on a special board, fastened at the constructed centre for the curve, arch or chord - sometimes more than one centre is necessary. The centre point is fixed with special arrangements.

Another method is to set up specially curved rules - and draw the running mould along these. They can describe any possible curved form.

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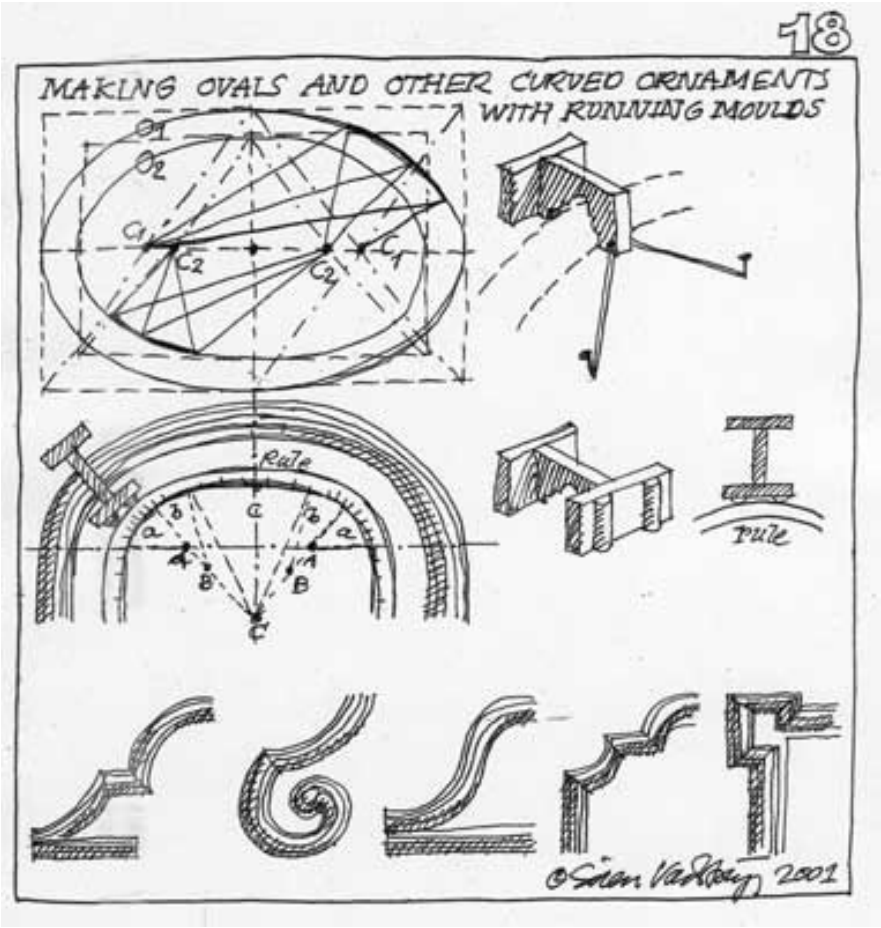
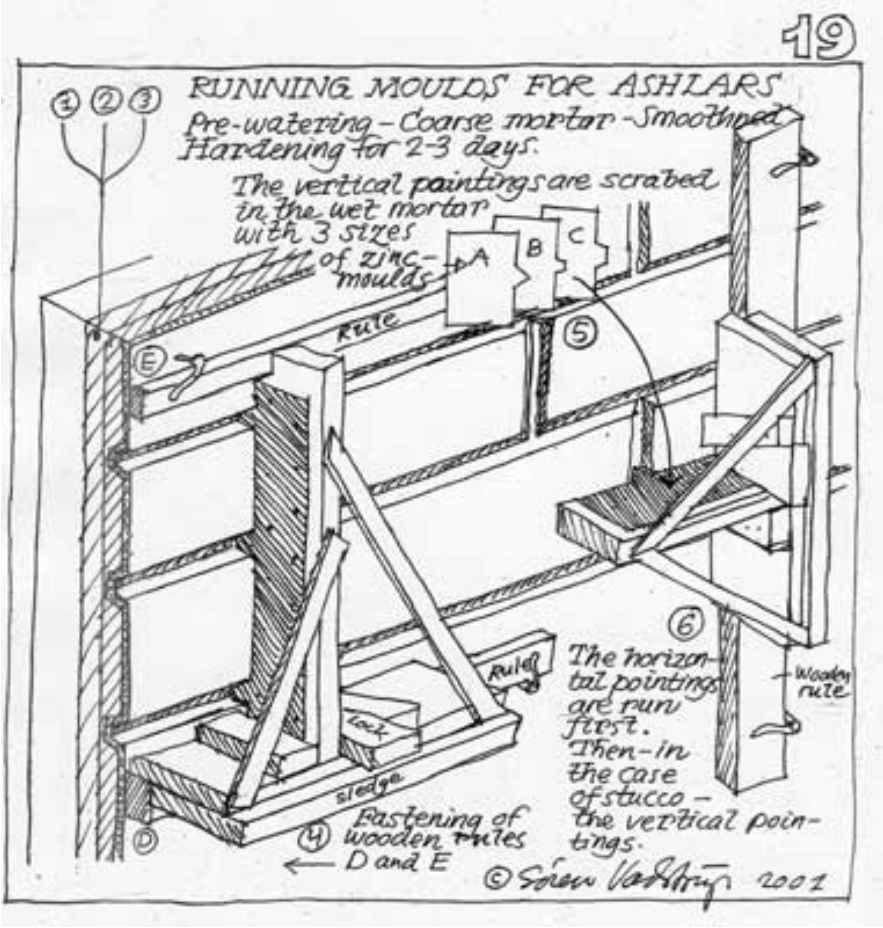
Other curved ornaments on facades made by running moulds



A lot of other curved ornaments on facades, elliptical, oval, convex-concave, cornice-shaped etc., can be made with the running mould technique, using various types of running moulds. Very often these decorations are made by the running mould technique at the workshop and, after the hardening, cut to suitable pieces and mounted on the façade. But they could also be made in situ.

The methods are either with strings or curved rules - combined with specially designed running moulds in each case - followed by hand modelling of the connecting parts with special floats and trowels.

Making running mould stucco and ashlars



As mentioned above, artificial stone walls and ashlars are often carried out with a running mould technique, as shown on drawing no. 19. Here it is only necessary to fabricate one sheet zinc reverse mould, as the running mould and the sledge can be "moved outwards" in two tempi. This has the purpose of constructing the plaster decoration in 2 various layers of mortar, a rough ground layer, which has hardened before the second, fine grained finishing layer.

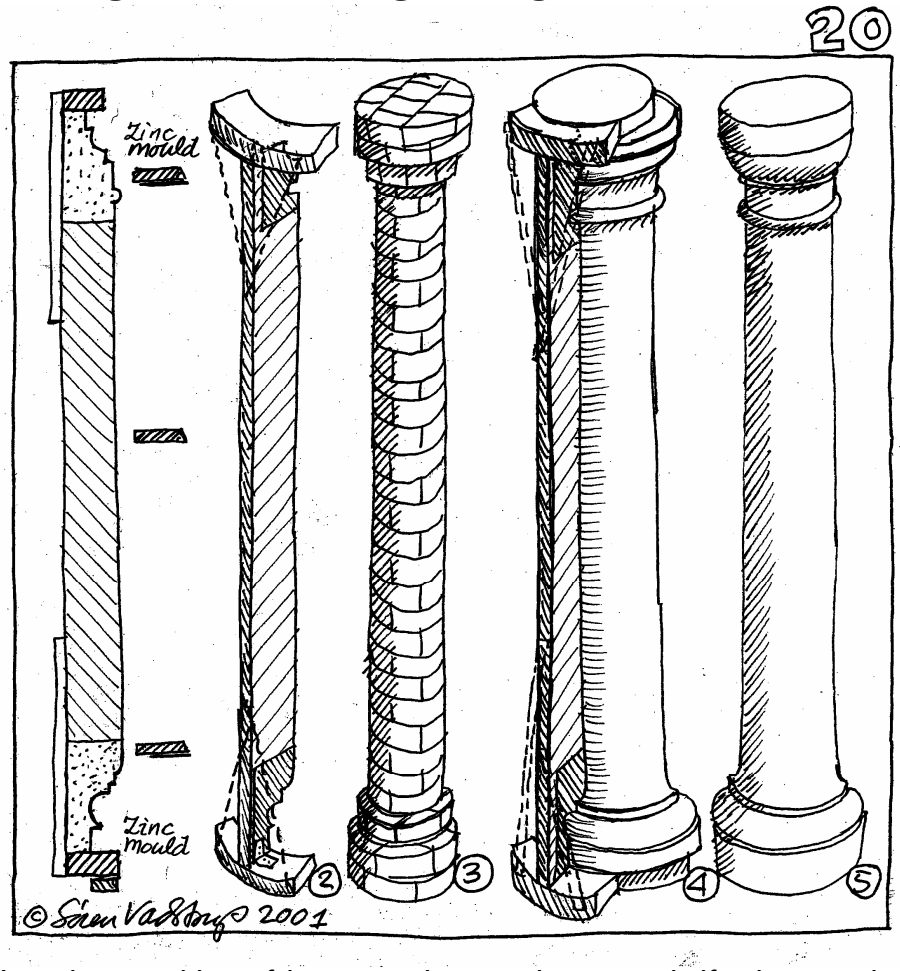
The running mould process starts with the executing of horizontal pointing grooves. The vertical traces are drawn afterwards in the still wet mortar. The vertical pointings are scraped in the mortar, which can be done partly with a scraper, partly with the reverse running mould, in 2-3 various shapes.

