LIME MORTAR IN MODERN CONSTRUCTIONS

FACTS – ASSUMPTIONS – OPPORTUNITITES

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Presentation is also here:

https://www.murforum.no/aktivitet/arsmote-nordisk-kalkforum-2023/

Lime mortar in modern constructions

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Text

I will try to explain the differences in the life of the materials of a wall that is a few hundred years old, and that of a new one. I will also show some tests where we compare the properties of cement mortar and lime mortar. I want to spend some time discussing this before we get to the point: Can the lime resurrect and have a prosperous future in today's construction culture?

Over time, construction methods have adapted to new requirements and have been successful in many ways. There is little need to change construction methods that work. The margins are very small, so: If it works, don't fix it.

Guidelines for any changes must come from the proper authorities within building acts and regulations.

If there are instructions to change the choice of material, one will first seek to exchange like for like.

We cannot replace cement with lime directly. Nor can we say that what worked 150 years ago will

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Text

Work in today's modern buildings.

The building constructions are different today than in earlier times. It's easy to overlook this and walk into pitfalls.

We need to understand the technical development history of construction.

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The change of the masonry's outer walls over time

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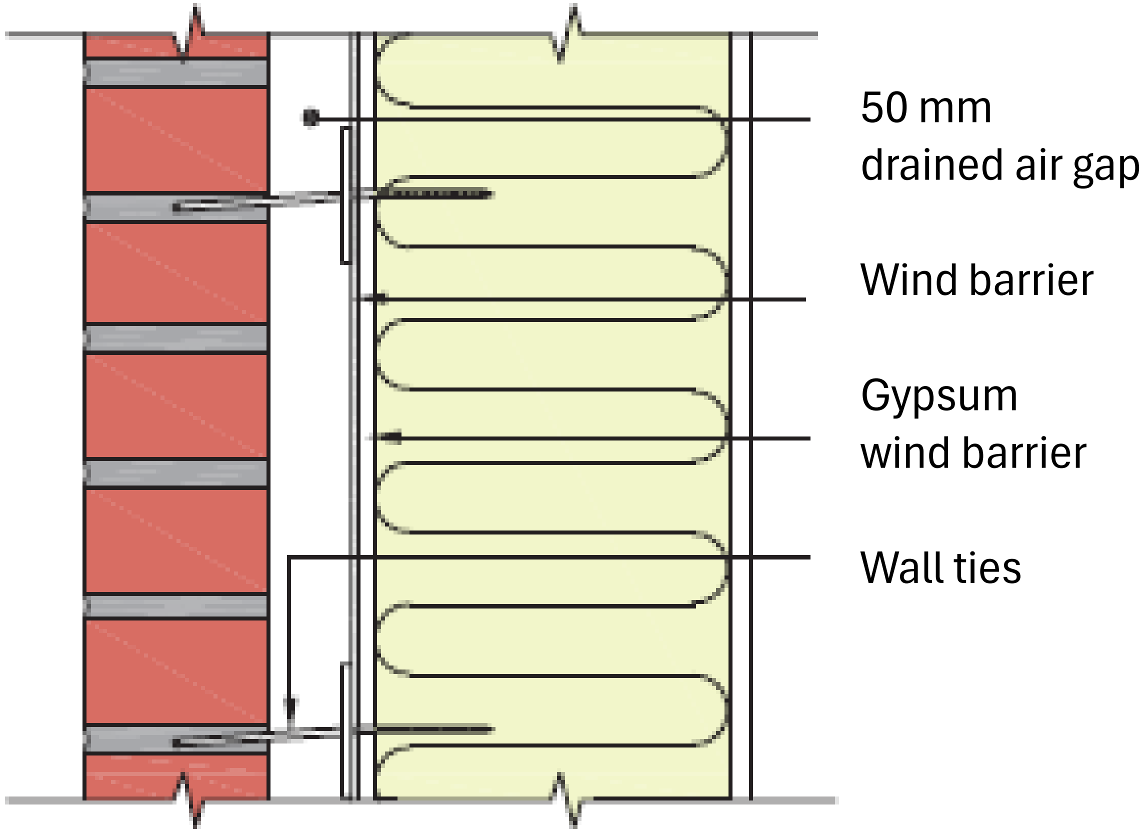
50 mm
drained air gap
Wind barrier
Gypsum
wind barrier
Wall ties

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Text

Outer walls have changed from "warm wall" to "cold wall" Massive wall to Cavity wall.

The massive walls without insulation benefited from heat loss from the room inside and had, in addition, large pore volume to handle a lot of moisture without frost affecting this significantly. The buildings were drafty, and this helped keep them sufficiently dry.

A modern building is airtight. The outer wall consists of a well-insulated climate wall within a climate shell. The climate shell is separated from the climate wall with a well-drained air gap. This climate shell is a "cold" wall. This exists under harsh climate conditions without the help of any heat loss from the rooms within.

The change from warm to cold wall in history is a fundamental one, and we must understand the consequences of it. The "cold" wall is subjected to more moisture and frost, and modern materials must take this into account. The building is exposed to a climate cycle - the four seasons. If the cycle is balanced, this will be the case for years. Torrential rain-frost-thaw-sun and drying. Over time we have found solutions for this in line with new requirements for buildings.

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Outer walls

Have changed from "warm wall" to “cold wall" and from massive wall to cavity wall.

