The history of mortar

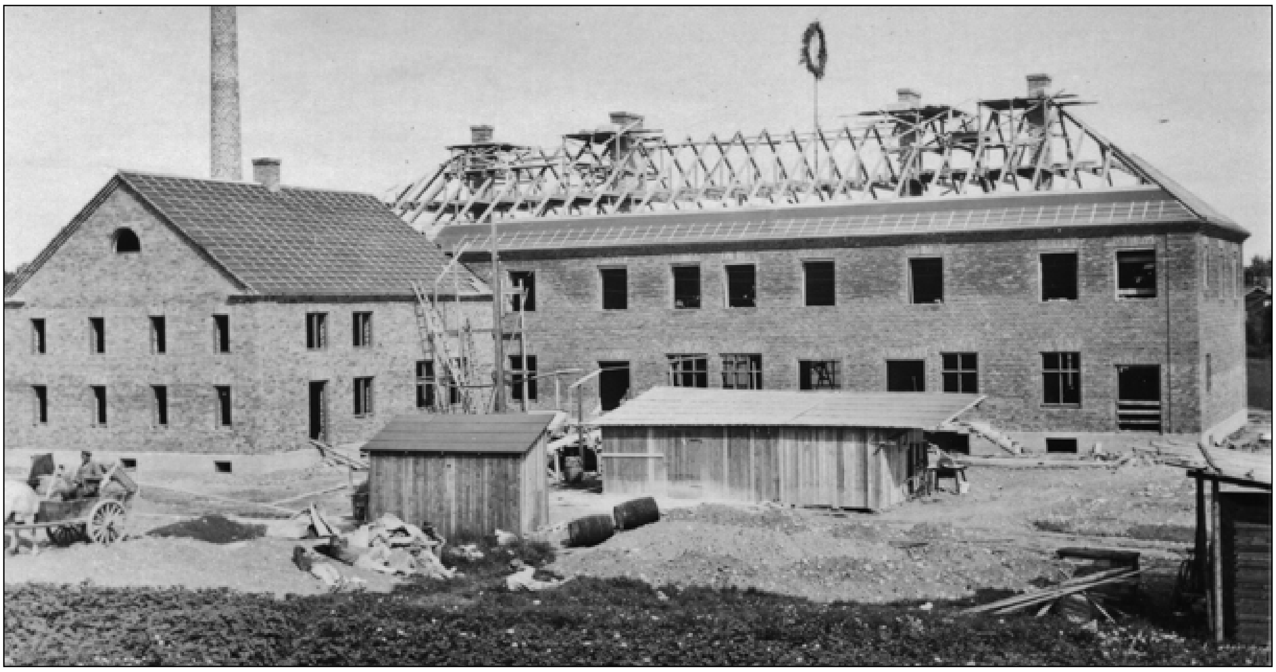
THE DEVELOPMENT OVER TIME OF MORTAR AND RENDER

The limestone quarry in Slite on the island of Gotland in Sweden.

by Knut Åkesson

This publication is dedicated to the memory of the late Director-General of the National Heritage Board ***Sven B.F. Jansson*** *"Runjanne" who, together with his wife "**Tuss**", guided me into the task.*

I would also like to thank Erik Durrant who kindly translated this document into English.



Krylbo dairy 1926, from the archive of Lars Östlund.

The photograph shows how a bricklayer's workplace looked in 1926. The machines and safety measures we now take for granted were totally absent. All work was performed by hand. The brickwork is constructed with block-jointed, full-sized red brick from Bältarbo, with beaded jointing and beautiful vaulting over the apertures.

The brick format is approximately 295 x 140 x 70 mm. The chimneys have been completed and roofing is under way prior to the completion during the autumn of the facade joinery and interior rendering.

A potato patch is in flower in the foreground. On the left can be seen a horse and cart with the carter in his seat after delivering coal. Some workmen are resting on the grass in front of the smaller shed (the limeshed). Several of them are wearing typical bricklayers' clothing.