The same procedure is followed for the finishing layer of mortar. Apart from this all the measures and guidelines described above under running mould have to be followed.

Making running mould ashlars

A The wooden rules are placed on the masonry
B Coarse mortar is thrown on
C The running mould scrapes off superfluous mortar
D The last coat is finished
E The surface character is made

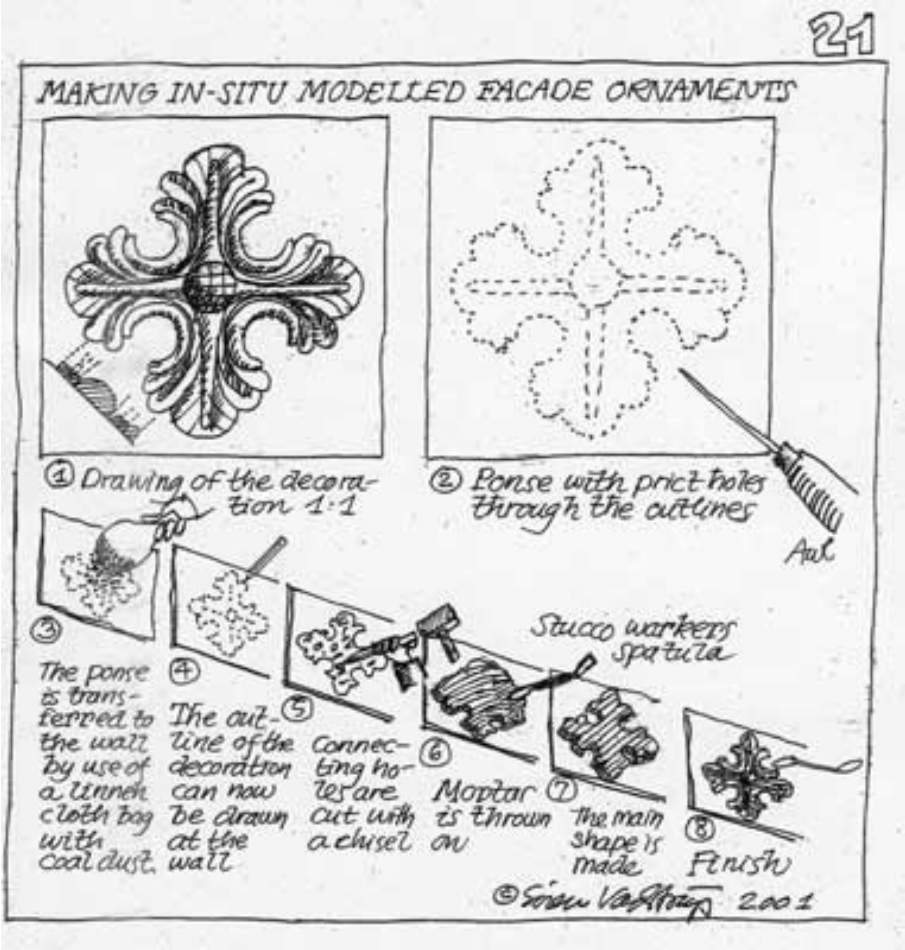
Making vertical running/turning mould for columns



It is also possible to fabricate a plaster column or a half column in the running mould - here vertical turn mould-technique.

The column is set up in masonry, including the necessary corbellings, leaving approximately 4 - 5 cm to a finishing coat of plaster - constructed of three layers of hydraulic lime mortar. As the turning mould can be moved outwards, by adjusting the slide pieces, there is no need for two different mould sizes to obtain the previously described three coat construction of the plaster.

7.
In-situ modelled decorations in plaster on facades



In-situ hand modelling of plaster decorations on facades is a very old crafts technique belonging to the stucco worker's profession.

Typical hand modelled elements can be consoles, festoons, medallions, animal heads, column capitals, etc. See examples on drawings 1 and 22.

First a full scale drawing of the decoration, either produced by the craftsman, the artist or the architect is made on paper, which is impregnated with a coat of shell lacquer. This is however not always necessary, if the paper is sufficiently strong and stiff. Now the outline of the figure is riddled with an awl, making small holes through the paper, now called a *ponse*.

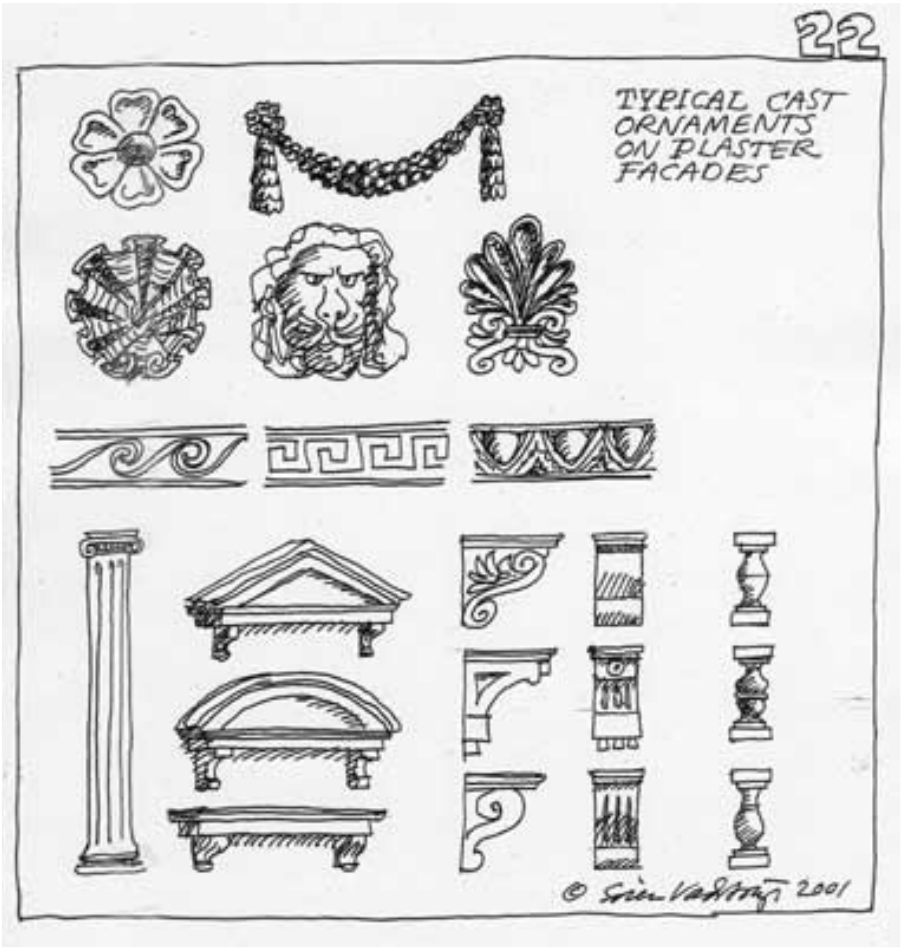
With a little slightly un-tight linen bag, filled with charcoal-dust, the black powder is sprinkled over the *ponse* and through the pricked holes in the paper. This, of cause, is done at the exact place for the decoration on the facade, and when the *ponse* is removed, the contours of the decoration are nicely transferred to the surface.

The outlines are drawn up and the application of mortar prepared by cutting grooves in the

surface and the contour with a chisel. After the usual pre-watering of the ground, the mortar, preferably a medium fine hydraulic lime mortar (1:2:9), is thrown on. Now first the exact outline and next the details of the decoration are hand modelled with the use of stucco worker's tools: various round, square and hollow spatulas.

If the construction is thicker than 5 - 6 cm it is recommended to use two separate layers of mortar, as previously described. The binding to the ground will also in that case have to be reinforced with laths in stainless steel.

8.
Cast decorations in plaster, gypsum or cement



Quite a lot of the decorations on plaster facades are cast in Ordinary Portland Cement mortar, gypsum or other specially mixed materials and thereafter mounted to the plaster surface.

Portland Cement is created among other things to suit this purpose, but it is hard to believe, that a relatively weak material as gypsum can last for long time on rain, frost and salt exposed exterior facades. But experience shows that cast gypsum decorations have a surprisingly good durability and can under certain circumstances last for several hundred years.

The gypsum decorations are in spite of this mainly reserved to quite flat reliefs or friezes, or they are placed well sheltered from water under a large main cornice or roof eaves. It is furthermore very important that the cast gypsum decorations on facades are surface treated and protected by a layer of linseed oil paint. Possible bearing and mounting iron has to be rust protected carefully or made in stainless steel.

A very special material, used in Britain as early as the late 1700s and still used today is

composition or *comp*, a very early "plastic" material, consisting of linseed oil, animal glue, natural resin and clean whiting as the filler. Heat and steam was used to speed up the curing.

The main material for cast decorations is however Portland Cement, which appeared as a very popular and used product for this purpose at about 1860.