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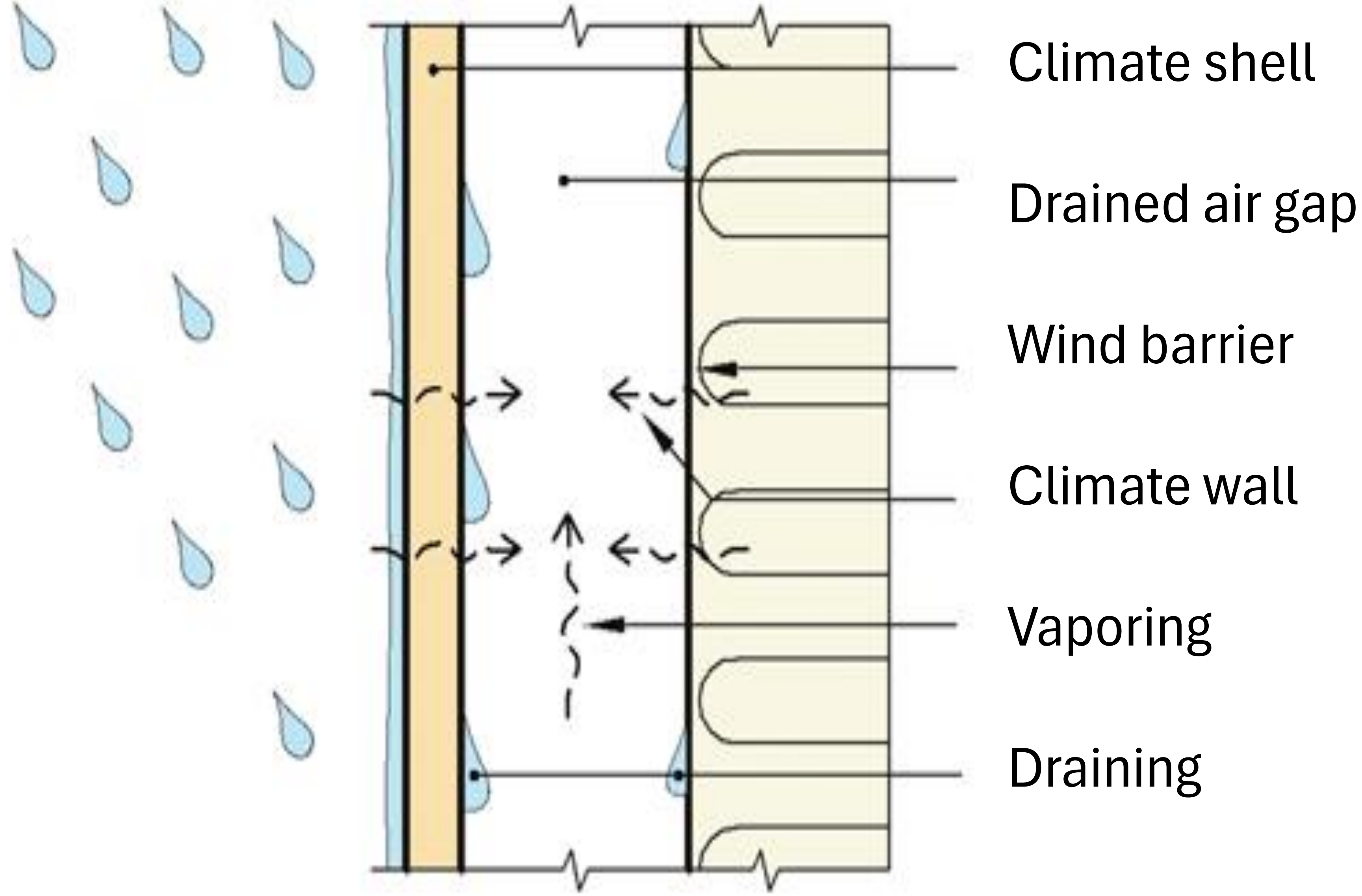
Climate shell
Drained air gap
Wind barrier
Climate wall
Vaporing
Draining

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Text

The illustration shows the basic principle of an exterior wall

Text

Norway has the world's second longest coastline, 100,915 kilometres. It is along the coast with a view towards the sea we will stay.


AIDA
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Text

Our coast often surrounded by mountain ranges ensure that we are heavily exposed to torrential rain and freeze-thaw cycles on a daily basis.

We are also exposed to acid rain and sulfuric acid


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Text

Ålesund. a beautiful weathered landscape

Text

Northern Norway. wild and beautiful

We are obliged to use materials and solutions that can withstand the climate cycle.

NS 3420 Materials chosen by the contractor must be resistant to the anticipated climatic or operational stresses.

The rigid cement has helped to solve this.

If we want to use traditional and more yielding composite materials again, we must adapt these to today's construction methods and requirements. However, it is also possible to change the construction methods to meet these changes.

According to today's building regulations, we must design, choose materials and execute construction so that the buildings are resistant to the expected climatic or use-related stresses. This must be documented before we build.

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Text

Constructive and climate-exposed walls.

With the arrival of cement, we made the masonry stronger and stronger. So strong that we are sure it will last.

On the flipside? How weak can masonry be, and still do the job? Can we use the material we used 150 or 500 years ago? Will it then withstand the load and the exposure?

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The engineer

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Tabell NA.904 – Konstruksjonsfastheter og elastisitetsmoduler for murverk av teglstein.