To the right of the limeshed, a couple of wooden quicklime barrels which have been emptied of their contents of burnt limestone, CaO, are lying in the gravel. The lime shed was where the quicklime was slaked with water and whisked together with aggregate to make mortar and render.

The mortar and render were strengthened by the addition of cement and gravel to make concrete for the foundations and beams.

The ground between the sheds and the bottom of the larger shed are white from lime and cement spills.

Masonry and bricklaying are dependent upon the continual lime cycle:

$CaCO_3 \rightarrow CaO + CO_2$

Calcium carbonate ($CaCO_3$) is converted into calcium oxide (CaO) and carbon dioxide (CO_2) when heated. Carbon dioxide (CO_2) is released to the air and calcium oxide (CaO), often known as quicklime, remains. The process is usually called "calcination".

$CaO + H_2O \rightarrow Ca(OH_2)$

When water (H_2O) is added to calcium oxide (CaO), calcium hydroxide ($Ca(OH)_2$) is formed. This is also known as slaked lime.

$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$

Calcium hydroxide ($Ca(OH)_2$), which is used in e.g. mortar, reacts with carbon dioxide (CO_2) from the air and is converted back into calcium carbonate ($CaCO_3$). Water molecules are released into the air in the process.

Summary

Throughout the centuries, limestone has been roasted and slaked under primitive conditions. The burned lime was then whisked together with whatever ballast was available to form mortar and render which often had the right properties.

Many of our older buildings still show surprising evidence of how well that worked.

”By the right properties we mean that the mortar, because of its elasticity, is able to absorb the forces created by the temperature-driven changes in volume of the building stones so that these forces do not spread and increase laterally”

In time, the production of binder lime evolved to become a quality controlled industry and this entailed a number of problems for masonry, as described below.

The twentieth century was typified additionally in masonry by the increasingly common use of cement even in the maintenance of historic buldings.

Traditional masonry.

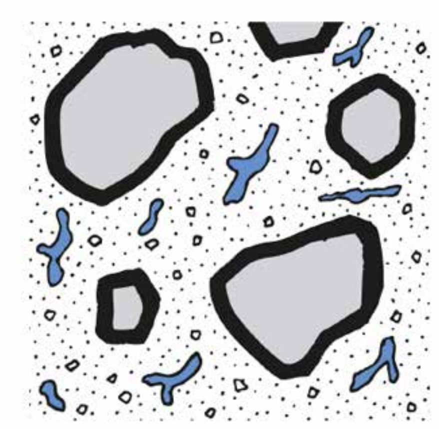
Cement was later blamed for causing a multitude of problems affecting masonry, although these can usually be blamed on the change to the use of leaner mortars, richer in sand, regardless of the binder material.

The lime-rich 1:1 mortars changed eventually to sand-rich 1:3 mortars as shown below.

The 1560s

The 1960s

Lime kilns became progressively more efficient. In order to avoid the shrinkage which occurs when the lime binder cures and dries, mortar was made leaner and leaner (richer in sand).



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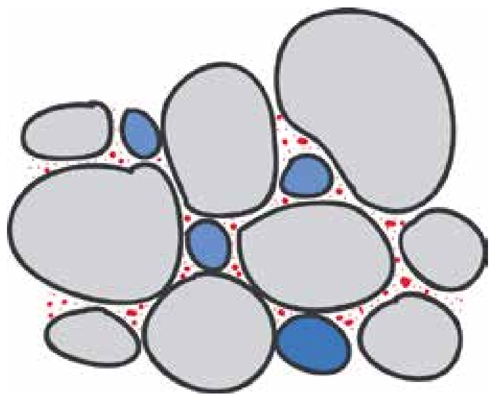