It is quite often difficult to see, whether a facade decoration is hand made on the spot or cast and mounted. Only more close investigations will disclose or verify this. The treatment in case of damages and deteriorations are quite different.

The cast decorations were often cheaper than the hand made, as they can be mass-produced and still look relatively individual, because of the huge amounts of products and enormous sales potential. Complete catalogues with drawings, sizes, variations and prices were sent to the crafts firms, to the architects and the building owners from the big factories in each country. Columns, half columns, balconies, balustrades, consoles, casings, friezes, festoons, medallions, etc. etc.

There are three methods for casting in Ordinary Portland Cement:

1 Pressed semi-dry casting method in a rigid reverse piece mould
2 Wet casting method in a rigid reverse piece mould
3 Wet casting method in a flexible mould

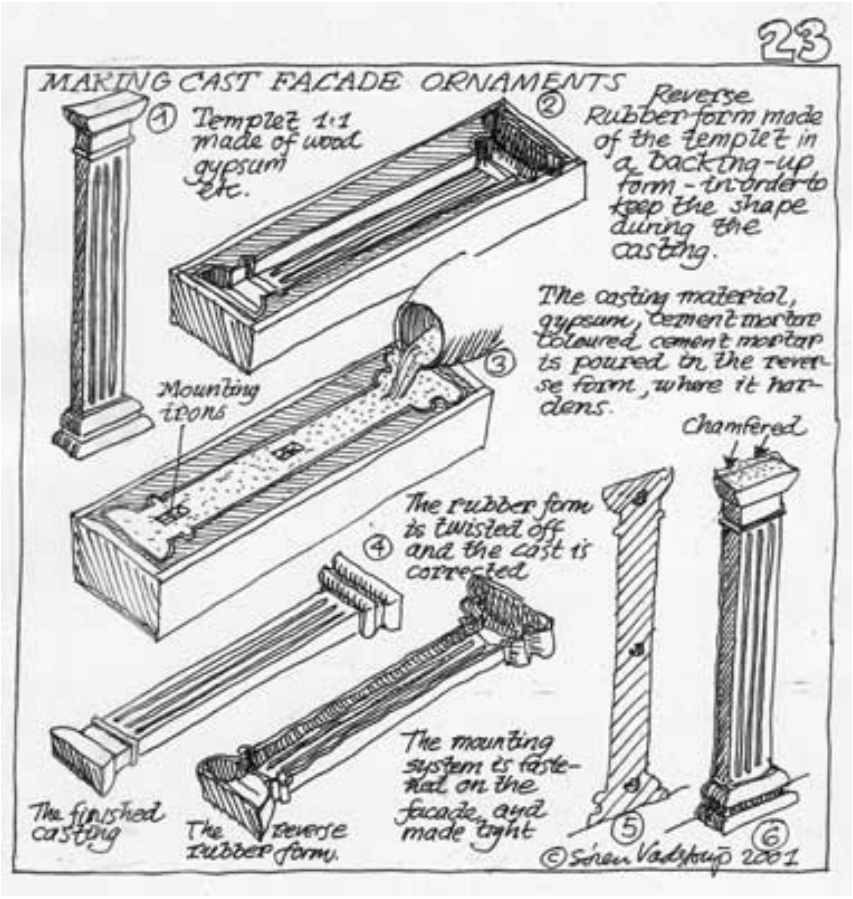
The advantage of the semi-dry technique is that it is by far the fastest, as a casting takes 20 to 30 minutes. A wet casting demands a day in the mould to harden.

When recasting old facade ornaments on historic houses today, primarily the flexible moulds are used, so only this method is described in the following.

The most suitable material today for recasting brand new façade elements, is Ordinary Portland Cement (OPC) mortar, adjusted in suitable mixes with selected coloured sand 1:3 – *without* the many modern adherents and reinforcements as fibreglass (GRC), PVC and others.

For repairs of old Portland Cement castings, it is recommended to use a hydraulic lime mortar 1:1:6 or 1:2:9 (cubic measure of air lime: hydraulic lime: sand/gravel)

Wet casting with Portland Cement in flexible reverse moulds



1 Production of a full scale model in an appropriate material: Gypsum, wood, cement.

2 Making of a reverse casting mould in cement, gypsum (being hard piece-moulds) or, to day, silicone rubber (flexible rubber mould). The mostly used type is "open" in the back, only with mould quarters on the five sides - including top and bottom.

3 The casting mass, Portland Cement, gypsum, more rarely hydraulic lime mortar, is poured into the casting mould. Irons or other systems for mounting are fastened in the wet and soft material

4 After the hardening the cast element is removed carefully from the casting mould and possible defects are repaired or retouched.

5 Finally the cast element is sold, transported to the building site and mounted at the facade.

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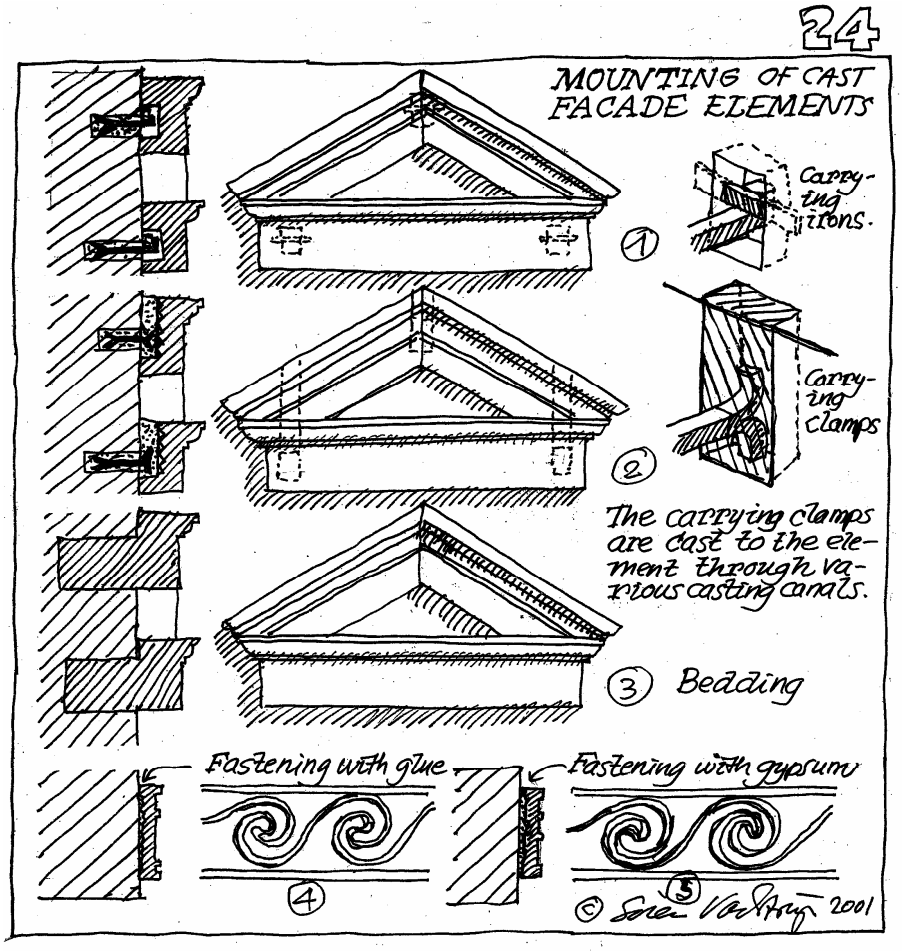
Mounting systems



Drawing no. 24 shows the various mounting systems, anchors, glue, and even simple wet gypsum mass. Other methods can be used and must be explored from case to case.

The iron anchors cause the heaviest problems, as they will start to corrode, when possible cracks or gaps allow water to expose the iron surface. The inevitable result is corrosion which again soon will cause bursting and breaking masonry because of the expansion of the iron.

Today cast façade elements will be mounted using big counter slinked, stainless steel screws, secured to the masonry with raw-plugs. The same method is used, when old cast elements are secured.