Teglstein		Mørtel	Murverkets egenskaper – se NA.3.6(901)									
TYPE	trykk-fasthet	trykk-fasthet	trykkfasthet		bøyestrekk-fasthet		skjærfasthet		elastisitetsmodul			
	N/mm²	N/mm²	N/mm²						kN/mm²			
			vert.	horis.	vert.	horis.	basis	maks.	korttidslast		langtidslast	
	f_{by}	f_m	f_{ky}	f_{kx}	f_{xk1}	f_{xk2}	f_{vk0}	f_{vlt}	E_y	E_x	$E_{y\infty}$	$E_{x\infty}$
MASSIVTEGL	65	20	13,8	13,8	0,78	2,95	0,70	2,10	13,8	13,8	10,0	10,0
		15	12,8	12,8	0,70	2,80	0,60	2,10	12,8	12,8	8,9	8,9
		10	11,6	11,6	0,54	2,60	0,45	2,10	11,6	11,6	7,5	7,5
		5	9,7	9,7	0,49	2,25	0,35	2,10	9,7	9,7	5,8	5,8
	50	15	10,5	10,5	0,70	2,45	0,60	1,75	10,5	10,5	7,6	7,6
		10	9,5	9,5	0,54	2,25	0,45	1,75	9,5	9,5	6,4	6,4
		5	8,0	8,0	0,49	1,95	0,35	1,75	8,0	8,0	4,9	4,9
	40	15	8,9	8,9	0,55	2,20	0,50	1,50	8,9	8,9	5,9	5,9
		10	8,0	8,0	0,46	2,05	0,40	1,50	8,0	8,0	4,9	4,9
		5	6,7	6,7	0,40	1,75	0,30	1,50	6,7	6,7	4,1	4,1
	28	15	6,8	6,8	0,47	1,90	0,45	1,20	6,9	6,9	4,2	4,2
		10	6,1	6,1	0,39	1,75	0,35	1,20	6,1	6,1	3,7	3,7
		5	5,1	5,1	0,31	1,50	0,25	1,20	5,1	5,1	3,1	3,1
	16	15	4,4	4,4	0,41	1,45	0,40	0,80	4,4	4,4	2,7	2,7
		10	4,0	4,0	0,32	1,35	0,30	0,80	4,0	4,0	2,4	2,4
		5	3,4	3,4	0,23	1,20	0,20	0,80	3,4	3,4	2,1	2,1
		2,5	2,8	2,8	0,20	1,00	0,15	0,80	2,8	2,8	1,7	1,7
HULLTEGL – hullandel, h_a < 25 %	65	20	13,8	9,4	0,78	2,30	0,70	1,60	13,8	15,5	10,0	11,2
		15	12,8	8,7	0,70	2,20	0,60	1,60	12,8	14,7	8,9	10,3
		10	11,6	7,9	0,54	2,00	0,45	1,60	11,6	13,0	7,5	8,4
		5	9,7	6,6	0,49	1,75	0,35	1,60	9,7	11,0	5,8	6,6
	50	15	10,5	7,1	0,70	1,95	0,60	1,35	10,5	12,0	7,6	8,7
		10	9,5	6,5	0,54	1,80	0,45	1,35	9,5	10,7	6,4	7,2
		5	8,0	5,4	0,49	1,55	0,35	1,35	8,0	9,0	4,9	5,5
	40	15	8,9	6,0	0,55	1,75	0,50	1,15	8,9	10,0	6,7	7,5
		10	8,0	5,4	0,46	1,60	0,40	1,15	8,0	9,0	5,6	6,3
		5	6,7	4,6	0,40	1,40	0,30	1,15	6,7	7,5	4,2	4,7
	28	15	6,8	4,6	0,47	1,50	0,45	0,90	6,8	7,5	5,3	5,8
		10	6,1	4,2	0,39	1,40	0,35	0,90	6,1	7,0	4,3	4,9
		5	5,1	3,5	0,31	1,20	0,25	0,90	5,1	5,7	3,3	3,7
	16	15	4,4	3,0	0,41	1,20	0,40	0,65	4,4	5,0	3,5	4,0
		10	4,0	2,7	0,32	1,10	0,30	0,65	4,0	4,5	2,8	3,2
		5	3,4	2,3	0,23	0,95	0,20	0,65	3,4	3,7	2,2	2,4
		2,5	2,8	1,8	0,20	0,80	0,15	0,65	2,8	3,0	1,7	1,8
LETTEGL 25<h_a<35 %	12	15	4,0	0,45	0,34	0,55	0,35	0,50	6,2	2,2	3,5	1,3
		10	3,6	0,40	0,25	0,45	0,25	0,50	5,5	2,0	3,0	1,1
		5	3,0	0,35	0,20	0,40	0,18	0,50	4,6	1,7	2,3	0,9
		2,5	2,5	0,30	0,18	0,35	0,14	0,50	3,8	1,5	1,8	0,7

Text

The engineer has a set of regulations to deal with when designing. For brickwork, the starting point is values from a table.

The table is based on tests carried out over several decades, with bricks and cement-based mortars.

The bricks and mortar they are based on, have high strength scores. For example, the mortar quality is M5.

Lime mortars do not have these kinds of tables. Here, testing and documentation is needed so that the engineer can use the lime constructively in modern buildings.

