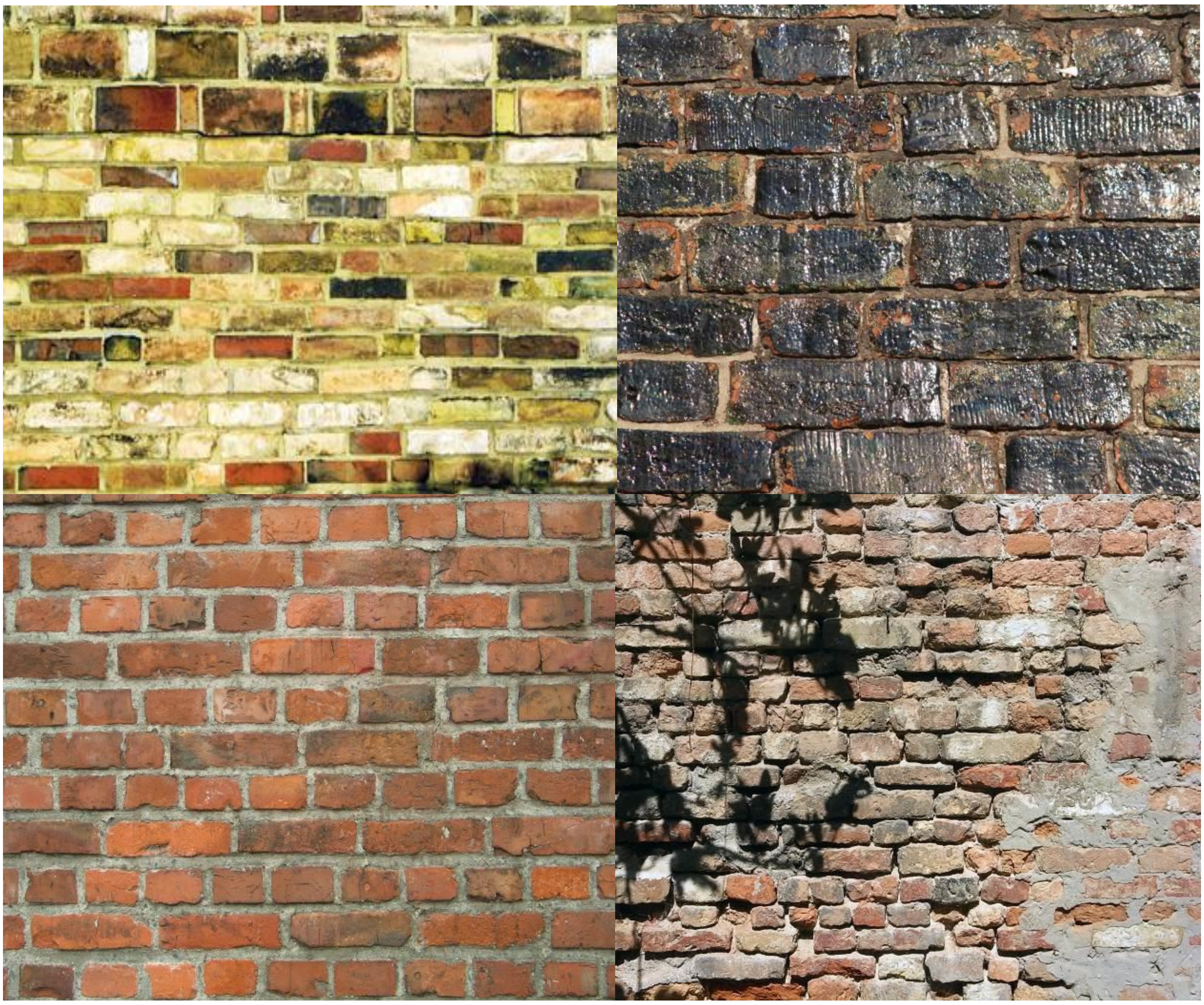
Bricks and Brick buildings

History, Weaknesses and Potentials



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The BRICK CONSULTANT Seminar organised by the Hamburg Chamber of Architects

Training programme Part I Consultant for Brick Facades held in the Hamburg Chamber of Architects. Course duration is 6 days and includes:

Module 1 – Bricks and climate protection "Status Quo"

Module 2 – History of a brick city – Hamburg

Module 3 – Brick: the material/stone and the joint

Module 4 – Renovation and insulation

Module 5 – Basic principles of Hamburg apartment economics II

Module 6 – Best practice examples of modernisation of brick architecture/field trip

Module 7 – Expert practice

Followed by Part II of the training “Quality assured brick facades”. Only those who have completed Part I of the course – Modules 1-7 – may participate. Part II is a half-day course and includes:

Module 8 – Authorisation as quality assurer through the BSU/WSB and WK.

(BSU: Ministry of Urban Development and Environment – WSB: Office for Housing, Urban Renewal and Zoning – WK: Housing Construction Loan Corporation)

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Script of the lecture for Module 3 – Bricks and joints/heritage monument protection problems

Content

Brick:

- **Joints, surface, materials, properties, building technology**
- **Basics of appropriate preservation for historical heritage buildings**
- **Focus: masonry facades, using the example of 1920s housing projects.**
- **Energy qualification**
- **Lecture and field trip**

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1. Introduction

During the last decade there arose overriding pressure to implement measures to repair buildings with brick facings. This was especially often the case in the group of buildings which were the housing developments of the 1920s. It is now assumed that buildings with an age of almost 100 years are over the ageing time in which various "natural" age-related damage appears that must be repaired.

However, the damage found, the extent of damage and the depth of damage often went far beyond ageing-related damage to the substance. As was able to be determined, renovations were carried out on the facades in the past few decades, which in turn led to consequential damage that now needs to be renovated again.

The housing projects of the 1920s are a group of buildings which differ in various construction details from the brick buildings which were their predecessors. "New paths" were taken in outer wall construction during their creation. The buildings were designed as "lying structures" of great length without vertical movement joints. The load-bearing leaf is often from limestone, which may still contain organic inclusions, the weather-conductive leaf of hard-burnt clinker. Between the supporting and the weather-conductive leaves – in the original plans of the time – there was usually a 2cm facing leaf joint provided, which in reality is less than or greater than 2cm or is filled with mortar. The rear anchor of the weather-conductive leaf can be present in the bearing leaf in complete courses, in individual header blocks or only at a few points.

So for example, the then Planning Director Gustav Oelsner in Altona expanded the facing leaf joint in the construction of his facades to a regular ventilation layer.

Cement for mortar was scarce in the aftermath of the First World War, so the mortar was accordingly mixed cement-poor. For the weather-conductive outer leaf, a variety of clinker qualities came into use. In the period of reconstruction after the World War II, because 80% of Hamburg's housing stock was destroyed, buildings were rebuilt in several different ways with purified brick rubble. Moisture protection in the construction of roof eaves was omitted for aesthetic reasons.

This non-homogeneous, damage-prone initial construction of the wall structures was further aggravated in the period after the World War II through renovation attempts to correct any moisture damage, such as through hydrophobisation treatments or thickening the coatings of the facades.

One method of facade cleaning which emerged in the 1970s, sand blasting and sanding the brick surfaces, destroyed the brick surface, opening the capillaries for water penetration, which in turn led to damage to the structure.

Joint repair

In the course of my work in heritage preservation, I have delved into the complex interconnections of masonry repair, especially in the determination of types of damage, the extent of damage and the depth of damage as related to the complex history of the building. Through this, in discussions about the planned building renovation, I was often confronted with the fact that neither the builders, nor the planners responsible for the renovation, had command over the necessary technical information regarding the "damage genesis" of the building. A restoration method was usually specified through cursory visual inspection and using the currently available industry products. That a building of a certain construction era can only be sustainably renovated with the techniques and materials of that time, had not, and has still not found its way into the common culture of discussion about possible building renovations.

The frequent failure to undertake damage analysis, followed by an insufficiently verified renovation method has, as I present in this report, led to considerable damage to brick buildings.

The following examples serve to make you familiar with the damage problems of brick buildings and to present possible solutions.

The field of building renovation/repair/energy qualification is too complex with respect to the structural, physical, chemical requirements of construction so that the issue could be dealt with extensively in a lecture. Therefore it should focus light on problems which crop up during the renovation of historic buildings, which we encounter in the everyday world of construction.

I would like you to take two key sentences in the renovation of a historic building to your heart:

1) No action without analysis.

2) A structure from a particular era can only be most sustainably renovated using the means/materials of its time of construction.

2. From clay to brick

The efforts of people to create a permanent dwelling is particularly clear in the development of the brick and its use.

Brick production is closely linked to the development of people in communities – only this makes it possible – as is impressively demonstrated in the archaeological remains of Mesopotamia, between the Tigris and Euphrates. Knowledge of brick production and its use has been steadily improved over the course of history and can look back on a long tradition. The brick itself already represents a "cultural icon", its use in the different eras makes the buildings distinctive cultural products of the respective architecture of that era.