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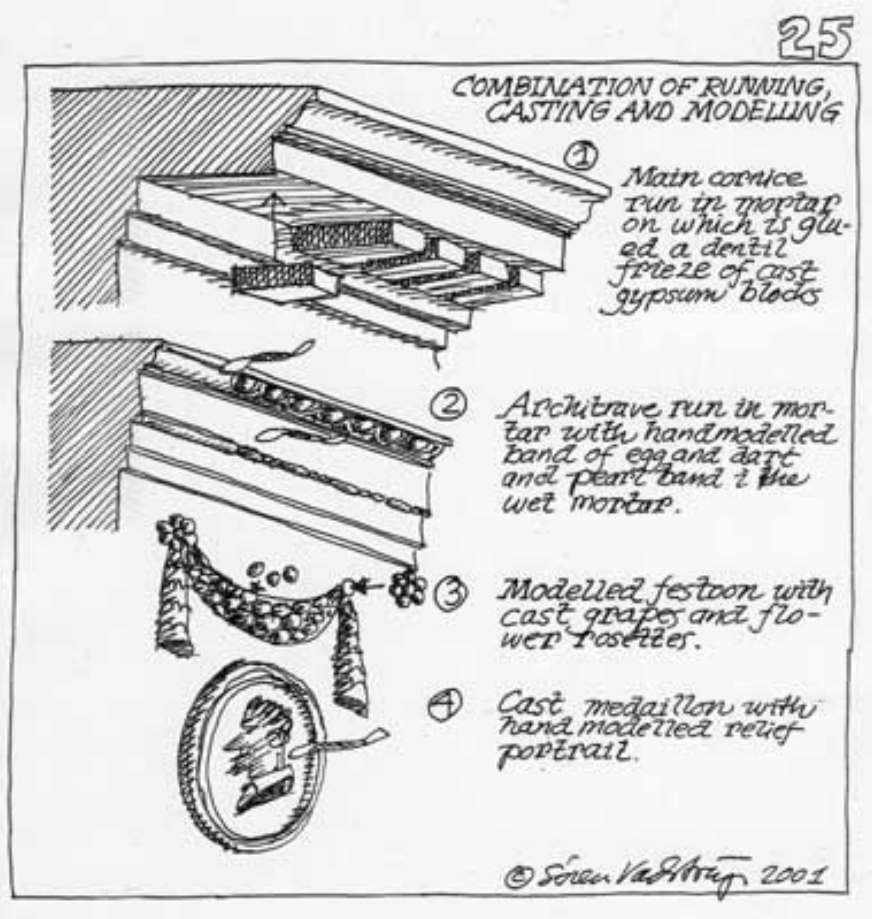
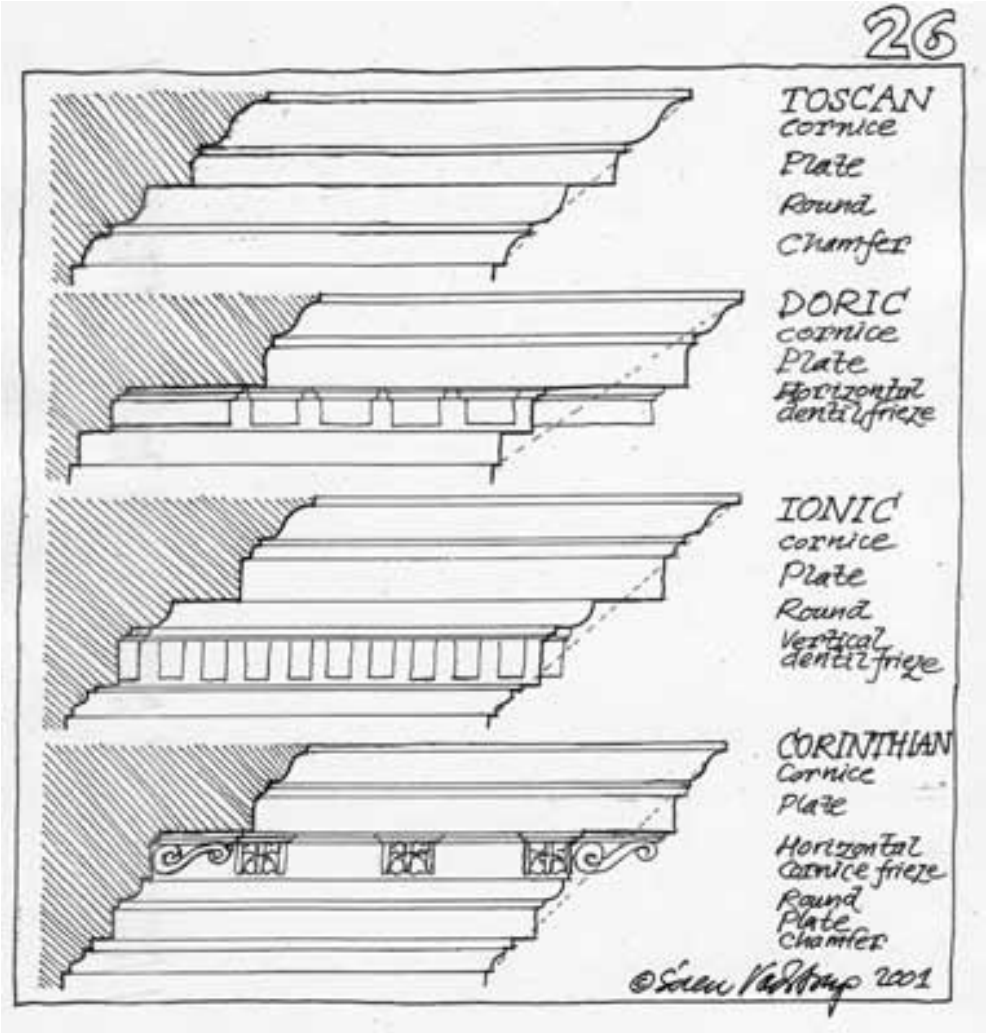
9.
Combined techniques



In the 200 years of the flourishing heydays of the decorative plasterwork architecture in Europe, the creativity was almost boundless, regarding experiments and improvements of materials and methods. Especially in combining the previously mentioned 5 main crafts techniques for the plaster decorations. Everything was tried and used:

1. Running mould with cast details
2. Running mould with modelled details
3. Modelled decorations with cast details
4. Cast decorations with modelled decorations
5. Prefabricated Running mould or modelled decorations

It is often very difficult to distinguish these combinations on the actual decorations or elements. Probably only the executing craftsman will know this for sure.


26
TOSCAN
cornice
Plate
Round
Chamfer
DORIC
cornice
Plate
Horizontal
dental frieze
IONIC
cornice
Plate
Round
Vertical
dental frieze
CORINTHIAN
Cornice
Plate
Horizontal
Cornice frieze
Round
Plate
Chamfer
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10.
Repair of plaster surfaces and plaster decorations

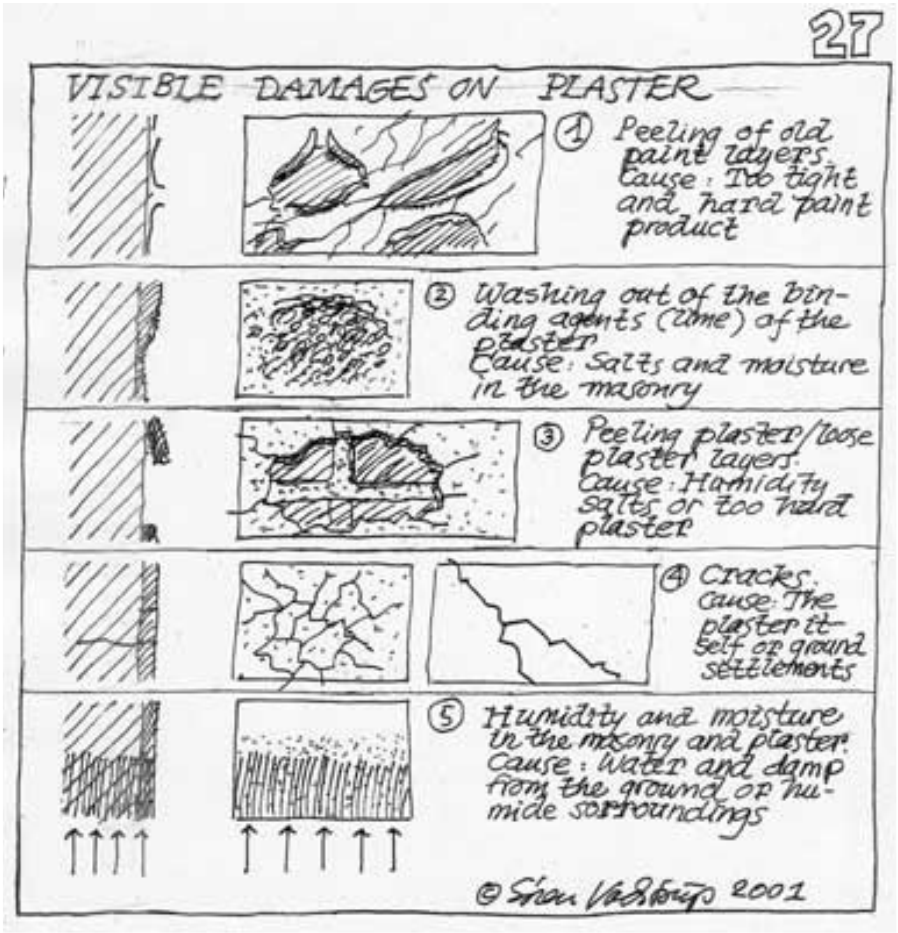
The deterioration and damages on facades

Insufficient understanding for and neglect of the gradual deterioration and damages on the facades are the causes of long term destruction or even loss of many historic buildings.

It is therefore very important to maintain the facade every year, in order to take all the small and easy things, when they are limited and quite cheap – not waiting, until they becomes bigger, un- manageable and much more expensive. This is unfortunately what often happens.

A house owner, or his advisor, must be able to look at the building and the facade to se and understand the visible "maintenance-signs", which the traditional material automatically dispatches. With use of other sense organs, such as the hand, ears, nose and tongue more information of the conditions can be investigated, as described in the following. Together this gives an overview, which is necessary to understand the physical conditions and the technical state, in order to make the right maintenance or repair work.