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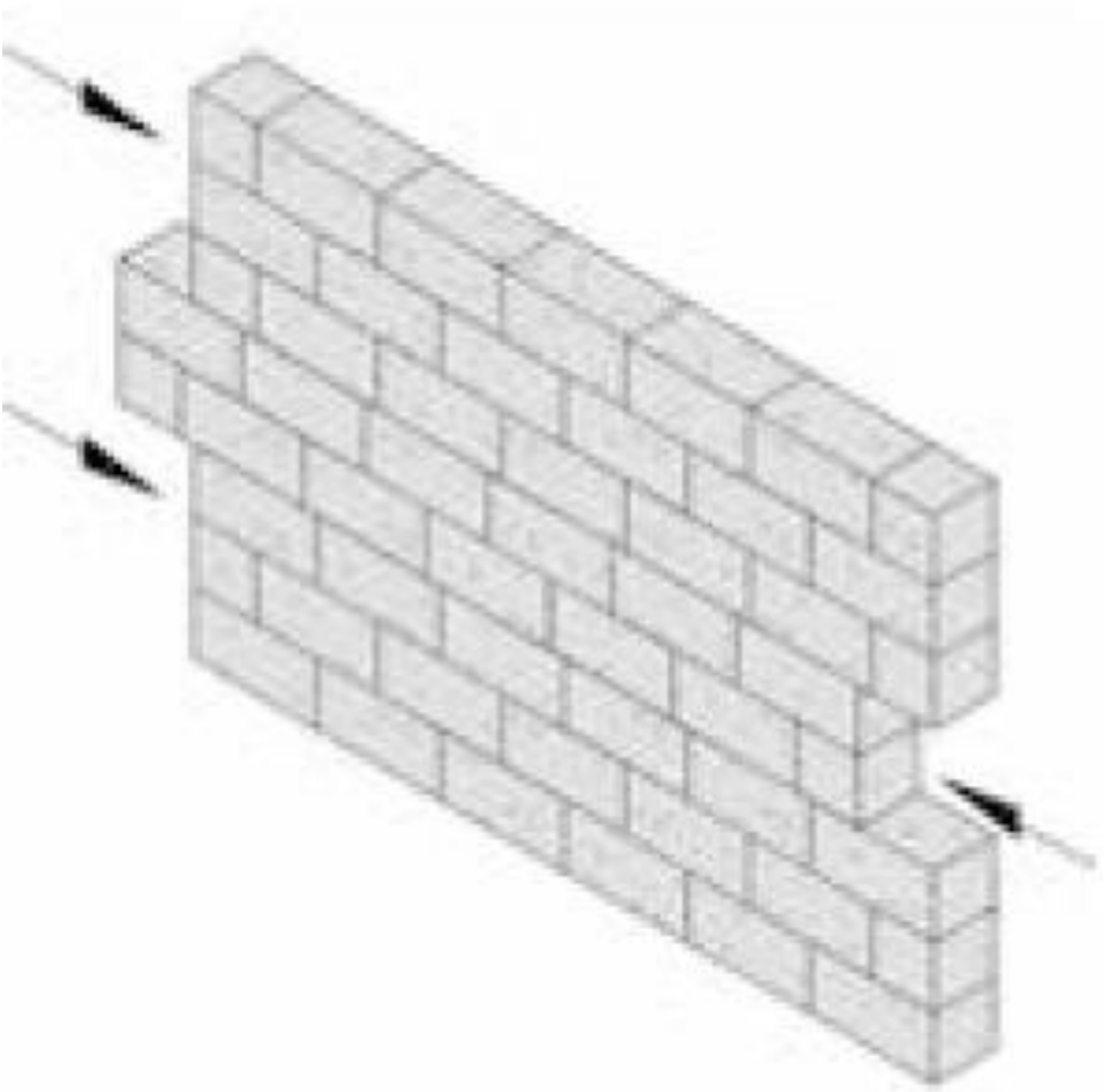
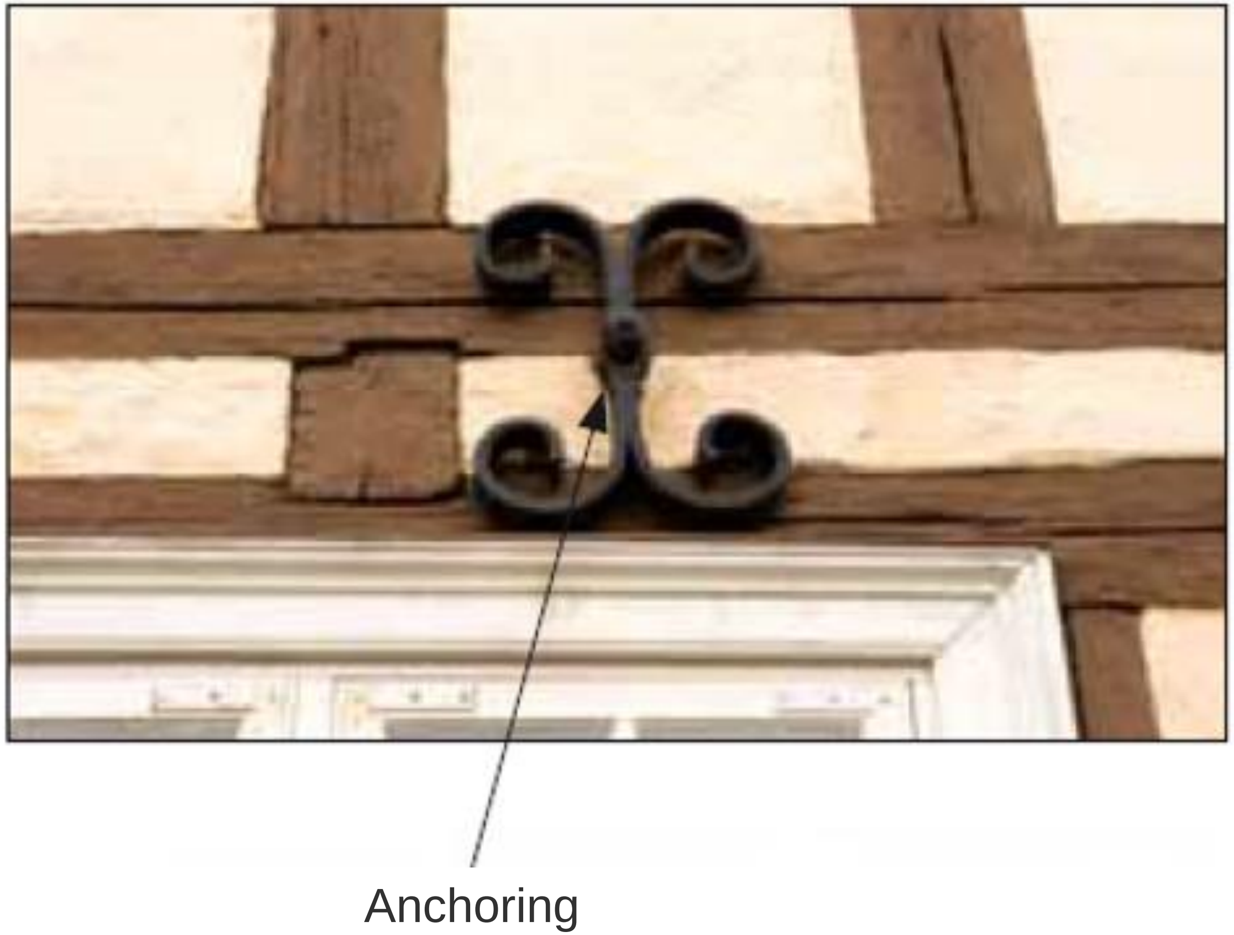