About 15,000 years ago, humans begin to wet clay, put it into moulds, then to let the raw clay dry in the sun. Soon the cracking susceptibility of the raw brick is improved by the addition of straw. The crucial step to improve the weatherability and pressure resistance begins about 6000 years ago with the invention of the kiln. In the following period the quality of the brick is further enhanced by liberation of the impurities in starting material, increasing the homogeneity by grinding and an increase in the firing temperatures. Until the 19th Century, bricks were fired in the field kiln at the site of the starter material. The raw brick is still produced in a form, by hand, with a coating process. In the middle of the 19th Century, with the invention of the ring kiln, an increase in the firing temperature and an increase in the number of bricks produced was achieved. The move to production-line bricks was effectuated with the invention of the steam engine. The milling, grinding, and cleaning of the starting material is now done by machines. The raw clay mass thus obtained is extruded through a die to create a long cable of material of the desired width and depth and cut by a machine into raw bricks of the desired length by a wall of wires. In the subsequent burning process, the properties of the brick can be reproduced in the same quality through the firing temperature and burn duration. Despite all the technological advances, most of the energy for the production of bricks is spent in the burning process.

This manufacturing process is explained in the following chapter.

Chapters 2.1 and 2.2 of the contents contain excerpts from the following works:

- Die Geschichte der Ziegelherstellung [The History of Brickmaking] by Erwin Günther Friedrich Rupp, 3rd edition 1993, published by the Federation of German Brick Industry
- Der Ziegelofen [The Brick Kiln] by Carl Scholze, 5th Edition, 1928 – facsimile edition 2/2001

2.1 Brick – starting material

Clay is used as starting material for brick production. Brick clay must be cleaned of particulate impurities. Mixtures of clay and sand are less "fat", not as strongly water-binding and therefore less shrinkable than pure clay.

Clay quality is dependent on the plasticity, binding capacity, water-absorption/emission capability and shrinkage behaviour during the firing process.

Fat clays have high plasticity and increased binding capacity. At the same time, this leads to greater shrinkage than in lean clays, since the proportion of swellable parts is higher than in lean clays.

Lean clays are porous and fast-drying.

2.2 Brick – processing

Shrinkage

Shrinkage is defined as the loss of free pore-water, which occurs up to a temperature of about 120 degrees Celsius.

Drying

Drying is defined as slow, crack-free drying through water discharge of the upper layers. The release of water then continues from the depths of the material through the pores in the material. The process takes place in a moist, warm environment.

Burning

In the temperature range of 200-300 degrees C, the loss of chemically bound water takes place.

From 800-1000 degrees C, the mass becomes porous because of the incineration of the organic constituents, expelling the carbon dioxide and carbonate soils.

From 1000 degrees C, softening, sintering, clinking begins, with pores getting smaller. The material shrinks, then hardness increases.

If hand-pressed into the wooden mould, then it is about 0.5-0.75 inches larger than the finished size of the fired brick.

Silica, lime, iron oxide, magnesium, alkaline agents serve as flux materials

Fuels

Wood, peat, coal, straw, heather, gas, etc., serve as fuel.

Dimensions

Brick dimensions follow the principle of side lengths 1 : 2 : 4

Thus: one (height) to two (width) to four (length)

Quality of bricks

Air drying: Air-dried clay bricks are reinforced with straw. The raw material is stamped in by foot. The preparation is usually done at the location of the material deposit.

Initial brickmaking took place about 15,000 years ago.

Historical development of the burning process

About 6000 years ago, the development of kilns begins.

Fired bricks greatly improve the properties of the brick with respect to weather resistance.

Weak fires up to about 600 degrees C are known from Babylonia.

Fires, even through sintering, were already possible in open clamp kilns made of piled bricks and small kilns. Until the 18th Century, deposit locations and burning locations are identical.

The increase in brick quality was made possible through the improvement of furnace/kiln technology. Coal became the fuel. Around 1800, a conversion from open clamp kiln to furnace took place, thereby production capacity increased.

Around the year 1840, the ring kiln was invented, which led to a saving of more than 60% of the amount of fuel the previous kilns used.

With the onset of the industrial revolution, there is a conversion from manual to machine production, making brick production increase further. Brick machines appear.

After the industrial revolution and the ongoing technical development, with new transportation and processing possibilities, the location of the kiln can be selected independently of the clay deposit location.

The principle of brick production is unchanged to this day.

2.3 Brick production using the example of a heritage site production facility; ring kiln Drochtersen

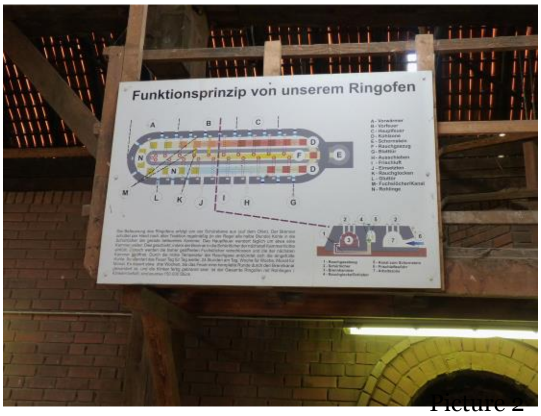
The ring kiln at Drochtersen. The sequence of steps in production corresponds to the pictures.

Picture 1

The site of the Drochtersen brick factory, with the former clay pit which has now become a pond.

On the right and left in the picture are the structures housing the conveyor belts for the bricks that run from the kiln to the storage location. The transport route is also used for cooling the fired bricks.

In a ring kiln "the fire never goes out." From one side the kiln is filled with raw bricks, then the access opening is walled-off. Then, from the top, the coal is added, the fire ignited and controlled. In the meantime, the next batch of raw bricks is placed into the kiln, so that the heat of the preceding internal fire continues to dry the newly introduced raw bricks. After completion of the firing cycle, the newly introduced and pre-dried batch is walled in, the chamber is filled with coal and ignited. For the finished batch of baked bricks, the brickwork wall is removed in order to cool the burned material. At the same time, a new batch of raw bricks are inserted for pre-drying and preheating.



Picture 2

The diagram illustrates the functional principle of the ring kiln.

This results in a permanent process of: cooling – burning – filling – pre-heating – pre-drying – burning – cooling.

All the processing steps in the kiln, the filling with raw bricks, walling-in the bricks in the combustion chamber, breaking down the wall, emptying the combustion chamber, including loading coal into the combustion chamber, is done manually.

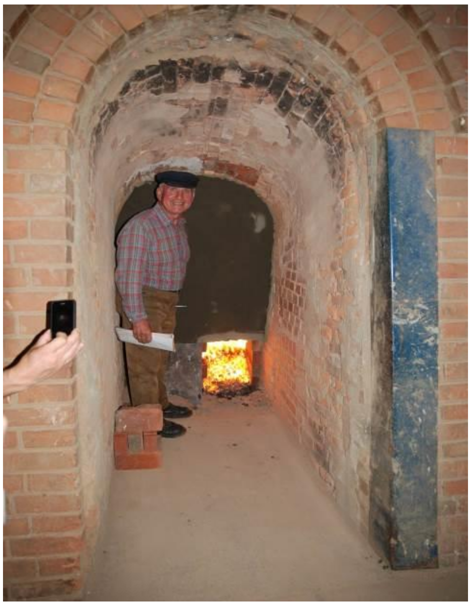
The high proportion of manual labour in this type of brick production requires a higher end-price than for that of an industrially produced brick. The manufacturing process in the ring kiln leads to a quality and surface texture of the bricks that make them unique and justify a higher price.

Picture 3

The roof of the ring kiln furnace, with openings for fuelling and fire control of the furnace.

Picture 4

The fired, cooled bricks in the ring kiln.



Picture 5

The lateral access to the kiln furnace, walled off, with open fire door.

2.4 Brick production using the example of the gas fire tunnel kiln in Glueckstadt. Modern brick production process

The following is the presentation of an example of a modern production process at a brick factory in Glueckstadt. The firing of the kiln is via gas.

The photos were taken as part of a brick factory inspection field trip in the framework of the Co2olBricks project.

The sequence of steps in production corresponds to the picture sequence.

Picture 6

The storage of the clay raw material on the site.

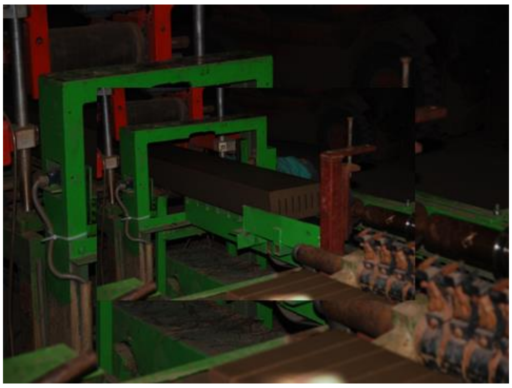
Picture 7

The process of grinding the raw material.

The origin, mineral content, and mixing ratio of the raw material as well as the firing temperature determine the colour and the technical characteristics of the brick.

Picture 8

Transportation of the raw material to the mixer.



Picture 9

The extruded mass after leaving the extruder on its way to the wire cutting machine.

Picture 10

The cutting of the raw brick is done by a wire cutter so that the raw brick now has its form. Through shrinkage during the drying process and during the firing process the "raw size" of the bricks is reduced to its final dimensions.

Picture 11

The cut brick train on the way to pre-drying.

Picture 12

The "staggered" raw bricks in pre-drying.

Picture 13

The filled pre-drying chamber.