Visible damages



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Some of the damages are immediate visible on the surface. For instane *(Drawing no. 27)*:

1 Peeling paint layers

2 Leaching of the bonding agents of the plaster

3 Peeling of layers of plaster

4 Small and larger cracks

5 Humid, moist or wet plaster from ground humidity


Causes of the damages

Most of the deterioration and damages have 5 causes:

1 Influence of water - and the consequences or followers of water: Moisture, ice, saltwater, acid rain. This causes dry rot and fungus in wood, salts in masonry and stones, frost damages, acid deterioration, algae, dirt etc.

2 Mechanical causes - from wear, ground decreases, insufficient carrying capacity and wind.

3 Technical faults - from insufficient constructions: Leakages, insufficient adjoins between materials, too hard and moisture tight surface treatments or finishing coats, changes in the physical balance in the constructions.

4 Forced deterioration of the surface materials due to leakages in the roof, joints, watertight surface on iron etc.

5 Other causes - incorrect use and arrangements, neglect of maintenance.

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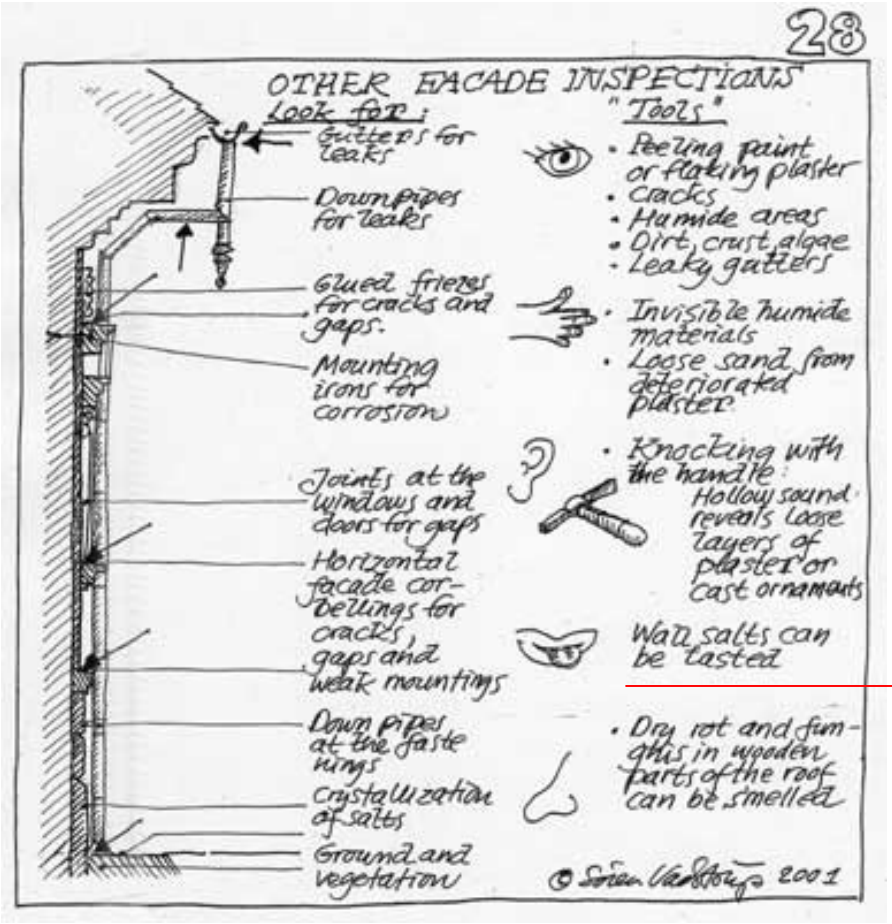
Technical survey on the masonry

But before the restoration of the facade, the masonry must be examined more closely. This should be executed preferably by an impartial authority, and not by the craft firm intended to be involved in the actual work. One or more of the following circumstances must be inspected depending on the type of construction:



1. Did any constructive circumstances lead to damages on the masonry like soilage on the facades? Are there constructions that should be altered?

2. Are the flashings, trims, gutters and leaders in order?

3. Is the masonry discoloured and is it necessary to clean it?
   If so, an experimental cleaning must be executed well in advance of the renovation to find the suitable method of cleaning, for instance by water jetting etc., the most considerate method towards both masonry and environment should be chosen.

4. Is the masonry coated with an impermeable paint layer that has provoked the damages on the masonry? If so, the paint-layer must be removed and replaced by a moisture penetrable type of paint.

5. Is moisture insulating layer induced in the footing, or is there any other obstacle for the soil dampness to enter the masonry?

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6. Are there smaller or larger cracks in the masonry or the plaster?

7. Are there cracks or gaps in the masonry, where water can enter? For instance in connection with mounted cast decorations, balconies, staircases, iron rails, iron anchors, wooden windows or doors, half-timbering, natural stone etc.
If so, this can be dangerous for the facade.

8. Are there evidence of corroded iron anchors, deeper in the masonry?

9. Is the plaster deteriorating, peeling, flaking, constantly wet or does it look "rotten"?
If so, there are probably absorbed salts in the masonry. The plaster must be removed totally and the causes for the salts, ascending ground-moisture, salt storing in the building, thaw-salting of the pavement etc. must be removed or reduced and the salts drawn out of the masonry by packages of distilled water or a sacrificed layer of lime mortar. A new layer of lime mortar, constructed as two layers of increasing fineness, is added. These parts of the masonry cannot be surface-treated with lime wash or paint before all salts are removed.

10. What design/mixture has the existing plaster?
The plaster repair must always have exactly the same design/mixture to ensure the same strength, elasticity, sough-ability - plus colour and grain-structure.

Plastic paint on facades

Frost-bursted joints and tiling often occur on lime washed facades successively coated with plastic emulsion paints, cement-based paints or modern silicone paints. Particularly old houses built with hand moulded bricks jointed with lime mortar are in the danger zone.

The cause of the damages is often due to the fact that the new materials used for surface treatment are much too impermeable which lead to a diminution of the transmission of the natural humidity and vapour. The humidity is accumulated behind the surfaces from which it slowly evaporates and crystals will deposit and keep growing.

This is shown by experience and it is documented by the so-called Z numbers (value given for pressure against moisture). The Z-values of the above mentioned materials are as follows:

Lime wash:	0,0 - 0,4
Paints based on cement powder	0,8 - 1,0
Plastic emulsion paints	2,0 - 7,0

These numbers emphasize that lime is without doubt the material with the highest diffusion. The importance of the open lime surfaces compared for instance to the more impermeable materials is revealed by all the damages that occurred during the last few years in connection with the new treatments. Well-harden lime mortar is furthermore deteriorating if it is enclosed by a material with a high Z-figure.

Other damages are provoked by the water that penetrates from the outside through fine cracks and accumulate behind the impermeable surface-treatment and does not have the

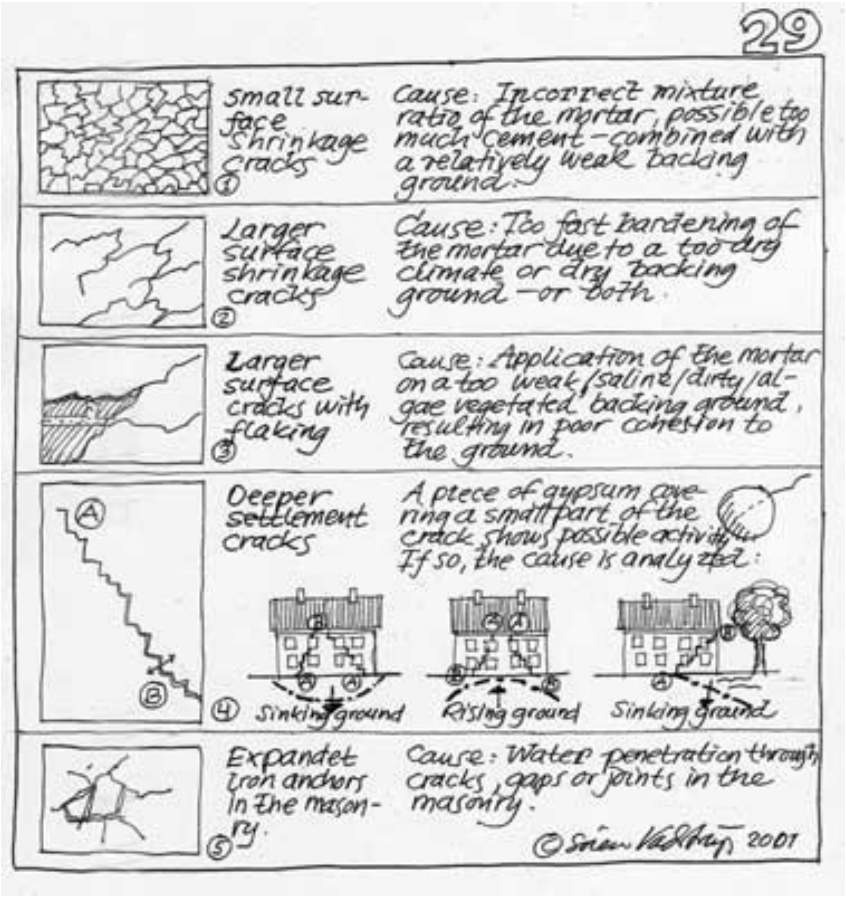
possibility to evaporate quickly through the dense surface coating. The accumulation of water in the masonry leads to crystallisations and frost damages during winter which manifest itself as bursts of joints and formation of stone.