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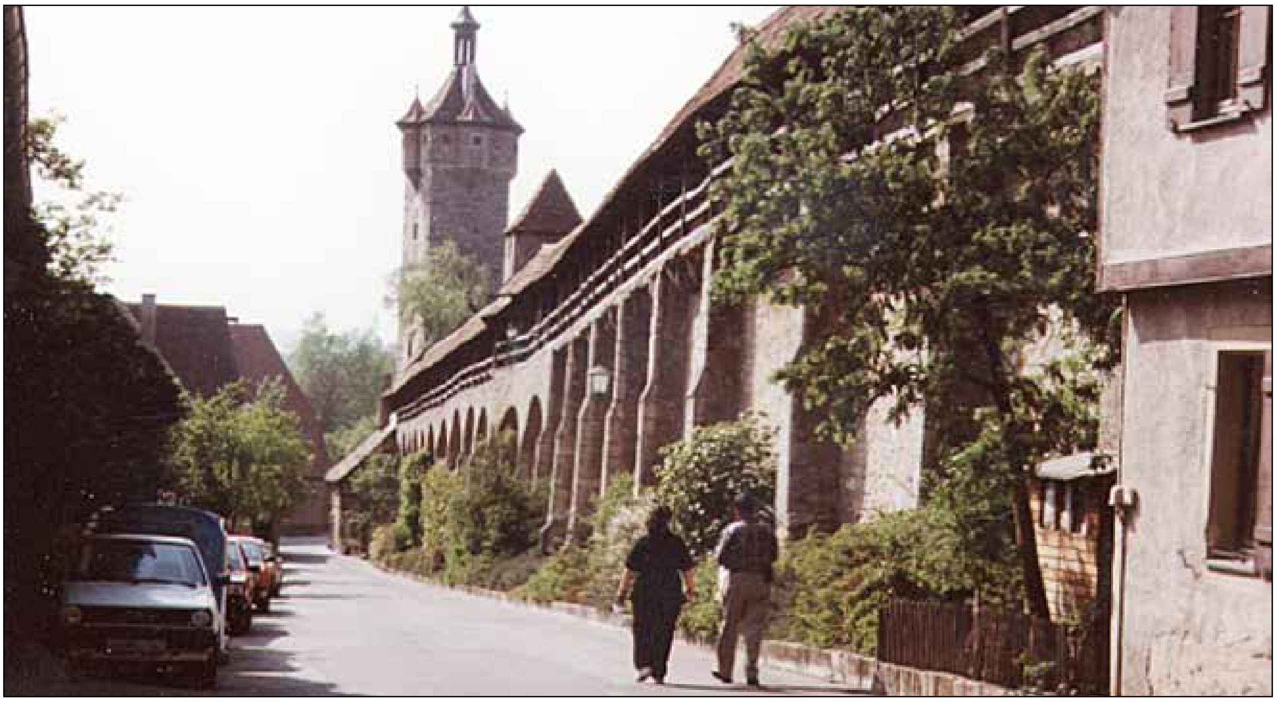
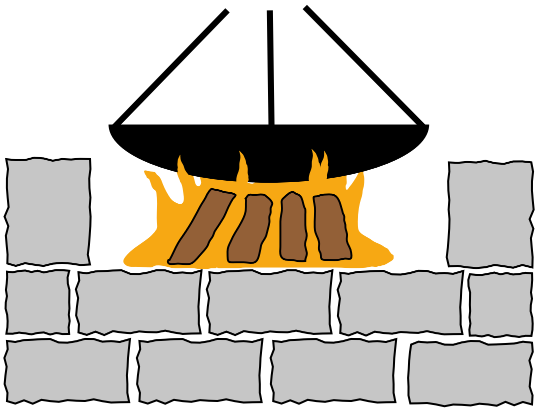


Elastic masonry which is protected by a peacetime roof.

In the following text we describe the probable development of mortar and render through the ages. Our text is the result of more than fifty years' experience of work, practical research and the testing of mortar and lime-wash in Europe from all epochs.



It may all have started thousands of years ago by someone or a group of people discovering that limestone became lighter after it had been heated strongly and for a long time and that it hissed when water was poured on it, heat being released and the stone almost dissolving into a paste-like material which later shrank and slowly regained a hard structure.