Picture 14

The removal of the raw bricks to the drying chamber.

Overall, the raw bricks remain in dry areas for about a week in order to ensure crack-free shrinkage through slow drying (higher use of energy).

Picture 15

Raw bricks stacked on the "kiln car" on the way to the kiln.

Picture 16

The bricks after firing when exiting the kiln.

This brick cooling process also needs time and the heat of the kiln. Only slow cooling, by slowly rolling the bricks out of the combustion chamber, prevents cracking.

More than 50% of the energy used is needed by the following processes:

pre-drying – burning – cooling.

The "tour through the brick production process" impressively presents the amount of energy and care that is needed. The finished product is durably weather resistant, universally usable in construction and, because of its mix, the burning process and its firing temperature, its individual colour and texture, thus possesses high quality and material beauty.

In the housing projects of the 1920s this material was dominant in the facades of whole residential districts.

3. The housing projects of the 1920s

After the first world war, the architects of the 1920s who were faced with the task – in times of scarcity – to provide housing for a broad swathe of the population, particularly in Hamburg, on large construction sites in the city area, used bricks as a "basic creative element" in building their facades. The emotions associated with the "quality, durability and beauty" of the material may also have been determining factors.

With the abolition of the Empire, centralised government in Germany went under and democracy was established. The reversal of influence in policy decisions from the Emperor (one) to the people (many) found allegorical expression in the use of bricks in the "New Constructions".

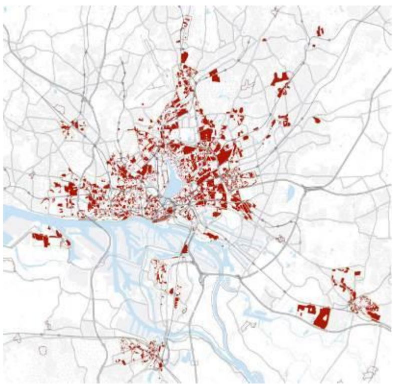
The supporting material – brick, the "together at its core" the building – occurs over a large area visible on the facade surface. The smallest component – the brick – some by joining technique and the effect of surface finish and design of the building.

The housing projects of the 1920s, with their recumbent building structures were visible architectural expressions of the "optimism" in society and in the architecture of the time.

The "recumbent" form for the building of housing estates, the leading brick structure elements, the arrangement of the openings for windows and doors as well as their detailed design, incorporate a distinctive creative symbiosis with the bricks and give the residential quarters in Hamburg their "distinctive appearance".

The "housing projects therefore present a level of construction particularly worthy of preservation in the architecture of Hamburg".

The maintenance of this group of buildings is especially difficult because so many different factors affect them, as the following chapter will show.



Picture 17

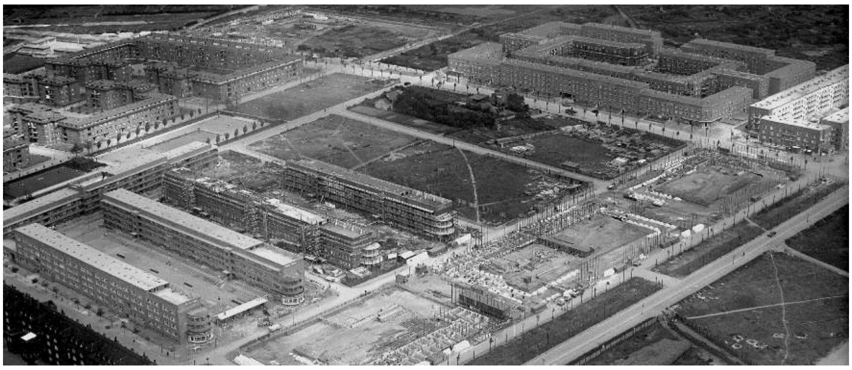
The area where brick buildings in Hamburg are subject to facade renovation through the city construction committees of the FHH (Free and Hanseatic City of Hamburg).

Picture 18

The area where brick buildings are under special heritage site protection.

3.1 Damage patterns that can lead to the loss of the "historic surface"

During the course of my work on the restoration of the group of buildings in the housing projects of the 1920s in Hamburg, it was possible to note that there were a number of factors having an effect on the housing estates that could have put the restoration in question or made it impossible. These will be illustrated in the following.



Picture 19

The construction site of the Frankschen Laubenganghäuser (portico-style) on the Dulsberg, at the end of the 1920s, example of the level of construction at the time. The northern quadrant is not yet completed, the two eastern quadrants in the north-south direction are not yet underway.

Picture 20

The south porch of a portico-style block before renovation.

Picture 21

The south porch of a portico block at the corner of Schlettstadter and Oberschlesische Str, after the renovation at the beginning of the 21st Century.

The facade was laid on a composite heat insulation system of the Meldorfer (resin bound epoxy clinker) type. The rounded balconies were closed with fenestration, and the top round balcony was covered with roofing. The roof edge has an extreme overhang, is unbalanced, and fashioned as a polygon.

On the balconies, a steel/glass structure was mounted as a "water deflector" in order to protect the balconies against precipitation.

Why this ugly, insensitive type of renovation? Was it possibly only for the purpose of saving energy?

Did consent from the Department for Heritage Preservation turn into a measure?

What happened?

The joints of the existing façade were renovated several times in the classic way without achieving a thickness which wards off driving rain.

After the renovation, the plaster on the steel girders on the balcony undersides and balcony edges cracked over and over.

In order to render the facade resistant to driving rain, in the 1980s it was treated with an aqueous solution to make it hydrophobic.

3.1.1 Inherent Defects

The load-bearing structural system of the building consists of:

- the rising masonry walls (surface clinkers with back wall of limestone plastered on the room side)
- ceilings of steel beams with concrete filling
- the steel beams are cantilevered through the outer wall and form the supporting structure of the porticos.
- The rounded balconies have a inner steel structure, the edge formed from a bent steel beam.

Due to thermal action, the steel elements and the plaster covering in the facade construction expand differently, resulting in the separation of the two materials. This thermal behaviour is clearly shown in the following images.

Picture 22

Detail of the edge of a circular balcony.

The mortar layer over the bent steel girder of the substructure burst repeatedly due to the thermally induced length changes. Bricks in the border area therefore fall off.

Permanent restoration is not possible.

Picture 23

A balcony view taken in the 1970s, on the occasion of a lecture by former Department Director Prof. Fischer.

The support system is clearly visible on the underside of the balcony; the plaster covering has fallen off.

Picture 24

A balcony view taken in 2006, by A. Schett, with the same damage pattern.

- The steel support layer is clearly visible.
- The plaster layer has fallen off.
- The damage is recurring.
- Permanent restoration is not possible.

There was no doubt about the analysis of the damage pattern; through the use of auxiliary structures, to reinforce what was there and enable ordered water management. The facade was given a new "water management layer" (composite heat insulation system with a clinker brick appearance), the balconies got "water deflectors", the circular balconies were closed-in with fenestration to prevent large amounts of precipitation from entering the structure. The following pictures show these individual measures.

Picture 25

Left: The "water deflector" attached to the balconies. Because loads for the structure were exceeded through the attachment of the water deflector, an additional load-bearing system of steel supports (10/10) were introduced to cope with the load transfer.

Right: The structure before renovation.

Picture 26

The first variation in the construction of the auxiliary water deflectors. The load is transferred vertically toward the ground with 10cm x10cm hollow steel pillars.

Picture 27

The second variation in the construction of the auxiliary water deflectors.

Here, the loads were suspended on pure steel cables and hung on the load-bearers. The steel beam support structure was anchored to the ceiling of the attic.

This construction is very costly, although their intricacy of design is more appealing than that of the steel columns.

3.1.2 Defects in construction

Shortly after the construction of the Frankschen Laubenganghäuser tenants reported moisture penetration (information: builder). In general, the top three floors in the main wind direction (west) were affected. The problem of inadequate rainfall-proofing has accompanied the building over its entire life. Accompanied by the Department for Heritage Preservation, the housing company conducted two conventional joint renovations in the 1990s in order to make it water-resistant. Both renovations could not eliminate the problem: water penetration from the exterior walls returned shortly after the renovation.

For reasons of cost, the housing company rejected a third joint repair because of its uncertain outcome.

3.1.3 Defects in the renovations of the past few decades

3.1.3.1 Hydrophobisation

An intensive search of the files, which has now been carried out, showed that all the facades were hydrophobised in the postwar period (1980s) with an aqueous solution to eliminate the problem of facades which were not water resistant.

As has been shown by previous attempts at repair of the joints, the joints were not repairable with the means used.

The problem of moisture after renovation and hydrophobisation (to solve the moisture problem) spread sporadically to other building blocks throughout the whole quarter.

Meanwhile, the Department for Heritage Preservation, together with SAGA, and accompanied by the ZMK, carried out an attempt at joint repair in Jean-Paul-Weg in Hamburg on the previously damaged and hydrophobised brick facade.

Several joint mortar materials and compositions were introduced for the joint and their water absorption behaviour in precipitation tested. A suitable joint mortar was not found. As a result, it should be noted that hydrophobates in the form of aqueous solutions from the 1970s and 80s do not usually guarantee insulation against driving rain on composite surfaces of brick and tile. On the contrary, the measure led to a systemic pattern of damage, for which no evidence of repair was found in the technical literature. Here, a further research effort is required.