Cleaning for plastic paints etc.
The cleaning of masonry previously treated with plastic emulsion paints or materials based on cement must be done down to the firm ground.

Cleaning is done with low-pressure jetting, where possible. The work must be executed with great care in order not to damage the masonry additionally by admitting to much water. A possible mixture of sand and a successive water jetting should not be too hard as it will damage the fire coating of the tiles. In that case the surface of the bricks will be damaged and consequently they will absorb much more humidity than before. It is recommended that experiments are made in every single instance until the correct method is found.

Building parts, windows, doors, cornices etc. that are not to be cleaned must be covered properly before the treatment is initiated.

Assessment of cracks



The cracklings may appear both in an early state after the coating of facings, which is the most frequent situation, or it may appear much later, many years after the finishing of the building.

The cracklings on plaster can, as shown on *Drawing no. 29* are grouped in:

A: Surface crackings
B: Deeper crackings or slots

Surface crackings

Surface crackings do not overcome the thickness of the single or multiple layers. In general they do not follow a specific direction. They may appear in any direction and they often give origin to closed cracking lines, such as large cells with big or small dimensions.

Surface crackings are generally due to wrong application of the coatings.

1 The use of mortars with unsuitable composition or mixture will cause crackings as shown on drawing 29, figure no. 1.

2 The application of mortars on too dry or hot surfaces causes too quick stiffening and the consequent laminar retraction, shown on drawing 29, figure no. 2

3 The application of renderings on dirty surfaces with any kind of fungi, power, or under some active chemical decomposition, give origin to a kind of cracking followed by detachment, as seen on drawing 29, figure no. 3.

Deep crackings

Deep crackings attain deeper in the walls, over passing the coating and attaining as well the composing elements of the wall supports, bricks, stone blocks, hydraulic binding and reinforced concrete.

Deep crackings also differ from others for their specific direction and location of specific points of the building architecture, as seen on drawing 29, figure no. 4.

Deep crackings are generally due to structural movements, mostly downwards, in the foundations of the facade.

The deep crackings and the surface crackings may have the same appearance when they are not coincident at the surface of the rough wall and in the coating. This happens when the wall detaches itself from the coating.

Another type of deep crackings is due to the expansion of corroded iron anchors, situated deeper in the masonry. Drawing 29, figure no. 5.

Examination

The method of examining the conditions of a cracked plaster/rendering is by knocking/percussion on the surface with a wooden shaft/handle of a hammer.

A clear and open sound indicates adhesion of the plaster to the support
A hollow and deep sound indicates detachment from the support

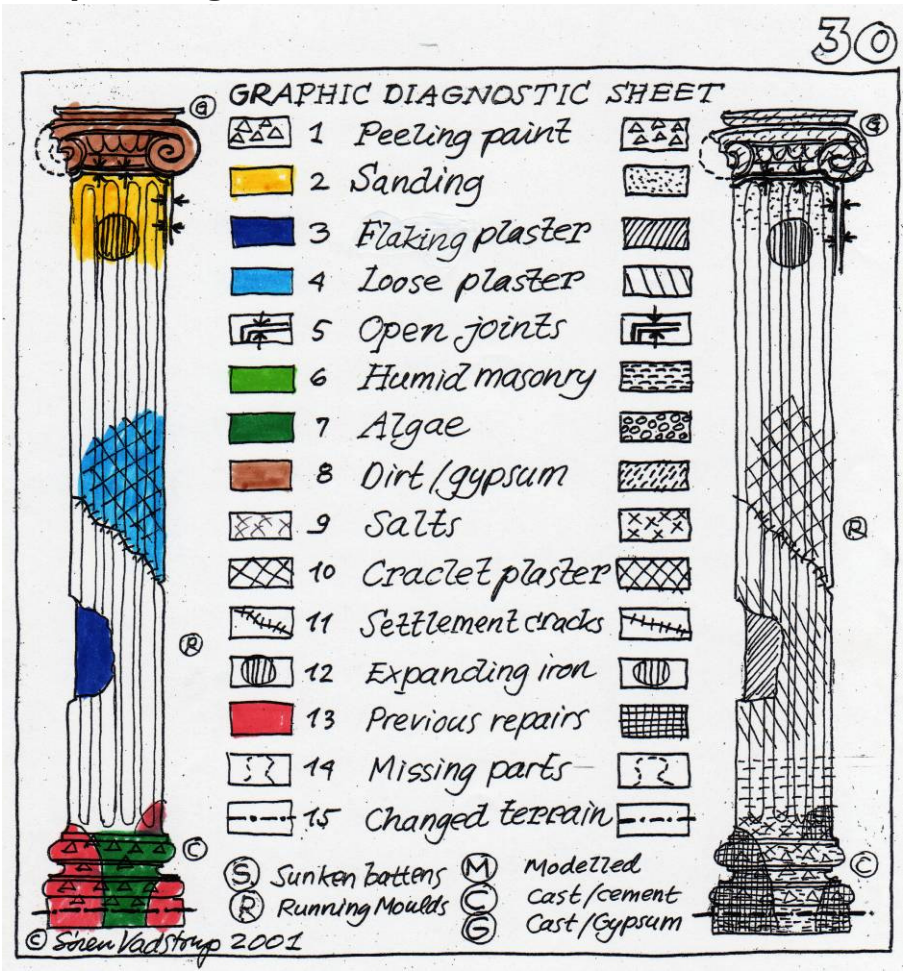
Repair of cracks

If the following conditions occur in a new rendering, it will be sufficient to fill up the crackings with a thin past of the binder, used in the rendering:

The affected area is limited
The crackings are small
The dimensional stability has been checked
A finishing layer, lime wash or painting is to be applied.

If the affected area is wider or if the crackings overpass 2 mm, the new rendering should be taken of and a new layer applied, with the right composition or mixture and the right construction.

Graphic diagnose sheet of the deterioration and damages



In order to produce a documentation of the technical state of the facade, and at the same time get an overview, it is recommended to work out a Graphic diagnose sheet, as shown at Drawing no. 30.

She sheet can be made with colours or with graphic symbols, covering the most common types of damages on plaster on facades.

A Flaking of plaster layers

B Detail of flaking

C Gaps in joints between cement elements

Historic research on the masonry

Besides these technical examinations of the masonry it will be relevant to investigate the history of the facade, that is the previous colours, previous repairs, previous alterations previous plaster coats - or other surface-treatments.

The sources for this can be written documents or records in archives, old drawings, paintings or photographs, but primarily, careful investigations and observations on the facade of traces of colours etc.

Restoration attitudes

1 First of all, the *original parts* of the building must be preserved and protected by restoring the building as carefully as possible. *Repair* should be preferred to replacement.

2 The maintenance and restoration of the building must be carried out with the same *traditional materials and crafts techniques* that were used when the building was originally built.

3 We must have a *thorough understanding of the materials and constructions,* regarding both the weak and the strong points, in relation to what is required of them. Therefore the restoration work must be carried out by multidisciplinary expertise and specially trained and experienced craft skills.

4 It is important, through the repair- and restoration work to keep up or improve the architectural entirety of the facade.

5 When a restoration implicates severe alterations a brief and concise *documentation* is required including for instance descriptions, photos, drawings etc., in case information about the constructions should one day be needed. The documentation must be available in a public archive.

The traditional building- and crafts techniques

The traditional building- and crafts techniques involve a number of carefully prepared preventive elements to avoid these life-threatening damages of the buildings. They represent a kind of natural physical balance, which will be destroyed and cause more damages, if unconsidered changes are being made.

The traditional building constructions have 5 preventive elements, which will diminish the chances and cause later damages:

1 **Quality-improvement** of the materials and micro-constructions by the crafts-techniques. Examples: Hand-wrought iron, quarter sawn wood, waterlogged wood, mixing and application of lime mortar, mixing and application of paint, etc.

2 **3-double protection** of critical constructions and elements. Examples: The joint between window and masonry, the construction of the wooden windows, rust protection of iron, the tile roof, the plinth/socket-construction, the building of wooden balks in masonry etc.

3 **Sacrificial layers:** On very critical points, the traditional constructions operate with sacrificial layers or elements, which are easier to change or repair than the vital elements. Examples: The plinth-mortar, the mortar-joint on windows, the linseed oil putty on windows, the traditional paints on exterior wood, the horizontal bottom- or top boards in wooden constructions, etc.

4 **Maintenance-signals:** The traditional materials and constructions send out distinct "maintenance-signals", when they need to be maintained. Examples: Linseed oil paint and other traditional paints, lime wash, tile roofs, windows, exterior wooden boards etc.

   It is very important to know these distinct "signals" and to read them right. Uninformed people often interpret these as serious damages, needing to be renewed - and not just maintained.

5 **Repairable elements:** The traditional materials and constructions are "repairable", which is a very important quality. If something happens, you can repair parts or whole elements. This gives these elements, for instance wooden windows, a life-long durability. There are thousands of examples of wooden windows lasting more than 200 years - and still in an excellent state of preservation!