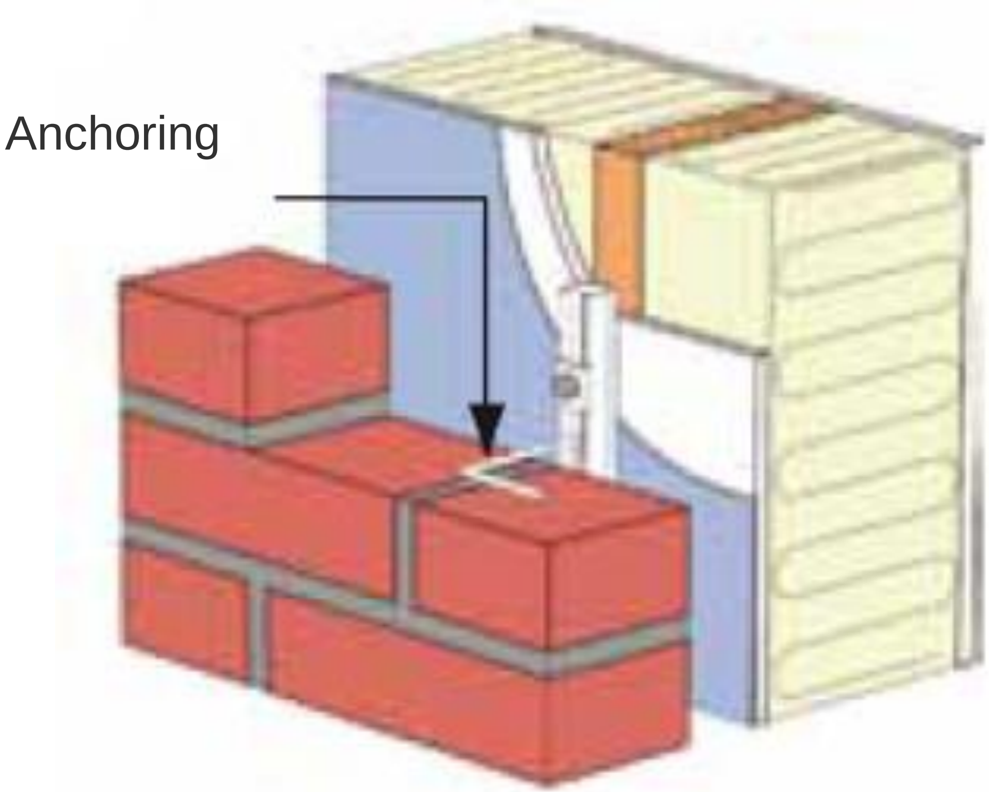
f_{vk0}

Text

For all new projects we expect Shear test (Stick between stone and mortar):

From EC6, a capacity of around 0.2 N/mm^2 is assumed unless otherwise specified.
Normally we say that the minimum value for shear tests should be 0.15 N/mm^2.





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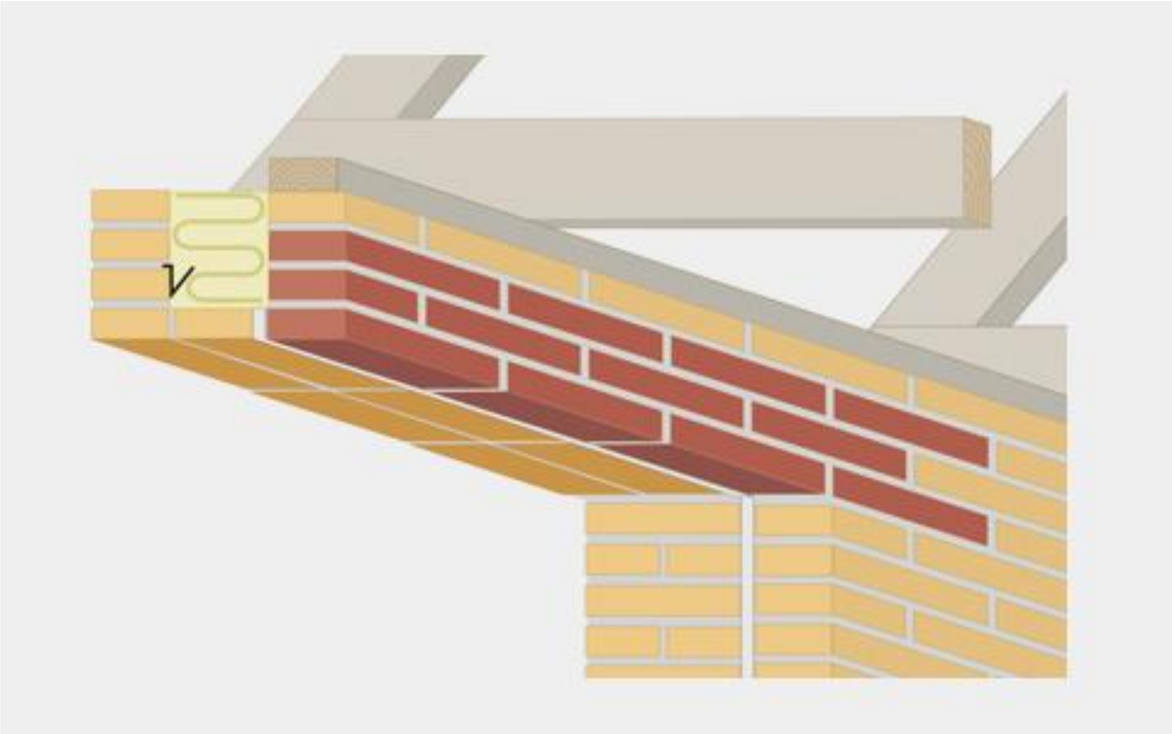
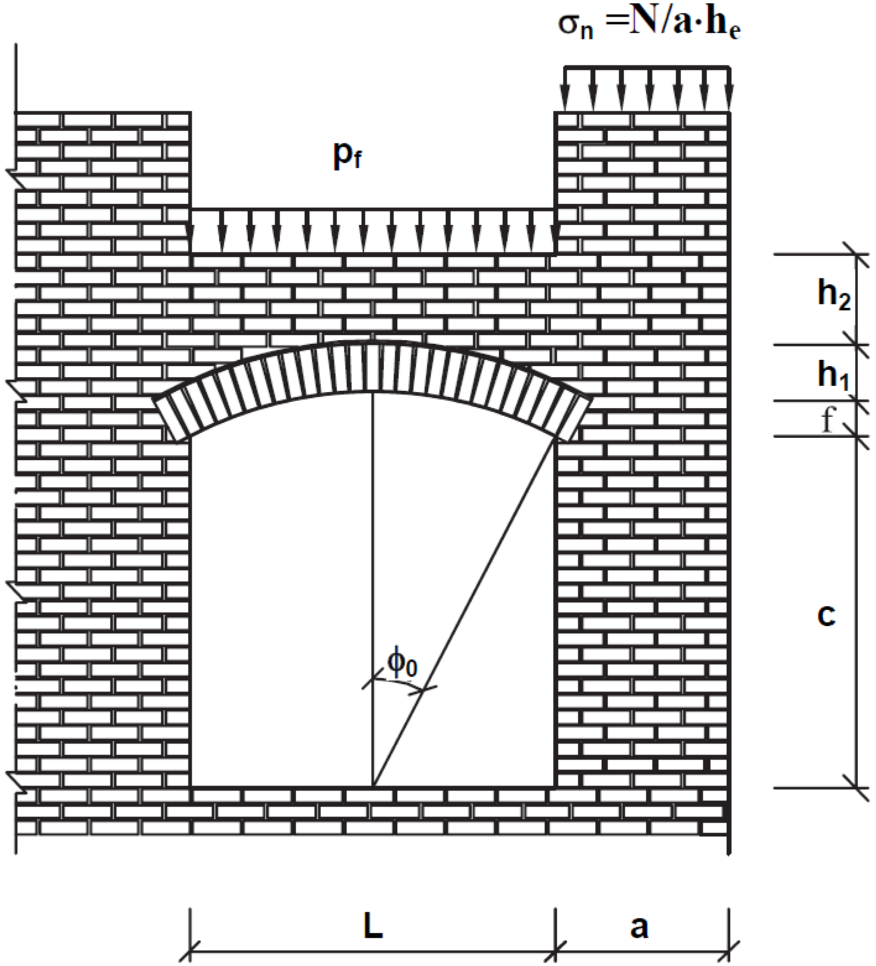
Text

Anchoring of the masonry is also based on mortar quality M5.