For the street facade of Jean-Paul-Weg, the plan is to keep the upper three floors rain-free with a "water deflector". The courtyard facade was coated with a composite heat insulation system in order to have a new, functioning water-management system.

There is also a plan to formulate a research brief in order to find restoration methods in the joint area for hydrophobised masonry facades.

Analysis of the damage revealed that through thermal activity on the facade, a crack is caused between the brickwork and the joint. Normally, this is not damaging, since the joint and the brickwork can repel the surface water. In the case of the normal hydrophobisation of the 1980s, the surfaces of the joint and the brick became waterproof. Precipitation which penetrated could only be released as water vapour through the cracks between the mortar material and the brickwork.

The time-period for the release of water vapour is therefore much greater than for the period of water intrusion. In times where the drying phases are longer than the moisture absorption phases, this moisture behaviour is unproblematic. In the transitional periods where the moisture absorption phases are longer than the drying phase, moisture can occur on the room side. Mould growth is a possible consequence. In addition, facade dampness results in increased heat transfer. In the extreme case of a damp facade on the outer surface, it causes frost-shattering of the brick surface, as is shown in the following chapter.

3.1.3.2 Hydrophobisation/extreme example

In the following, an extreme example of hydrophobisation damage to a brick surface is presented.

The actual damage was characterised by:

- Angled, flaking brick surfaces at the edge region
- Cracking in the brick surfaces
- Bricks damaged due to frost
- Edge breakage of the brick joints
- Falling mortar
- Damp walls
- Mould growth indoors
- Driving apart of the natural stones in the roof area

The building at the Ohlsdorfer Friedof (cemetery) is a funeral hall in the Jewish part of the cemetery. The facade was hydrophobised in the mid 1980s for 1275 German marks.

In 2000, the the facade was renovated. The renovation costs amounted to about 1.2 million German marks.

Applying a second water-bearing layer on the facade was rejected for reasons of heritage preservation. Therefore, all the damaged bricks, stones, etc., which had lost their technical characteristics (weather resistance), were removed from the facade, and replaced by bricks with similar properties. In the case of the natural stone elements, repair was no longer possible, replacement too expensive, so they were covered with a copper coat and remained at the location.

Picture 28

The view of the facade from which the following pictures are details.

Picture 29

Detail of the damaged ornament below the cornice. The form stones were originally green with a glazed surface. The form stones of the cornice above are also damaged by frost.

Water penetrates into the joint areas, the non-evaporated moisture leads to frost-shattering and thus to the destruction of the water-repellent. surface.

Picture 30

The form stones removed from the facade.

Picture 31

The newly burned stones, replaced into the facade. This is how it looked originally (surface/colour/size).

3.1.3.3 Facade cleaning/sandblasting

A process for cleaning the surface of building facades, a mechanical process which results in the loss of the weatherability of brick, must be addressed here: Sandblasting.

In every type of surface cleaning, mechanical or chemical, what must be given attention to is that the technical properties of the bricks remain intact, therefore careful inspection must be made of every location which is to be cleaned. In the following, the results are shown of a facade cleaning without the necessary analysis having been done.

In the following example, the facade of the Adolf-von-Elm-Hof in Hamburg-Harburg was cleaned by sandblasting.

Picture 32

The renewed brickwork areas of the lintels over the windows (lighter), the brick surface on the facade is dull.

Picture 33

The boundary line between the sandblasted brickwork (dull) and untouched brickwork (glossy) in the upper left corner.

Through the application of hard blasting on the brickwork, the burned skin of the bricks was destroyed, the capillaries of the bricks made open for the absorption of water, which then enables water to be transported from the external side of the facade to the interior room side.

The extensive range of the replacement of masonry over the lintels shows impressively that penetrating rainwater led to the rusting of the steel lintel-bearers. Not only was the steel rusted by the entry of water, but there was large-scale manifestation of dampness on the room side.

Hydrophobisation was ruled out because of past negative experiences; an alternative method of restoration, which was not facade-changing, was not available.

In the end, only a second functional water-bearing layer in the form of a composite heat insulation system could be applied, the insulation carried out simultaneously was a "by-product".

Picture 34

The facade after an exterior composite heat insulation system was applied.

Picture 35

3.1.3.4 Joint repair

Usually moisture damage on the room side leads to a search for causes of damage to the facade. After several decades of life, visual inspection of the joint demands its repair, sometimes breakage or sanding is visible. Here as well, it is important that the individual components of the measure are closely coordinated. The first step is to clarify what action leads toward the goal, that is, elimination of the damage.

The procedure for a facade restoration is presented in detail later, in Chapter 5: Facade-preserving restoration methods for heritage sites.

In this chapter, sources of error in improper handling of joint renewal will be presented.

"Joint sealant cutters" to open the joints are meanwhile available.

The blade used for removing mortar from the joint, in the worst case, can be wider than the width of the joint chosen. Then, to remove the mortar to the required depth, the burnt skin of the bricks will be damaged on the edges of the set and horizontal joint side. Water will now be able to penetrate into the capillaries of the brick and then, in the worst case, to cause frost-shattering (see Chapter 5).

If the blade selected is smaller than the joint width, the remaining mortar material can be removed without damage from the brick edge with a chisel.

A simple but time-consuming method is to perform a relief cut in the centre of the joint with a cutter blade to relax the joint and then to clean the brick edges.

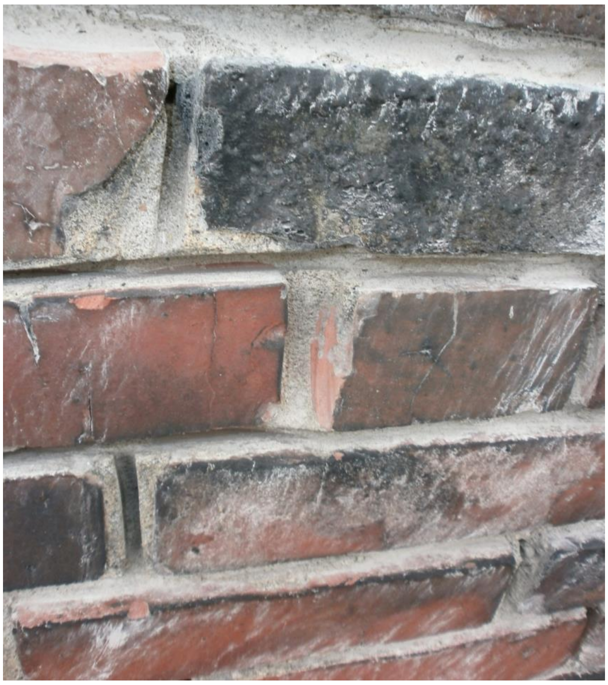
The following two images, with explanatory text, show the process of joint opening and possible damage occurring to the brick edges.

Picture 36

Opening a brickwork joint with a joint cutter blade. As can clearly be seen, not just a relief cut was made in the centre of the joint. The edges of the bricks were "trimmed" in the set and horizontal joint area.

In the area that was cut, the burned skin of the brick was destroyed, the capillaries opened, giving precipitation entry to the internal brick structure. For this type of work result, it is necessary to examine the hardness/water absorption/frost-resistance of the brick. Only after clarifying these three criteria can a decision be made as to whether the joint can be closed with a classic mortar or whether it must be hydrophobically treated to protect the edges against water penetration – with all its potential negative impacts.

Hydrophobisation of the brick surface and of the "trimmed" edges leads to the problem of the difficulty of preparing the new the joint material required for adhesion (demand to know the warranty period of the material according to the manufacturer's specifications!).



Picture 37

An almost correct opening of the joints (few edge trims).

The relief cut was made in the middle of the joint, the joint is "relaxed". Now, using a chisel, the rest of the mortar edges can be removed (avoid damage). The new joint material can be introduced.

The composition of the new joint mortar should largely correspond to the composition of the old mortar in order to match the technical properties of both mortars (old mortar/new mortar).

3.1.3.5 Thick coatings/facade coating systems

In the 1970s and 80s it was necessary, due to facade pollution or for reasons of maintenance, to apply new paint to a building. Often, along with the new colour, additional protection against rain should also be applied. In our example, in the Veringstraße in Wilhelmsburg, a type of paint known as "thick coating" was applied.

The argument that the wall structure remains dry if you deny the precipitation from entering into the wall structure is striking, however, it does not take into account all the other conditions for the dehydration of the building's exterior siding.

These coating systems become brittle over time, cracks in the system are the result. Precipitation water can penetrate the cracks, which in turn can lead to the formation of water-saturated pockets, which in turn leads to water penetration of the wall construction from outside!

Thus, the moisture enters the interior walls, mould growth can be the result. In our example, the damage location, the internal damage pattern, can be traced to the external damage type.

Picture 38

An example of penetration of rain water behind the paint layer (second floor).

Picture 39

The formation of a saturated area and water pockets which have already burst on the dark painted pilaster.

Picture 40

The building after renovation. The facade was stripped, a mineral paint applied, the colour of the facade was restored after research which found the original colour.

3.1.3.6 War damage/reconstruction

In order to trace the causes of current damage patterns in the housing developments as possibly resulting from the effects of war and the subsequent reconstruction, a comprehensive comparison with the relevant damage registers is necessary. The extent of damage can be regarded as significant; 80% of Hamburg's housing stock was destroyed after World War II.