Experiences of the cycle described above led in time to the burning and slaking of lime-stone to form a binder in mortar so that more primitive dwellings could gradually be abandoned. Mortar and render with lime or cement binders became one of the most valuable building materials ever created.

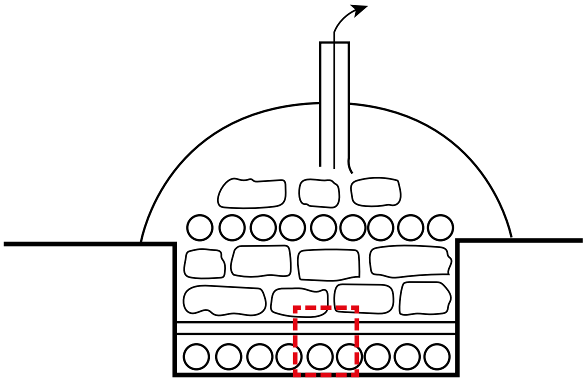
Burning and slaking in the past

At first, the manufacture of lime occurred very simply at the building site by layering limestone alternately with firewood in a hole, covering it over and firing it. When the stone had cooled down, it was slaked with water, aggregate was added and it was all whisked together to form mortar.

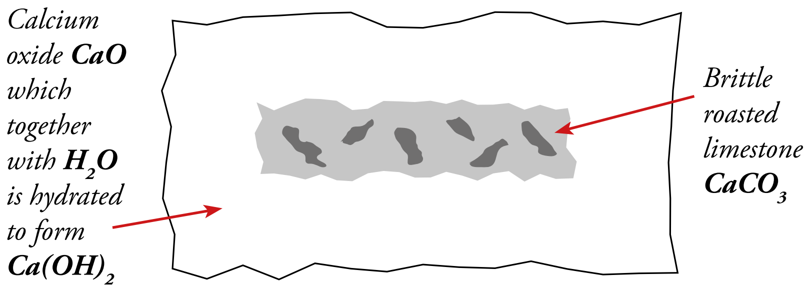
Lime burning was incomplete, seen through our current view of quality control, as most of the limestone was not burned sufficiently to be slakeable to a binder.

The stone that was not slaked was however so brittle due to the heat that it could easily be broken up so that there were not too many large lumps in the final mortar. Mortars became lime-rich and thus so elastic that enormously long walls could be built and stand for centuries without the necessity for the creation of special stress-absorbing dilation joints, see p. 7.

As regards quality and function, the earlier lime-rich mortars and renders excel by comparison with most of those produced after the 1890s. In the nordic climate they require good protection against damp and need to be of sufficient thickness for there to be space for additional damp without the pores becoming filled with water when frost strikes.



Lime burning in a hole dug in a slope.



Lime-rich mortar and render without contraction cracks showing roasted soft lumps of limestone. That on the left is from the late middle ages and on the right from the 18th century. Both with equal parts by weight of lime and whichever aggregate was available.

Template moulding in lime render.
Photo: Simon Patetsos, TP Mur & Puts AB

Analysis of older intact mortars typically reveals that the proportions by weight of lime and aggregate are nearly equal. One part lime with a low content of binder was whisked with an equal part of aggregate.

This did not lead to the problems associated with shrinkage that always occur when the proportion of binder exceeds 13% by weight.

Cracks arise on shrinking and render loosens from the substrate even if the crack is refilled.

400 year mortar with small lumps of limestone and fragments of charcoal.

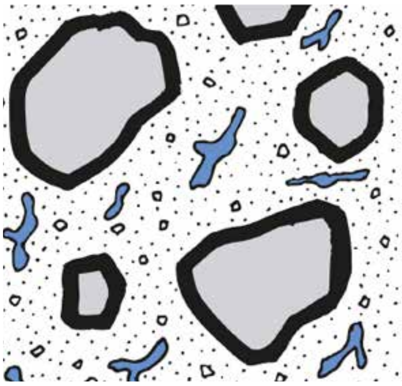
The lime-rich mortar we today call 1:1 is so elastic that it absorbs movements even from the temperature-driven volume changes of large stone blocks in such a way that the forces do not increase and spread sideways.