There are a lot of examples of how more knowledge and awareness of these 5 important, but often forgotten qualities of the traditional building materials, building constructions and crafts techniques could save both the house-owners and the different countries quite a lot of money.

Repair methods

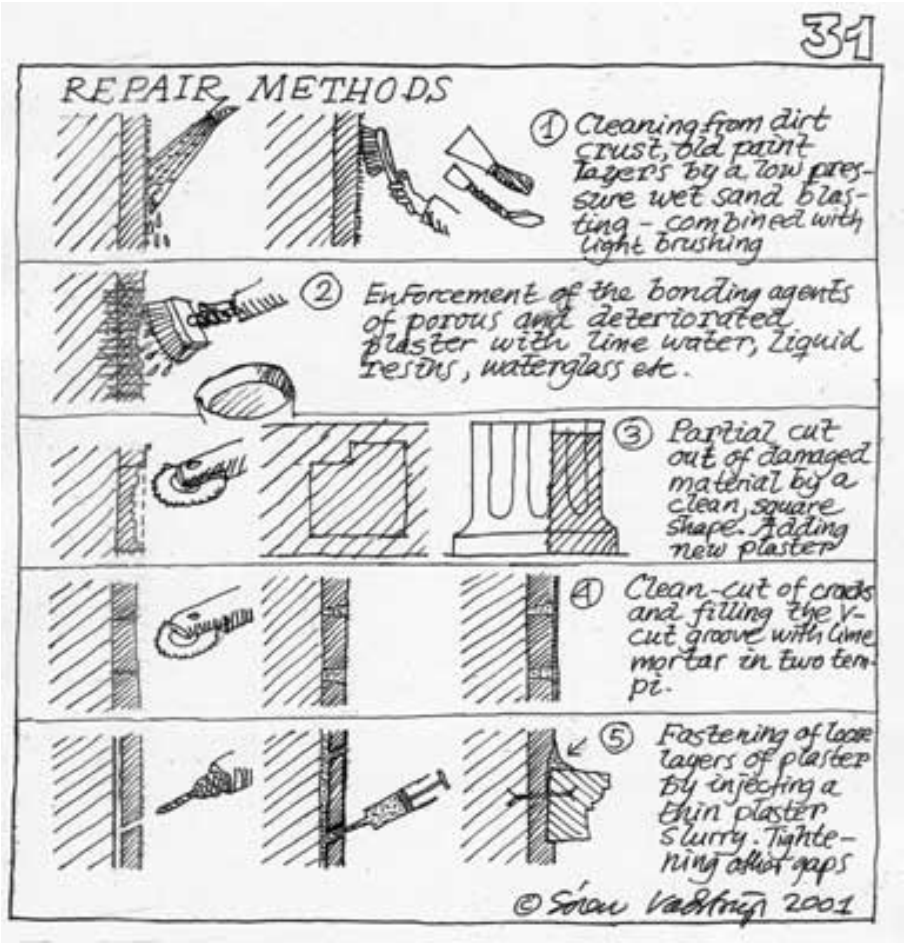
After a cleaning of the façade has taken place, a repair of defective and frost bursted bricks has to be executed: Defective stones are cut out and new hand moulded or sand faced tiles are bricked in which lead to the best adherence to the following lime wash. Frost bursted joints are scraped out until firm mortar, min. 3 - 4 cm, and new joint filler is applied.

Any parts with loose plaster, cracks etc., are cut of. Plaster or mortar joints repaired with cement or mortars containing cement must also be cut out and replaced by lime mortar, as the lime does not adhere sufficiently to cement-based surfaces.

The surface of cement-based mortar is tight sheets of silicates absorbing humidity behind the surface and a humidity absorption that slowly evaporates. The more open lime mortars quickly give off the moisture again. Lime washed surfaces on which repairs are made with cement mortar will appear much stained in damp weather. Cuttings up to the existing original, but appropriate plaster shall always be made with right lines and right angled corners.

After a cutting out of bricks and joints down to a firm ground the masonry is carefully cleaned of remains from the mortar, dust etc. and water is sprinkled on until the surface is saturated as much as the bricks and joints will be able to absorb a little of the mortar water. The joints are completely filled and a backfill may be necessary too and eventually all joints are compressed with a brick jointer.

Technical principles for plaster repair



When carrying out repairs on existing plaster on masonry or making a new layer of plaster on old buildings, there are 5 main principles, which have to be followed:

1 All repairs on existing plaster on masonry or new coats of plaster should use an air-lime-mortar, without hydraulic additives or cement, or, on certain extreme positions, a slightly hydraulic mortar. This goes also for repairs of old cement-plaster.

2 The plaster shall be an exact copy of the existing plaster, regarding roughness, colour, surface-character, traces of the tools etc. The mason has to make a sample for a critical comparison, before the whole work is started. Certain research-institutes can analyse the old plaster and determine the type of the binding agents, the sand and other additives.

3 Before adding new plaster, the masonry has to be cleaned of dust, dirt and detached parts by brushing and subsequently the surface is watered carefully with plain tap-water.

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Partial repair of plaster (Domhuset, Copenhagen)

4 Layers of plaster shall be carried out in three coatings or layers:

A: A 1 cm thick rough ground layer of air lime mortar 1:3 (or hydraulic lime-mortar 2:1:9, 1:1:6 or 1:2:9 - depending of the deterioration, weak- or hardness of the background masonry) with quite rough gravel, *thrown* on the masonry, and left fairly uneven.

B: After hardening: a 2-3 cm second backing coat with coarse gravel, thrown on and then drawn to an even layer, and after that allowed to harden for one week.

C: Then followed by a very fine finishing layer/coat with fine grained sand, also thrown up and drawn to an even coating.

The thickness of the layers must not be superior to 2 cm, as thicker layers will cause thermal differences and internal pressure between the interior areas and the area more exposed to the weather conditions, where the water evaporation and the quick cooling of the mortar occurs. This favours the retraction effect with inevitable uprising of cracking.

5 A good and lasting result implies previous, appropriate interventions against structural settings in the masonry, ascending ground moisture or hygroscopic salts.

Demands for weather and temperature
Mortar-repairs must under ideal circumstances take place during a relative humidity in the air at 75-95 %. The temperature should be minimum +5 Celsius and maximum +18-20 Celsius. A total absence of wind is also recommendable.

Materials
See chapter 2

11.
Reconstruction of missing plaster decorations

On deteriorated and damaged plaster facades, some parts of the structure will often be missing. They have fallen off, taken of or moved away for safety reasons.

If it is pieces of "plain" plaster, a piece of a cornice, a frieze or the plinth, this can immediate be remade, as described in the previous chapter, as the form is very simple.

But if the missing part is a more complicated sculptural or decorative element it is a much more complex situation.

If we are dealing with a piece of art of great artistic or architectural value, and nearly everything is lost, it is very difficult to justify making a reconstruction, because the artistic value is often strongly connected with the artist who made it. A contemporary artist's reconstruction will always be an uncertain rendition.

More common, but still complicated sculptural elements, which are missing, need a certain procedure in order to make a proper reconstruction:

1 First step is to make a conscious and profound documentation and measurement of the original remains.

2 Next step is to carry out a historic research to clear up the age, history, possible artist/craftsman, possible drawings, paintings, photographs, descriptions, etc.

3 Now we are ready to produce a reconstruction drawing, which involves:
The measurement of the possible remaining parts, including
The traces on the spot of the original form
The historic research: Photographs, drawings etc.
Similar decorations or elements on the same building/facade
Similar decorations or elements on other buildings from the same period
Knowledge of the art- and architectural history of the building and the period.
Preservation and incorporation of most of the surviving, original element

4 After approval of the reconstruction drawing, the reconstruction is carried out in full scale, in case of a very essential piece, with a full scale reconstructed model, possibly in gypsum, as a phase in between.

5 The reconstruction is mounted and fitted to the original place, without destroying any part of the original element. A visible joint to show what is old and what is new could be considered, if this does not cause technical or aesthetic problems.

Recasting and reconstructing deteriorated cast ornaments

As a very common damage on plasterwork on facades is bursting of cast ornaments in Portland cement, due to corroded iron mountings, directly fallen elements or deteriorated surfaces, it is often necessary to re-cast an old cast element.

1 The original element is carefully de-mounted, cleaned for crust, dirt and paint layers.

2 If possible an exact identically, but complete element from the facade is chosen and similarly cleaned in situ.

3 A reverse mould of the cleaned element is made - even if it is broken or parts are missing. This is done by making a thin squeeze in 2-component PVC-rubber etc. and at the same time putting a hard backing made of gypsum, reinforced with sticks etc. at the flexible rubber mould, to prevent later misshapenness, when it is removed.

4 If parts of the original elements are missing, a right/positive cast is made in gypsum from the reverse mould. This cast is completed by hand modelling of the disappeared parts in gypsum. From this *reconstructed model*, a new squeeze in 2-component rubber, including a reinforced backing, is made as a reverse mould for the new cast of the completed element.

5 The new element is cast in wet, Ordinary Portland Cement and gravel 1:3 with suitable water, pouring first a thin layer, which is "helped" out in every corner and detail of the mould, to prevent air holes, missing corners or bubbles.