Through the reuse of building rubble, cleaned bricks, etc., the masonry walls are composed of different materials with different properties and thus technically problematic. In the following example of a residential block in Heidhörn, no serious defects have shown up yet, but it clearly shows the degree of reuse of materials and construction in that time and in regard of the pressing issue of the elimination of the housing shortage.

Picture 41

The porticos on the courtyard side of the building complex Heidhörn.

The building was bombed away, the steel portico-style structure was preserved.

Picture 42

Afterwards: the reconstructed building with the same dimensions and same shape as before its destruction. The portico was preserved and reintegrated into the restoration concept. It still serves today as an integral

The following example of the group on Naumannplatz deals with an apartment block which was partially destroyed in the war and was rebuilt in the same cubic volume dimensions.

The damage was as follows:

- Large-scale water penetration of the outer wall surfaces after rainfall
- Rusting of the steel substructure of the lintels
- Formation of mould on the room side

All attempts at remediation to make the facades rainproof (joint repair) were unsuccessful. Nearly all the steel beams of the lintels were replaced (Pic. 40) and the facade restored; the restoration dragged on for many years. Finally, when the renovator brought his desire to install a composite heat insulation system to the Department for Heritage Preservation, it asked for an expert technical opinion on the facade.

Result:

- The wall was originally built 36.5cm thick
- The rebuilt wall was 36.5cm thick
- The layer structure of the rebuilt wall was 11.5cm = half a stone on the room side, and 11.5cm on the facade side. The gap was filled with rubble!
- The ceilings were in part supported by walls only 11.5cm thick.
- The facade between the individual floors was buckled.
- The leaves of the masonry walls had to be clamped in order to make them weight-bearing.
- A second water-bearing layer in the form of a composite heat insulation system had to be placed on the facade in order to make it resistant to driving rain.

Picture 43

The facade before renovation with a composite heat insulation system. Clearly visible through the different colour of the bricks over the lintels, are the window supports which were almost completely replaced.

Picture 44

Crack in the pillar at the entrance; the stress fracture could probably be due to the effects of war.

Picture 45

The facade after renovation with a composite heat insulation system.

The changed surface is clearly visible.

Picture 46

An detailed example of a composite heat insulation system at the entrance. A Meldorfer (resin bound epoxy clinker) type facade restoration was used.

As shown in the previous examples, there are a large number of buildings, for which the extent of damage, for various reasons, results in the historic facade not being able to be handed down to posterity, or that the structure – in the extreme case – must be abandoned .

To clarify the situation: The knowledge gathered from the preceding measures and from various external influences is not only helpful, but time-and cost-saving.

The Department for Heritage Preservation has developed, together with the VNW (Association of North German Housing Industry), a Baubuch (building book) where all relevant prior information can be recorded. This is a set policy, as is the commissioning of further expert opinions to clarify the structural situation of a project, thus making it easier.

3.2 Help for the assessment of damage patterns/*Baubuch* (structural specifications)

Contents	Location	Photo historical state	Photo current state	Plan
1. Site				
2. General property information				
3. Location in the city				
4. Building type				
5. Evaluation of the individual components				
6. Technical aspects of the building and evaluation				
7. Energy consumption				
8. Climatic conditions/esp. weather stress				
9. Plans/title				
10. Special features				
11. Results				

The preceding section described the type of damage that buildings with a brickwork facade can sustain and lead to the fact that conventional joint repair to preserve the facade cannot be performed, and a facade-changing system, such as a composite heat insulation system, must be applied. In general, the main damage is the destruction of the "water-bearing layer" of the brickwork.

Coating systems which led to the damage of the buildings cannot always be completely removed. The cleaning activity is very costly or may cause damage by removing the surface layer of the burnt brick skin, which again leads to the destruction of the water-bearing layer and thus to the application of a new water-bearing layer (a facade-changing composite heat insulation system).

How large the number of buildings with the types of damage described that need to be restored with a system that changes the facade is not known!

It therefore seems to be urgent to find out how many historical buildings there are, based on VNW criteria, and to check and see in order to get an overview of the number of damaged and heavily damaged buildings, at the same time to get a picture for the city of Hamburg to be able to develop a scenario for the expected changes.

4. Housing developments whose "water-bearing layer" is intact, i.e. can be conventionally repaired

4.1 Avoidance of facade-changing systems for "energy qualification": solutions for energy qualification in interior spaces

For the – hopefully – large number of buildings which have an outer leaf that functions technically and are of heritage monument status, solutions for "energy qualification" can be developed at a stage when it is still comfortable to implement them.

At this time, heritage monument sites are still exempt from the implementation of the Energy Saving Ordinance (EnEV). But it seems foreseeable that because of the development of the costs for heating as well as the obligation to conserve resources, energy saving measures will be thrust upon heritage monument sites as well.

When tenants can no longer afford the "second rent" in energy costs, and move to buildings with lower heating costs, the heritage sites fall out of use. As a result of the vacancy, the building’s technical situation would deteriorate further.

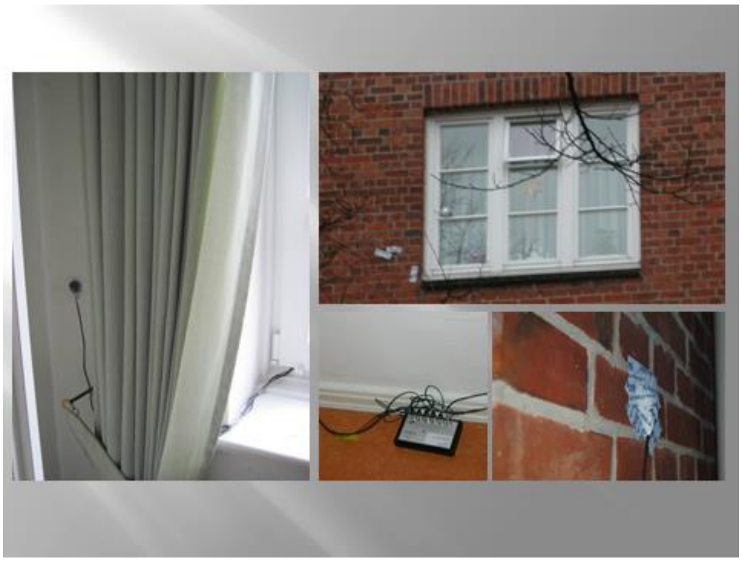
Therefore the Hamburg Department for Heritage Preservation commissions expert opinion reports on energy qualification for interior spaces, as for example on the housing projects of the 1920s, on single-and double-leaf masonry structures, funded by the climate control centre of the Hamburg Senate.

Thus light is shone on how heat transfer through the outer wall component – depending on the moisture component – behaves under real conditions.

4.1.1 Expert opinion report on the actual passage of energy through the structural component. Exterior wall – Department for Heritage Preservation, Hamburg

Picture 48

A humidity and a temperature sensor.



Picture 49

A data logger is connected to the different measuring points.

Alternatives to facade-changing measures (e.g. composite heat insulation system) should be found.

Currently, the calculated amount of energy savings is in doubt. Investigations are already underway which identify significant differences between the calculated values and reality.

One of the causes of these significant discrepancies may lie in the insufficiently exact entries required for the calculation, as in the following table of the calculated U-values and those parameters determined from the characteristics of the materials.

U-value comparison according to intermediate report of TUHH from Feb. 2011			
Object	U-value according to HH energy-pass (W/m²K)	U-value after sampling (W/m²K)	Difference
Helmholtzstraße	1.46 – 1.70	1.35	7.5 – 20.6 %
Passierzettel	1.77 – 1.81	1.52	14.1 – 16.0 %
Heidhörn	2.16	1.70	21.3%
Großheidestraße	2.34	1.37	41.4%
Mülhäuser Straße	2.13	1.81	15.0%
		Average/improvement	19.4%

Picture 50
The difference in the U-values of the outer wall according to the calculation for the energy performance certificate (left column), and after removal of a brick from the facade and the determination of its material characteristics and the resulting U-value (right column).

Calculation example:

U-value according to energy-pass – 1.46 = 100%

U-value after sampling – 1.35 = x% of 1.46%

1.46 : 100 = 0.0146% = 1%

1.35 : 0.0146 = 92.46% of 1.46

100% - 92.46% = 7.5% difference

Average/improvement (7.5 + 20.6 + 14.1 + 16 + 21.3 + 41.4 + 15) : 7 = 19.4%

Measurements in the Hamburg project will be completed in mid-2013, so that the evaluation can be presented in 2014.

If, as assumed, the external wall loses less real energy than calculated, a "thinner" insulation thickness can be resorted to for interior space energy qualification.

The abundance of urgent technical problems for brick buildings in Hamburg has led us to look for partners in Europe who are faced with similar problems and seek solutions.

The Department for Heritage Preservation of Hamburg could therefore, as a result of my initiative, call the Co2olBricks project into life in 2011; then 8 more states in the Baltic region, with a total of 19 organisations, could be won over to participate. The project is financed by the EU.