Elastic joints permit the use within certain limits of larger and smaller building stones without these affecting the neighbouring stones.

Traditional mortar - Mortar 1:1

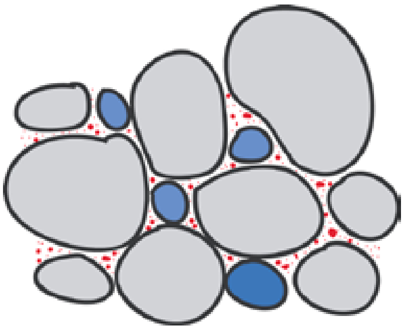
This mortar is typified by its ease of working and is a microscopic porous copy of the wall itself: the individual aggregate particles and building stones are embedded in lime and pores.

The aggregate provides strength to the mortar and significantly reduces the amount of lime needed.



Mortar 1:1.

Modern mortar - Mortar 1:3

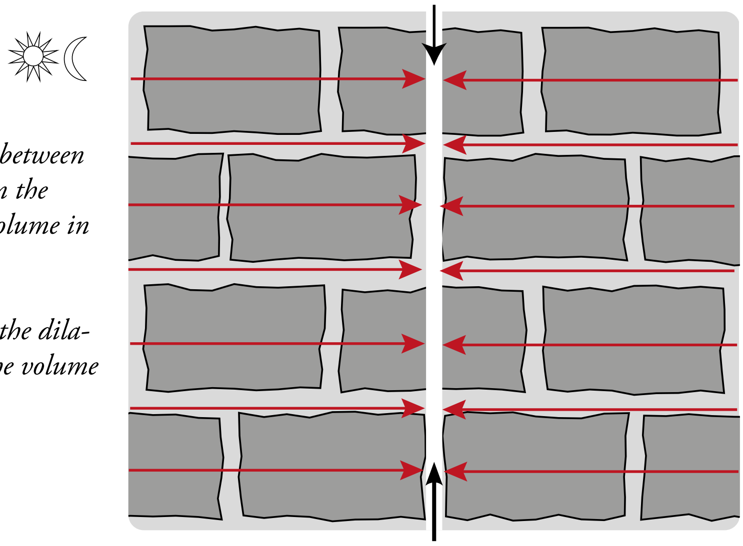


This sand-rich mortar is called 1:3 and is bound with lime and/or cement. The plasticity and porosity of the mortar are achieved through the addition of various chemicals.

Over time and with the increase in construction, production developed into an industry where nearly all the limestone that is burned is converted into binder, $Ca(OH)_2$, which can be used in mortar up to a maximum of 13 per cent by weight.

Throughout almost all the twentieth century, 1:3 mortar bound with lime and cement was used even for repairs and maintenance of historic buildings. Numerous problems have been observed with these mortars.

The lean mortars lack elasticity, thus requiring the construction of dilation joints. This is necessary even in new brick walls where the horizontal joints form a pressure bar forcing the corners away from the wall.



Variations in temperature between day and night and between the seasons create changes in volume in the wall.

The black arrows indicate the dilation joints which absorb the volume changes.

An example of the problems

The wall in the photograph below has no protective roof and collapsed at the beginning of the 21st century after having been repointed during the 1950s - 1960s with a lean lime/cement mortar.

The mortar prevented the damp which penetrated through the unprotected crown of the wall from leaving the inner part of the wall. Over time, sideways forces appear and increase in the outer part of the wall to such an extent that bulging portions of the wall are pushed away.

An example of a wall which was repointed with a sand-rich, non-elastic mortar.

Conclusions reached after many years of laboratory and full scale testing

Mortars and renders used in historic buildings can present a variety of different problems which are often blamed on the presence of cement.