To the left a hard backing in gypsum, pieces of wood etc, supports the reverse squeeze in rubber in the middle, of a similar, unspoiled original decoration, and to the right, the recast decoration in Portland Cement.

12.
Maintenance of plaster surfaces and decorations

When a facade has been repaired and restored it is highly important to maintain the good state very carefully. This is of cause also the case, if the facade is in a general good state, without any restoration.

Before a restoration, but also in general, it is a good idea to analyse the possible weak points or other threats on the facade, in order to prevent returning and recurrent damages and maintenance demanding work.

Preventive works on facades in masonry and plaster.
The preventive works represent deeper interventions, than ordinary maintenance. For instance:

1. Tightening of gutters and runners, which might be leaky. Ensure that the metals zinc, iron, cupper, lead are connected and combined in an electro chemical correct way.
2. Removal of damaging materials, dirt and elements from the facade, for example plastic paint and hard layers of cement.
3. Regulate too high ground or terrain level, with a declining curve away from the house, devastating surroundings for instance trees, bushes or shrub.
4. Insert a damp proof vapour barrier in the masonry, which will prevent the ascending damp.

   The recommended methods for this are:

   A: Cutting in a horizontal groove from both sides with a large, special circular saw, about 20 cm above the ground, and pressing slate plates into the groove. After that sealing with injected, thin hydraulic mortar.

   B: Mechanically pressing special corrugated stainless iron plates in a horizontal joint, About 20 cm above the ground.

   C: Injection of a watertight fluid through slanting bored holes staggered in two levels.

5. Reinforcement of foundations
   This needs a specialist's assessment and a specialist's project and work.

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Maintenance principles

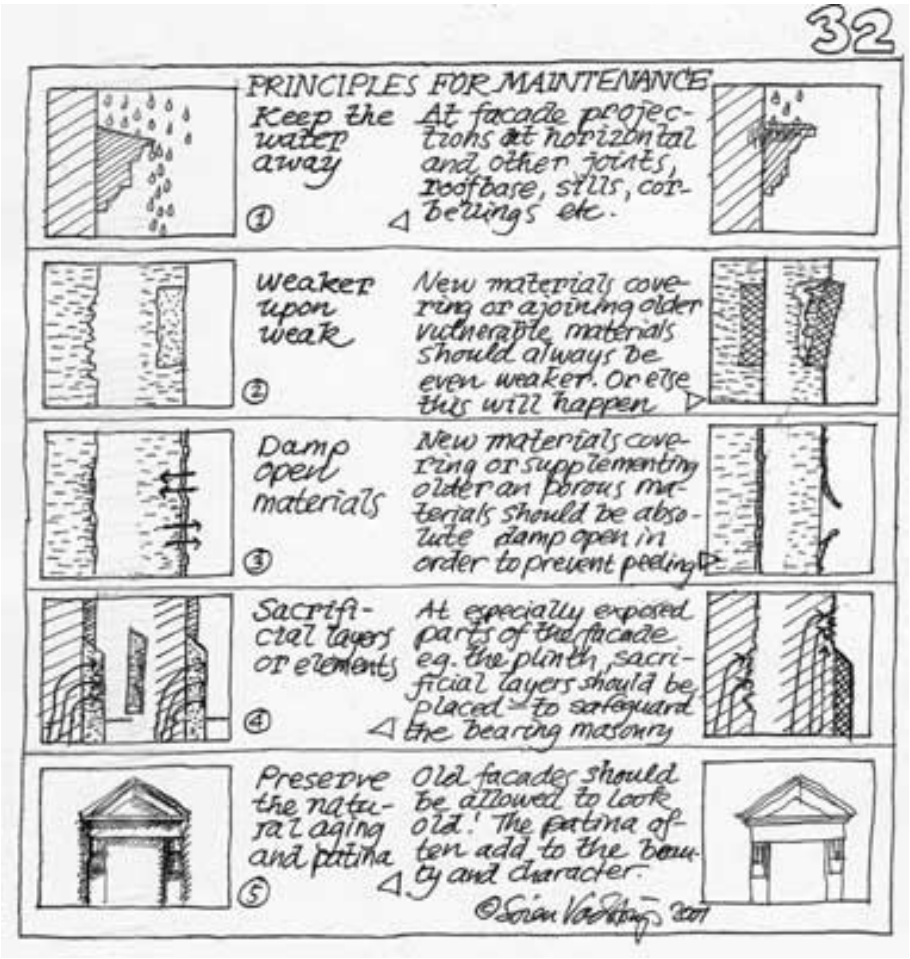
A problem in connection with much maintenance work, carried out on old buildings is that it is done wrongly in three ways:

1 The maintenance is done with wrong materials.
Many new materials, especially paint types, cement mortars, coating- and reinforcement-materials, are too hard, strong or tight for old buildings and old facades.

2 The maintenance is done too often and too much
In order to look nice, clean and presentable, facades are surface cleaned or painted perpetually. Too thick paint layers, due to continual painting, are not suitable, and will peel or crack faster than thinner layers. Too much cleaning and scraping wears out the original materials.

3 The maintenance is done without awareness of the special technical conditions on old facades, made of traditional building materials and building techniques.

On drawing 32, is shown 5 principles for appropriate repair and maintenance on older facades:



1 Rejecting water

As water is the worst damage causing factor, it is simply a question of keeping the water from lying on top sides of walls, projections, friezes etc. by making the top side slander. It is also very important to tighten all gaps, joints and material adjacent, where water can settle or intrude.

2 Weaker upon weak

Never put too hard materials on weak and vulnerable materials and surfaces on old houses. A "fight" will often occur between the materials, which the strong agents will win - and either reject the weak materials or be rejected itself very quickly, at the same time spoiling parts of the old, original materials.

3 Damp open materials

It is important always to use damp open materials on old facades. Too water tight surfaces or layers will result in immediate peeling or flaking - and all the work is wasted and furthermore, has to be removed, damages restored and new and more suitable treatments applied. This is waste of original materials and waste of money.

4 Sacrificial layers

At certain exposed and vulnerable places on the facade, for instance just above the ground, on top sides of unprotected walls and projections, where the deterioration goes faster, the traditional building techniques operate with *sacrificial layers or elements*, which can be replaced and substituted continuously with new materials, when the old ones are too destroyed to function. The plinth render is in this way a sacrificial layer, where the salts and moisture are gathered, so the basic masonry in this way avoids these damaging substances and therefore is protected from deterioration. This means firstly that the plinth render has to be changed more rapidly than the basic masonry, secondly that it is a bad idea to put a hard and tight surface treatment at the plinth render, the result of which is that the salts and moisture rise even higher - and cause damage here.

5 Natural aging and patina of old buildings

The first rule for all maintenance is to do as little as possible - but adequately enough to keep the constructions and materials in good shape. There is absolutely no reason for replacing old and vulnerable materials and elements, just because they are old, if they can still fulfil their purpose and function. Many old materials in excellent condition - often much better than the replacing new materials - have been changed during the years, and still today, without any other reason, than the uncertainty and ignorance of the owner, advisor or craftsman. This does also cost the house owners many unnecessary amounts of money. Old houses should be allowed to look old, aged and furrowed and with their natural patina.

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Regular maintenance routines

The most important principle for the maintenance of old buildings – and new as well - is a consequently planned system and regularity. Here is a proposal for *regular maintenance routines* for facades:

Every year:
Carried out from ground, ladders and windows etc.

1. Clean gutters and down pipes
2. Tighten all available gaps, joints and material adjacent, where water can settle
3. Wash dirt from all available top sides of facade projections, sills, portals etc.

Every 5th year:
Carried out from ground, ladders and windows etc.

The above mentioned points 1 - 3 plus

4. Check the terrain around the facade
5. Check possible settlement cracks for activity

Every 10th to 15th year:
Carried out from a scaffolding.

The above mentioned points 1 - 5 plus

6. Tighten all possible gaps, joints and material adjacent, all over the façade where water can settle. Especially mortar joints around windows and doors. Possible rubber- or silicone joints must immediately be replaced with lime mortar joints.
7. Wash dirt from all top sides of facade projections, sills, portals etc.
8. Wash the whole, or just the necessary parts of the facade with water and light cleaning detergents and soft brushes or soft water squirts.
9. Check and tighten roof foot, eaves, gutters and down pipes
10. Check and rustproof possible iron elements, including anchors, the gutter bearings, and iron rails etc. surface-treatment of other materials: wood, cast iron, etc.

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Literature

Literature about plasterwork of lime- gypsum and Portland cement mortar on facades

Materials, working methods, deterioration and repairs

Chronologically:

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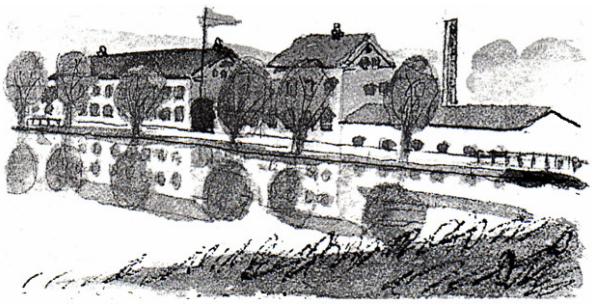

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