4.1.2 The Co2olBricks project

4.1.2.1 Overview map of the partner countries of Co2olBricks

Picture 51

4.1.3 The partnership structure of Co2olBricks

Germany

1 Free and Hanseatic City of Hamburg
2 Ministry of Culture/Archaeological Service
3 Hamburg, Ministry of Urban Development and Environment
4 Construction Training Centre in Hamburg GmbH
5 Kiel, Department of Environmental Protection

Sweden

6 Stadsmuseum Stockholm
7 Energy Agency for Southeast Sweden
8 Swedish National Department for Heritage Preservation
9 Malmö, Environment Agency

Denmark

10 Aalborg University, Danish Building Research Institute

Estonia

11 Estonian Heritage Society
12 Kohtla-Jarve City Council
13 Centre for Development Projects

Latvia

14 Riga, Infrastructure Department
15 Riga Technical University

Poland

16 European Foundation for Monument Protection

Byelorussia

17 The Republic Centre for Technology Transfer

Finland

18 KIINKO – Education in the real estate industry

Lithuania

19 Vilnius Gediminas University

Work packages (WP) were formulated within the project and responsibilities for the work packages were delegated. Albert Schett Ing. Architect from the Department for Heritage Preservation Hamburg is the designated supervisor for WP 4 Technical Innovation.

An overview of the work packages and activities:

Work packages (WP 1-5)

WP 1 – Project Management and Administration

WP 2 – Communication and Information

WP 3 – Policy Development

WP 4 – Technical Innovation

WP 5 – Education and Economic Promotion

Knowledge gained from the work packages will be shared among the individual member countries and should be incorporated in

- Policy (legislation)
- Training (vocations/school/university)
- Economy (new technical solutions)
- The general public (information for all)

Four of the member states are carrying out pilot projects and studies in WP 4 area.

In Hamburg, the Department for Heritage Preservation is carrying out measurements in four apartments in the building complex Passierzettel/Am Gleise.

Picture 52

The Passierzettel/Am Gleise in Veddel, north view.

The measurements should record the actual heat transfer through the exterior wall, depending on the moisture component. This makes the dynamic conditions in an outer wall mappable, such as the changing U-values in the case of precipitation, solar influences, etc. – in real conditions. These results can then be compared with the various theoretical calculations.

So the procedure goes far beyond simulations based on assumptions. Simulations based on real data collected can display more factors of influence – such as the glaze for example – than only a description of a static state. The measurements are being done by the Technical University of Dresden; the measurements are recorded at 15-minute intervals and transmitted weekly via DFU to Dresden and evaluated there.

The results will be published in the final Co2olBricks project brochure in December 2013.

For the pilot project four apartments of nearly the same size were fitted out in the following manner:

- two apartments were insulated on the room side with 5cm calcium silicate boards
- two apartments remain uninsulated
- one apartment – insulated – was fitted with a wall heater (radiant heating)
- one apartment – uninsulated – was fitted with a wall heater (radiant heating)
- one apartment – insulated – was fitted with a convector (air heating)
- one apartment – uninsulated – was fitted with a convector (air heating)

Picture 54

The piping in a wall-heating (radiant heating) system as affixed to the wall by technicians.

Picture 53

The apartment before renovation. Here is a night-heat-storage device which is operated with less expensive off-peak power. Currently there are a number of different heating devices in the buildings. A general renovation is planned in which a central heating system is to be installed.

Picture 55

A room in the apartment with a flat panel radiator (air heating) on the inside of the outside wall after renovation.

5 Facade-preserving restoration methods for heritage sites

5.1 Application of insulation in the interior

As we have seen previously, interior insulation in existing buildings with components such as:

- panel materials with wallpaper and paint as room enclosures
- vapour barriers under the panel material, fixed through adhesive tape on the surrounding walls/ceiling/binding components
- battens on the wall
- insulation on the wall

often caused considerable damage.

The permanent wetting of the inner plaster surface may lead to its loss, so that is no longer available for heritage preservation research.

As was frequently the case, it was not possible to permanently prevent the entrance of air and water vapour to the inside "cold" wall surface. A common reason was the breaking of the connection between the vapour barriers (tapes) and the surrounding components, or damage to the foil materials on the surface.

The penetration of water onto the inner wall surface below the insulation afterwards often led to mould growth on the room side. Moulds can be harmful to people's health (Mould Guidelines/Ministry of Health).

In the initial phase of interior insulation in the 1980s, calculated insulation thicknesses were, in contrast to the external wall, applied to the interior. The resulting consequences for the physics of an outer wall are:

- reduction of the surface temperature on the inner wall surface (under the insulation)
- reduction of the surface temperature on the outer (facade) surface
- increase in the risk of a rise in water absorption of the facade
- increase the risk of frost damage because the facade has not dried out

As illustrated above, "composite systems" for interior insulation pose the risk of being unable to sustain the demands placed on them for long periods.

An alternative is presented by insulation materials that:

- can be fully bonded to the substrate, so that a subversion of the insulation through water vapour as well as condensation can be prevented.
- can absorb the water vapour contained in the air, like plaster, and release it again.
- have a composition similar to a mineral plaster, thus itself a mineral system with the same material properties as the substrate (e.g. calcium-silicate panels, or comparable products)

Since the 1990s, the industry has provided products for this area of application which, because of the knowledge gained, have now been adequately tested.

A simulation from the parameters humidity, wall materials, properties of the insulation and temperature conditions, is necessary to help prevent damage to both the indoor and outdoor surface and to establish the optimum insulation thickness with respect to the moisture absorption properties and drying properties.

A simple stationary viewing, according to Glaser, is regarded as insufficient for such a system because it does not take into account the necessary variation in sizes.

The facts are displayed graphically below in pictures 56 and 57 (Page 58 and 60).

5.1.2 Graph of surface temperatures/double-leaf masonry

The graphs were provided by the architectural firm Dittert + Reumschüssel, Mr. Dittert and Mr. Kaul, TU Hamburg-Harburg.

Moisture penetration/drying – surface temperature, wall cross-section temperature as related to thickness of insulation (see Picture 56 below)

The wall cross section shown for both graphs is constructed as follows:

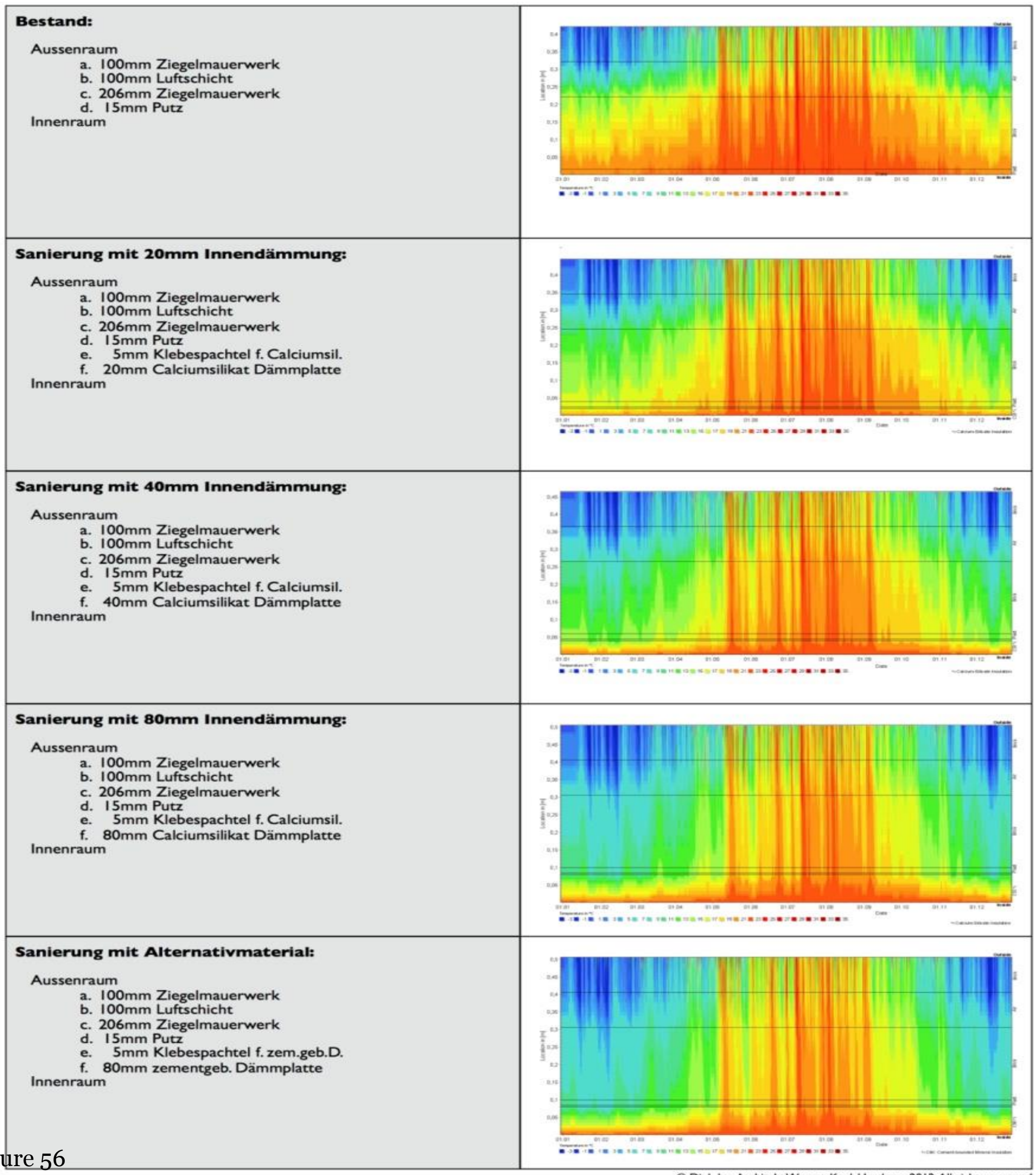
- 100mm brick outer leaf
- 100mm air layer
- 206mm brickwork inner leaf
- 15mm plaster room side
- 5mm adhesive putty
- As interior insulation, a calcium-silicate insulation panel, with an insulation thickness of 20mm/40mm/80mm, was simulated
- Alternative interior insulation, cemented insulation panel with a thickness of 80mm

The graph shows, from top to bottom:

1. Graph: uninsulated object

2, 3, and 4. Graph: internal insulation with calcium-silicate insulation panel

5. Graph: cemented insulation panel



Picture 56

The temperature profiles within and on the surface of the wall, depending on the insulation thickness.