It is important to have sufficient information on how good the adhesion is between the reinforcement and the mortar. We have this for cement mortars, but not for lime mortars.





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Text

This capacity is generally assumed to be low for lime mortars. Can we find other types of reinforcement to use with lime mortars?

Possible solutions could be:

- Prefabricated beams (Can cause problems for larger spacing where there may be a need for adhesion between units and mortar)

- Steel beams above windows.

- Use of brick arches (Requires more from architects, and will be difficult to implement in relation to lighting requirements in modern apartments)

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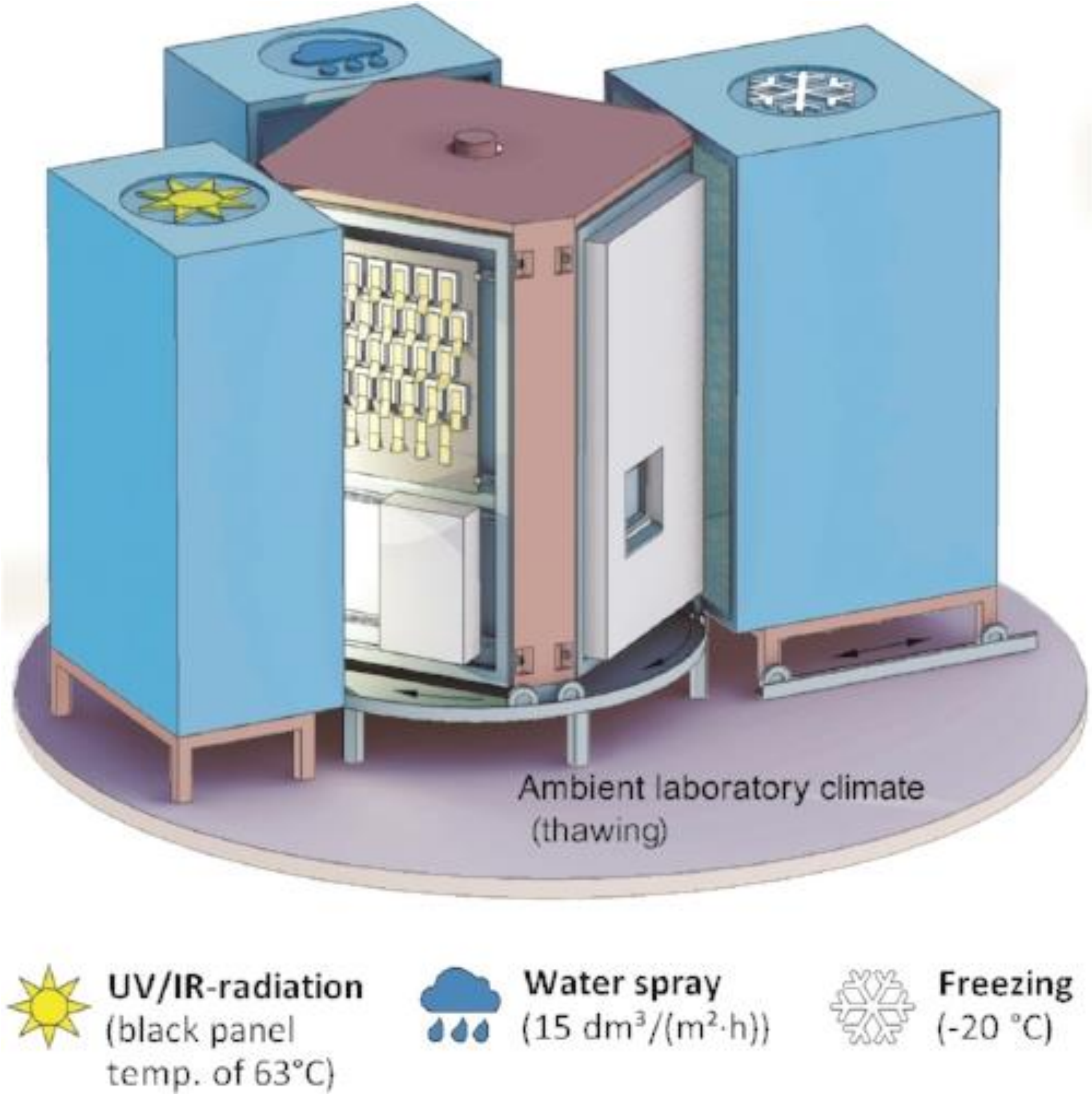
Weathering

Text

If we find that the strength of the lime is good enough, we must then check that it cannot weather. It is important to understand weathering and find solutions to prevent it. Pointing with a stronger mortar, may again be relevant where the masonry is to be left untreated.

And when we use reclaimed brick in the facade, why shouldn't we render the whole thing with lime mortar?


Ambient laboratory climate
(thawing)
UV/IR-radiation
(black panel
temp. of 63°C)
Water spray
(15 dm³/(m²·h))
Freezing
(-20 °C)

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Text

Masonry with lime mortars should be tested in a climate chamber the same way we do with cement mortars.

A comparison with M5 or M2,5 mortar would be of great help. It doesn't need to have the same strength, but a comparison would tell us something about its resistance to weathering.

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Strength test at NTNU

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Text

The table I refer to is based on several tests over time. We have now run a corresponding test with NHL 3.5. What we want to know is, how weak can the mortar be? Can it be strong enough for the construction and yet weak enough to be dismantled for reuse?

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First line, EC (M5), are properties of strength calculated according to Eurocode 6.