Our analyses and experiments which started in the 1970s show that the real cause in the nordic climate is the plentiful admixture of silica sand.

When aggregate grains lie glued together in horizontal joints they function together volume-wise like concrete.

An example of a brick cavity wall expanding over the corners as a result of the horizontal joints forming long pressure bars.

Our interest in the quality problems of mortar was aroused during the 1970s during our cooperation with, amongst others, Ivar Öhrnelius from Stråbruken AB concerning how to prepare a new mortar for repair work at Skokloster and Strömsholm.

After experimentation we gradually came to two conclusions:

• The proportion of lime binder should not exceed 13 per cent by weight.

• The concentration of limestone in the lime mortar is achieved by reducing the silica sand content and replacing it with ground limestone as a substitute for the roasted lime stone of older mortars.

By these means, we have been able to reconstruct a lime mortar with the correct properties required for traditional masonry, see page 1.

We and our clients are happy to see that the result of our analyses and tests has led to ever more use of our lime-rich mortars and renders for the care and maintenance of nordic historic environments.

Our theory also applies to the recycling of render

In the case of Våmhus church, we removed all the render from the tower in 1996, ground it down and restored it to the correct elasticity with limestone filler and lime binder and re-rendered the tower with a satisfactory result. For further information, consult our brochures on lime mortar.

A recipe for mortar and render for historic buildings:

- 10-12 per cent by weight of binder where the type is chosen with regard to factors such as the risk of frost and damp.
- 50-70 per cent by weight of silica sand.
- 25-38 per cent by weight of limestone filler consisting of ground limestone in order to ensure elasticity.

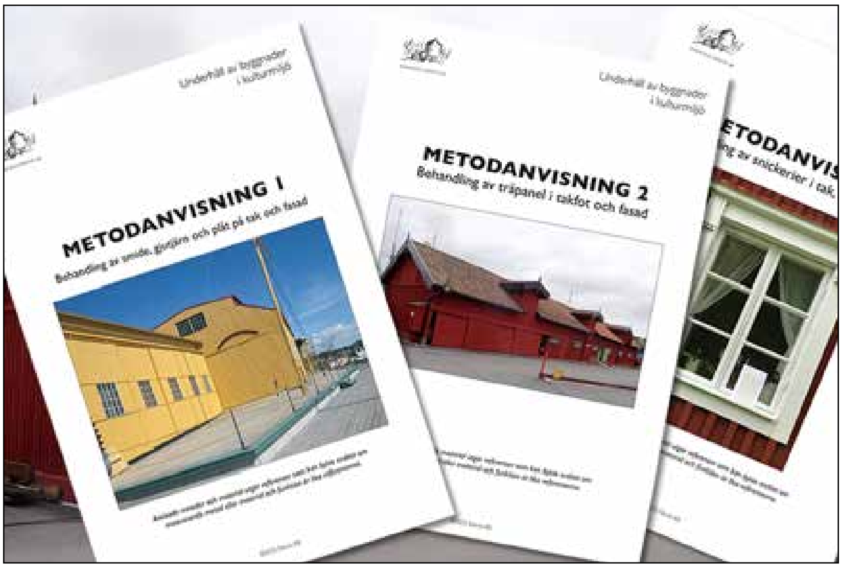
Further information concerning the use of lime mortar and limewash in the care of historic buildings can be obtained from our brochure ”*Lime mortar 8*”.

Våmhus church 25 years after its renovation. 12-7-2020

Future development

We are now focussing on updating the brochure "*Lime mortar 8*" to version 9 and are evaluating a large number of projects where a new type of lime mortar has been developed, specifically for the upkeep of masonry suffering from salt weathering (sacrificial render).

Our brochures about lime mortar and lime render, together with the methods described for upkeep of historical buildings, are available for use in projects in which we are involved.



What about the costs?

"Long term management demands that the price of cheap but faulty should not be compared with that of more expensive and correct."

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