In the graph above (of the non-insulated object) the depth of heat penetration of the wall cross-section during the heating period is clearly distinguishable (red/high temperature to blue/low temperature). Starting at 20mm internal insulation, the energy input into the structure declines; from an insulation thickness of 40mm, an optimum insulation thickness is, in this case, achieved. The temperature distribution on the room-side surface is uniformly high, the heating of the wall cross-section is significantly reduced (relative to the non-insulated version), the frost-hazard area is limited to the outer leaf, the doubling of the insulation thickness to 80mm does not cause a significant improvement in the temperature characteristics, however in contrast results in that the frost-hazard area extends to the inner supporting leaf.

5.1.2.1 Graph of moisture penetration/double-leaf masonry

Moisture penetration/drying – surface temperature, wall cross-section temperature as related to thickness of insulation (see Picture 57 below)

The wall cross section shown for both graphs is constructed as follows:

- 100mm brick outer leaf
- 100mm air layer
- 206mm brickwork inner leaf
- 15mm plaster room side
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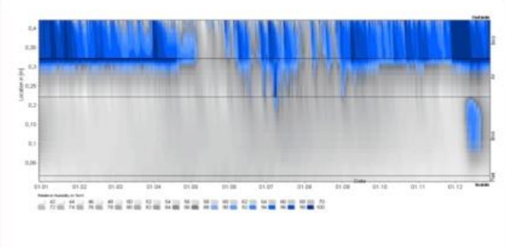
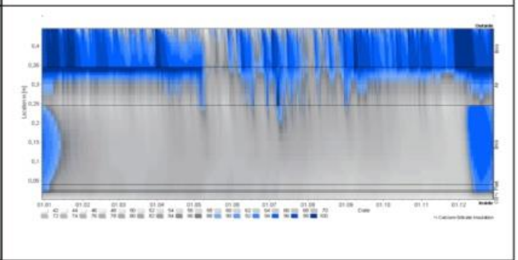
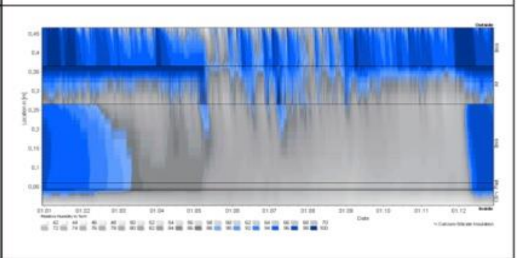
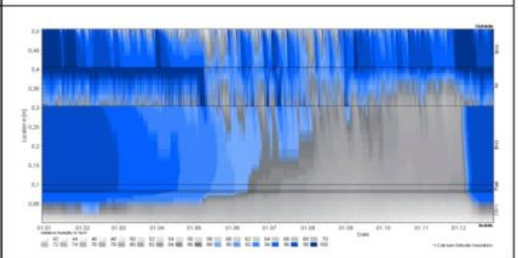
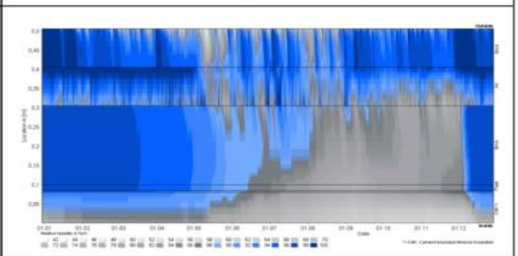
5. Graph: cemented insulation panel

Bestand: Aussenraum a. 100mm Ziegelmauerwerk b. 100mm Luftschicht c. 206mm Ziegelmauerwerk d. 15mm Putz Innenraum	
Sanierung mit 20mm Innendämmung: Aussenraum a. 100mm Ziegelmauerwerk b. 100mm Luftschicht c. 206mm Ziegelmauerwerk d. 15mm Putz e. 5mm Klebespachtel f. Calciumsil. f. 20mm Calciumsilikat Dämmplatte Innenraum	
Sanierung mit 40mm Innendämmung: Aussenraum a. 100mm Ziegelmauerwerk b. 100mm Luftschicht c. 206mm Ziegelmauerwerk d. 15mm Putz e. 5mm Klebespachtel f. Calciumsil. f. 40mm Calciumsilikat Dämmplatte Innenraum	
Sanierung mit 80mm Innendämmung: Aussenraum a. 100mm Ziegelmauerwerk b. 100mm Luftschicht c. 206mm Ziegelmauerwerk d. 15mm Putz e. 5mm Klebespachtel f. Calciumsil. f. 80mm Calciumsilikat Dämmplatte Innenraum	
Sanierung mit Alternativmaterial: Aussenraum a. 100mm Ziegelmauerwerk b. 100mm Luftschicht c. 206mm Ziegelmauerwerk d. 15mm Putz e. 5mm Klebespachtel f. zem.geb.D. f. 80mm zementgeb. Dämmplatte Innenraum	

Picture 57

The moisture penetration and drying properties of the wall cross-section, depending on the insulation thickness.

It is clear to see in the non-insulated version (top image) that the inner leaf always dries to a damage free moisture level. The outer, water-bearing leaf, moisturises without damage to the supporting structure.

Starting with 20mm of insulation thickness, a dampening of the inner bearing leaf starts in the cold months from December to February, their drying is ensured in the warm summer months.

From 40mm of insulation thickness, the process of moisture penetration of the inner leaf continues further until March. The remaining period for drying out is sufficient to ensure damage-free drying of the inner leaf.

From 80mm of insulation thickness, the process of moisture penetration of both leafs is so significant that the time allowed for drying is no longer sufficient to ensure damage-free drying of the inner leaf.

An insulation thickness of up to 40mm constitutes a technically meaningful boundary between water entry and water discharge in the wall.

At this point it should once more be emphasised that in the area of heritage monument preservation the focus on energy qualification is on the long-term damage-free maintenance of the structure, and thus on the heritage object and not on the achievement of requirements for funding opportunities.

5.1.2.2 Methods for cleaning using the example of Kaispeicher B/Maritime Museum

When cleaning masonry facades, cleaning should proceed according to the "character of a historic building". The influences of the time should be reflected on the surface of the facade; the facade should be able to tell its story.

Therefore, special attention must be paid to:

- the cleaning method
- the depth of cleaning
- the degree of cleaning
- matching of the cleaning concept to the properties of the material to be cleaned

In the meantime, a variety of mechanical and chemical methods for surface cleaning have been made available on the market.

Since the early 1990s, emanating from the development of new cleaning methods in shipbuilding, there have been a substantial amount of different cleaning methods developed for the removal of colour coatings for existing buildings. In addition to that, the cleaning method requirements for heritage sites have risen steadily in the last twenty years.

Cleaning method:

Cleaning with water

1. Using high water pressure with and without detergent
2. Using variable water pressures with and without detergent
3. Pulsed water jet method

Mechanical cleaning methods

1. Blasting with dry ice
2. Blasting soft pellets, e.g. nutshell granules of small grain sizes and materials, such as glass granules and very small amounts

Chemical cleaning

1. Pastes

2. Fluids – various application methods, chemical compositions and temperature ranges

It has been proven that various cleaning methods on the surface to be cleaned need to be "sampled" in order to avoid possible damage and to assess the "clean image".

Mechanical cleaning methods such as sandblasting, sanding the brick surfaces in whatever form, should be a thing of the past for brick facades. They destroy the "natural structure of the brick" in its most prominent and technically most difficult to control, place – the surface exposed to the weather! This method was treated in chapter 3.1.3.3 Facade cleaning/sandblasting.

Kaispeicher B was built in 1878/79 as a floor storage facility in its western half and as a silo in its eastern half on Magdeburger Straße. In 1884, the silo portion was converted to floor storage. It has survived in this state to this day.

Picture 58

The former Kaispeicher B/Maritime Museum after renovation.

Picture 59

A window and masonry detail after renovation. The cleaning "preserves" the history of the facade.

An examination requires information about:

- damage
- damage depth
- extent of damage
- surface characteristics of the area to be cleaned
- type of soiling
- depth of soiling
- extent of soiling
- other factors

From these tests, the restoration plan, the damage, or the cleaning concept can be derived.