Second line, NS (M5), are properties of strength taken from the national supplement in Eurocode 6.

The third line, M5 SS, is cement mortar from which tests have been carried out.

The last line, NHL 3.5, is a lime mortar that has been tested.

[N/mm²]	f_m	f_{ky}	f_{xk2}	f_{vk0}
EC (M5)	5	9,64	0,40	0,20
NS (M5)	5	5,37	1,23	0,26
M5 SS	9,31	9,6	0,77	0,37
NHL3,5	2,11	4,6	0,30	0,11

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Text

F.m, the compressive strength of the mortar: shows that an M5 SS has a higher strength than what the standard states. when it comes to the lime mortar, the compressive strength be 3.5 N/mm2. The table indicates a lower value, but the lime mortar becomes stronger over time.

F.ky, Masonry's compressive strength: Here, we see that in the table M5 SS (9.6 N/mm2) agrees quite well with EC (M5) (9.64 N/mm2) and that we've been too conservative in the national supplement, NS (M5) (5.37 N/mm2).
As for the lime mortar of 4.6 N/mm2, it is not unreasonable that it is lower, and it is also not too far from the value used today (5.37 N/mm2). Regarding compressive strength, this is positive.

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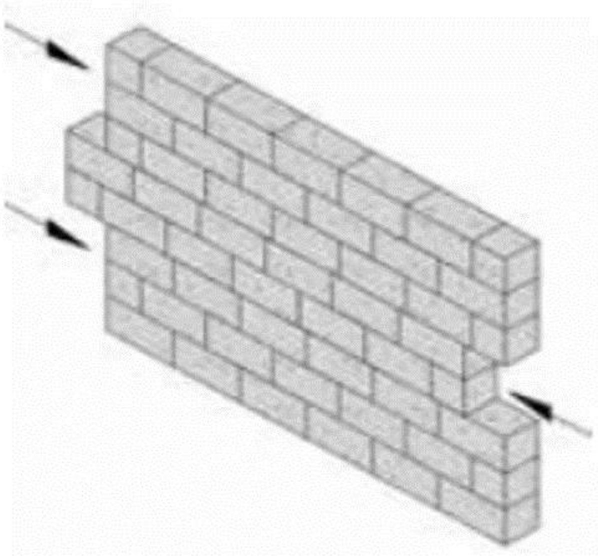
Text

F.xk2, The masonry's bending tensile strength in the horizontal direction: Here, Norway is bold with a value of 1.23 N/mm2, while the Eurocode only allows a bending tensile strength of 0.40 N/mm2. The tests with cement mortar (M5 SS) give an intermediate between EC and NS. The lime mortar is the one that gives the lowest bending tensile strength and that is no surprise.

F.vk0, Shear strength: Here, the M5 SS has the best results. Today, we strongly recommend that the shear strength of the masonry is tested in advance, as it has been experienced that it can be lower than what EC and NS provide. Here, that was not the case. The lime mortar has very low shear strength and in buildings where lime mortar is intended, it is important to take into account that the masonry cannot have such large shear forces. This primarily applies to openings.

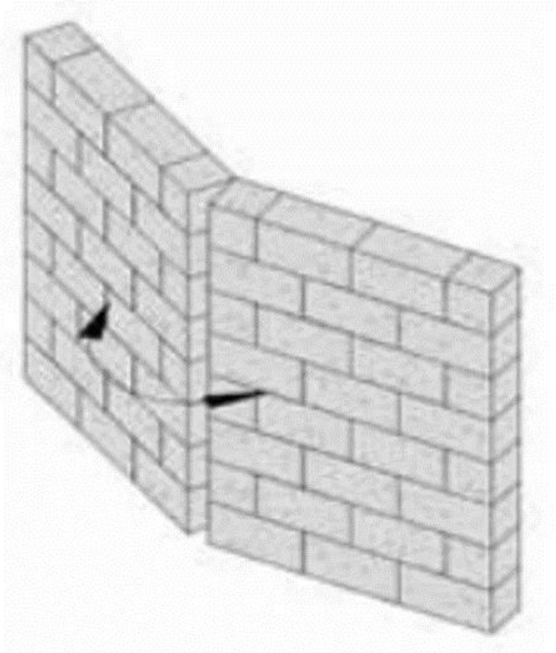
The lime mortar will stand out since the firmness is lower. It might have been more interesting if you could compare a cement mortar with the same firmness. It would have provided a better basis for comparison, e.g. compare M2.5 to NHL 2.5?



Skjær f_{vk0}

Text

Film from NTNU F.vk0, Shear strength



Bøyestrekk f_{xk2}

Text

Film from NTNU F.xk2, The masonry's bending tensile strength in the horizontal direction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Text

Film, dismantling for reuse

Interior walls

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Text

When we enter the building, we avoid many of these problems. The discussion of exposure classes is almost non-existent.

Internal brickwork has a lot going for it. We know how good it is for an indoor climate. Arguments such as heat storage, moisture regulation, being inorganic material and the fact that it does not release allergenic substances. School buildings, healthcare buildings and private homes will benefit from this.