After the scaffold was in position, different cleaning procedures were carried out on the facade. The water-jet method, with an average pressure range, with small amounts of cleaning additives, eliminated the technically disadvantageous dirt, and retained undisturbed the changes in the ageing process on the facade surface, such as signs of use on the winch houses, colour changes due to former chimney use, etc.

After cleaning, the facade was inspected, and all apparently technically no longer functioning bricks were either removed and replaced, or on broken areas where it was technically possible, amended with restoration mortar so that no bricks had to be replaced.

Picture 60

The former factory building (1902 to 1908) which is now the Prototype Museum at Lohseplatz. The facade was cleaned almost simultaneously as that of the Maritime Museum. As can be clearly seen, the cleaning level was set too high. After the renovation, the building gives the impression of a "new building".

Picture 61

A window and masonry detail after cleaning. The facade gives the impression of a "new building". The small masonry repair under the windows, which was carried out in former times, has the appearance of "forgotten work". The cleaning "destroyed" the history of the facade.

5.1.3 Masonry joint/joint repair at a heritage site

5.1.3.1 Possible sources of error in joint repair

Should moisture penetration occur on the interior in brickwork buildings, the relationship between water penetration into the facade (rain) and water migration through the outer wall is easy to ascertain. Simple test methods, such as the placement of a water penetration test tube, deliver fast results, whether the brick or the joint are the causes of damage.

Picture 62

Water penetration test tube (aka Karstensches Röhrchen).

Picture 63

Water penetration test.

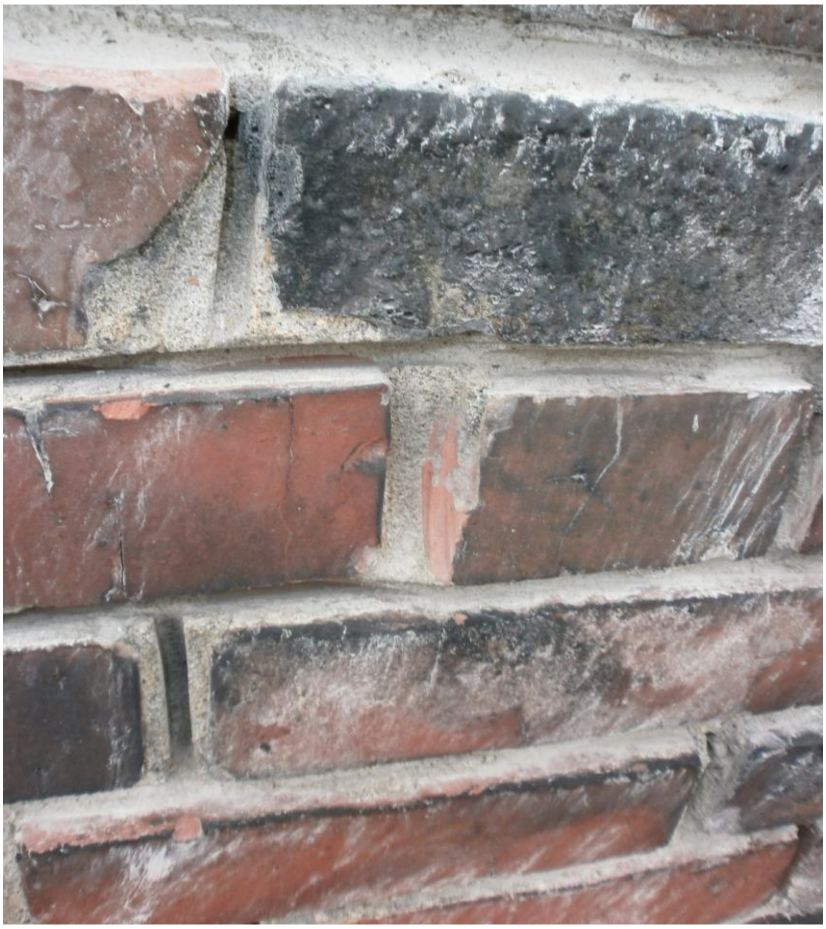
Often the joint proves to be defective, and joint repair is initiated to provide rapid relief. One possible cause of increased water entry is cracking of the mortar at the brick edges, due to the "thermal action" of the sun (different size-changes in length of mortar and brick). If the water penetration rate outweighs the water dehydration rate, damage may occur over time. Damaged bricks, or building-endangering damage (structure, changes in static conditions), etc., may cause more harm.

Let us focus on the joint damage site. As observed in the last ten years in the repair of brick facades, the following procedure is often the case:

The specialist company uses a "joint cutter" to clear the mortar from the joint. In order to perform this operation cost-effectively, that is, quickly, it is carried out in one operation. A wider joint cutter blade is therefore chosen than the joint to be cleared. Because of the width of the joint cutter blade, brick edges of the surrounding bricks are trimmed in the area of the set and horizontal joint (Picture 36).

Even with a technically correct opening of the joint with a cutter, the first cut to relax the joint is not in the centre, in order to remove the excess mortar from the brick edges without damage, but rather at the brick edges (Picture 36).

The mortar can be removed quickly. But the price of the offer in this case also dictates the quality of workmanship!



Picture 36

As can clearly be seen, not just a relief cut was made in the centre of the joint. The edges of the bricks were "trimmed" in the set and horizontal joint area.

Thus, the "burnt skin" of the brick surface is destroyed, rainfall water gains access to the brick capillaries. Water absorption is the result; frost damage is possible.

To avoid this potential damage, the open capillaries at the brick edges must be protected against the entry of water. In general, protection is performed through hydrophobisation. Now, in order to succeed with adhesion of the mortar to the edge of the hydrophobised brick, a (modified) mortar must be used that will cope with this condition. The components modified mortar, brick edge and hydrophobic surface require a reexamination interval, depending on the manufacturer of the components, which can stretch up to 10 years.

The use of hydrophobic components, or hydrophobics in facade renovation, means a control check of the system at recurring intervals (periodically).

The cost of this control, and possibly scaffolding and material, should be included in the relevant cost calculations.

In this damage-prone method of procedure, the joint gap is significantly widened, creating a negative change in the "image" of the brickwork facade.

5.1.3.2 Analysis of the characteristics of the material using the example of Passierzettel. Expert opinion by the ZMK/brick and mortar analysis

(ZMK – Norddeutsches Zentrum für Materialkunde von Kulturgut e. V.)

To prevent possible sources of error, the following procedure in joint repair is proposed:

1. Analysis of the cause. It is advisable to also analyse brick qualities (pressure resistance/water absorption/frost resistance) and, in case of edge trimming of old bricks during joint repair, to be able to decide on the use of hydrophobisation.
   If the brick is burned above the sintering, water absorption and therefore frost-shattering is not to be expected. The joint can then be closed with the chosen mortar.
   If the joint is the cause, then 2.
2. Analysis of whether the facade is damaged over its entire surface or only in partial areas.
   An easy-to-use and fast method of testing is with the water penetration test tube (aka Karstensches Röhrchen).
3. Complete an analysis of mortar composition. This should include the following components:
   a. binding material
   b. aggregates
   c. salination
   d. compressive strength
   e. mortar group
   f. particularities
4. Opening the wall joints with a joint cutter and a thin blade. A relief cut is made in the middle of the joint, then the residual mortar is freed from the brick edges with a chisel.
5. Subsequently, the cleared joint can be refilled with mortar, according to the composition of the mortar analysis, and compacted.
6. Through this method, damage to the bricks is prevented; additional chemical components such as hydrophobics, are not needed, the connections to the old structure are reacquired.
7. The basic premise is that a building of a certain age can be repaired most sustainably with means from the relevant time.

This is an excerpt from the ZMK (Norddeutsches Zentrum für Materialkunde von Kulturgut e.V.) study from the project Hamburg buildings from the 1920s, mortar and brick analyses which presents the structure and content, as well as a microscopic examination of the substance. The study also provides the basis for a mortar recipe that can be used to replace the joint mortar.

6. Concluding Remark

This work focuses a spotlight, from the perspective of heritage monument preservation, on the different conditions relating to the material brick. Every single chapter would, in itself, justify the production of a scientific report. This cannot and should not, at this point, be done.

The effort and care in the manufacturing process of brick should give one an idea of the quality and sustainability of the building material. The damage patterns shown have conveyed an impression of the actual difficulties in the maintenance of brick buildings.

From the example of the housing estates of the 1920s, the extent of the damage problem could be demonstrated. To preserve these "historical buildings", the Department for Heritage Preservation in Hamburg commissioned an expert opinion description of the heat transfer in the outer wall in order to find alternative energy qualification possibilities for the interior spaces. The problems described above have also been dealt with at the international level by the Co2olBricks project.

The strata of brick buildings in the city of Hamburg and the Baltic Sea Region is a special part of our common "architectural heritage". Although present in the memory of the individual, they are nevertheless in danger, as the previous presentation of problems has shown, of disappearing from the cityscape. There is still time to acquire an objective footing toward the conflict – climate change versus conservation – and show that both objectives are of equal value and adjacent to each other. The future of society needs the history of society in order to overcome the current constraints to action.

This work aims to contribute toward understanding the difficulty of preserving our brick architecture.

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