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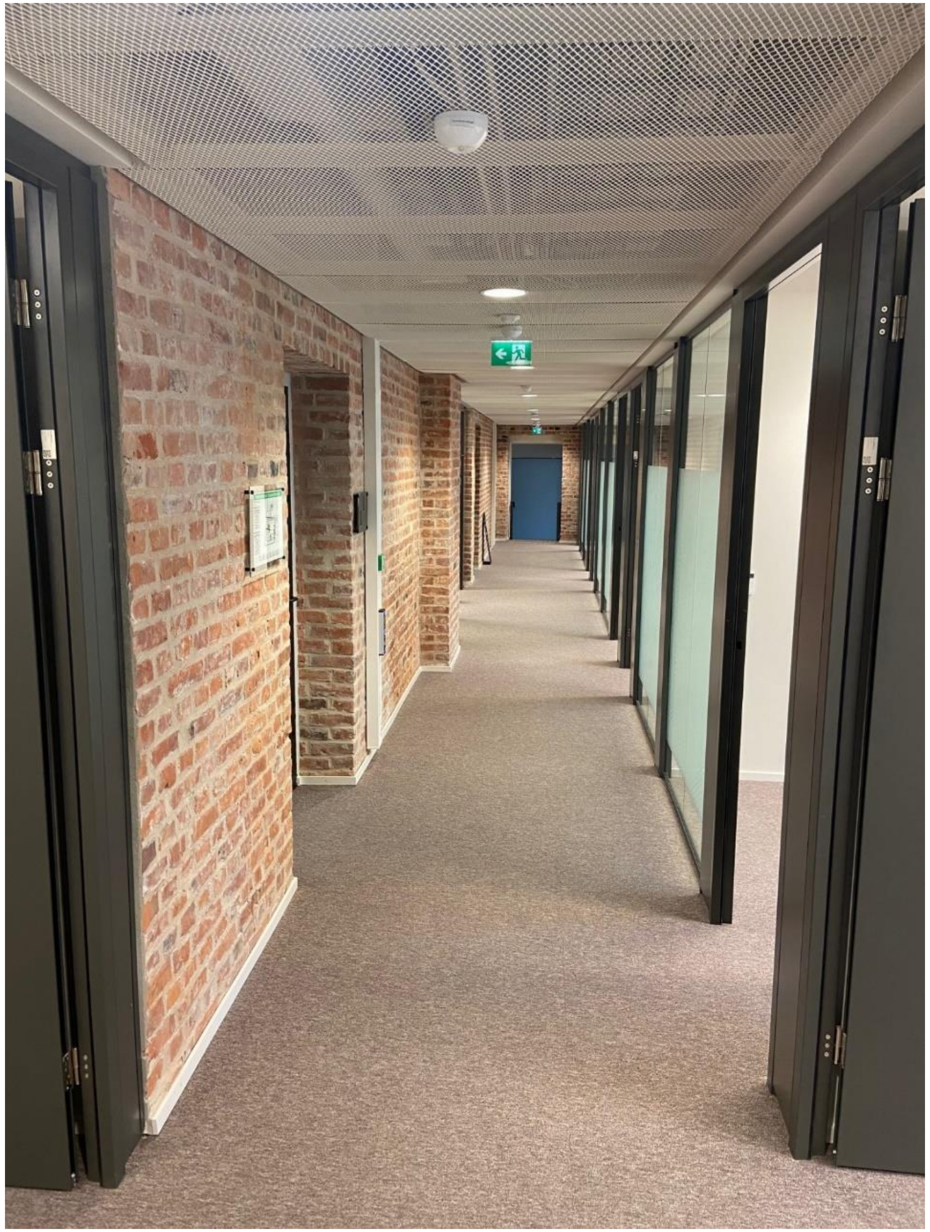

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Text

We know from calculations that a sound wall in brick and plaster can compete technically and economically with a sound wall in steel and plasterboard. These walls can easily be covered in brick and plastered with lime mortars.

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The way forward

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Text

It is about planning and competence. We can go all the way to the other end of the strength scale.

Paris. Centre Gilbert Raby,
Arkitekter: Tolila+Gilliland

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Text

Clay brick and clay mortar. When someone manages to design a building with this material, then lime should definitely be a huge possibility. The point is that we must have knowledge of the material and construction method.

What do we need to make this happen?

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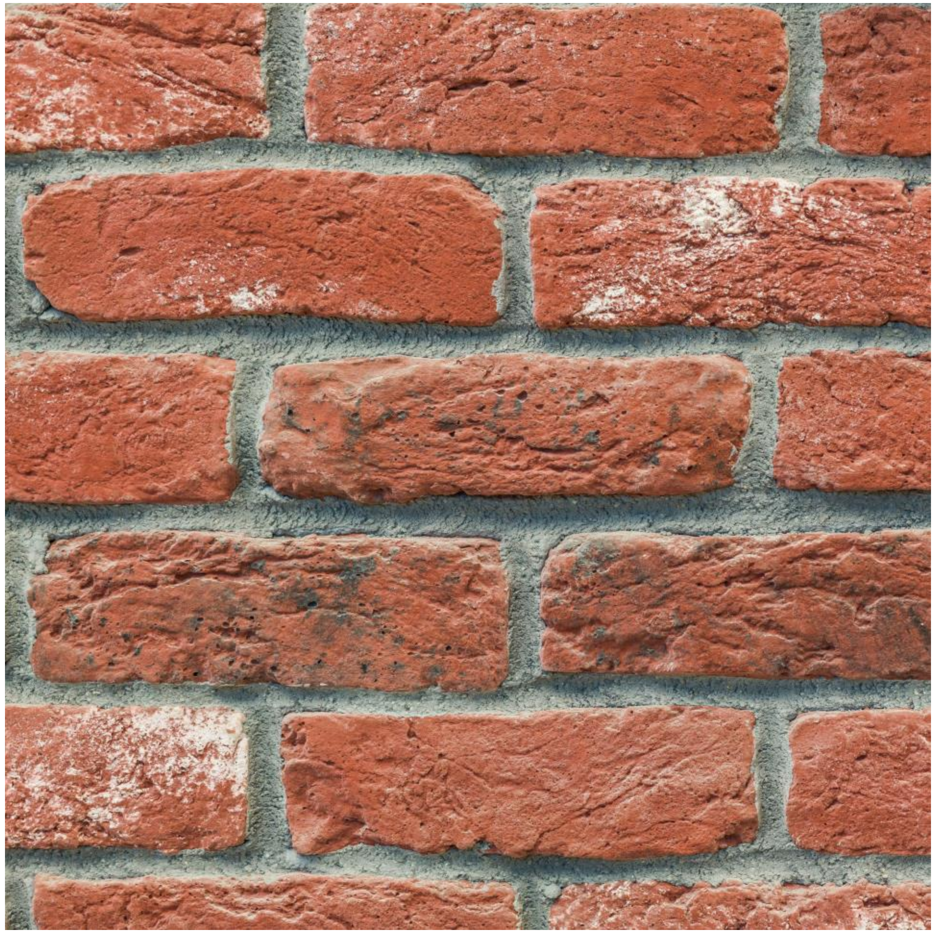
Text

We cannot assume that traditional material and building methods can be used directly in the same way today. Assumption is the mother of all fuckups

- More documentation on lime's interaction with other materials.
- More testing of constructive masonry with lime. It is both expensive and time-consuming, but necessary.
- More knowledge about weathering. Basis for comparison with materials we know today.
- And most importantly, the buildings must be planned and arranged to receive this type of materials.



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Thank you for your attention!

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