THE EFFECTIVE USE OF WATER-REPELLENTS

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SUMMARY

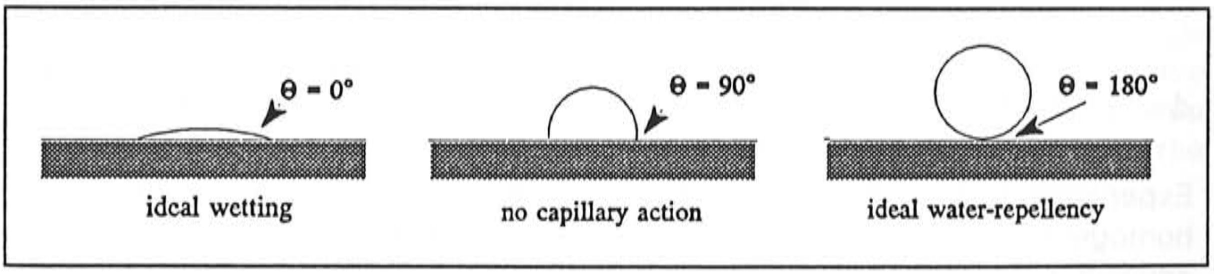
The use of water-repellents can be very beneficial, both to prevent various types of deterioration and to cure certain damages. However, especially when salts are involved a well menat treatment may lead to substantial damage. In addition, the choice of the water repellent and its application shall depend on both the purpose of the treatment and on the type of substrate. Further it shall be recognized that the pH-value of the substrate and thus also the presence of salts may have an influence on the efficacy of a water-repellent.

1 INTRODUCTION

Esthetical and functional damages of a physical, chemical, physico-chemical and/or biological nature to stone-like building materials and structures are due to the presence of water. Some examples of these categories in the order given are soiling, frost damage, formation of so-called swelling salts, salt crystallisation and growth of algae.

Water can ingress under the influence of some pressure, but, can also be sucked into a porous medium under the influence of so-called capillary forces. Water-repellent treatments are meant to suppress these forces.

Rather than blocking the pores ideal water-repellents only influence the surface tension of the pore walls. So, rather than decreasing the pore size a water-repellent changes the contact angle between the liquid and the solid. Since the capillary force is a linear function of cos(contact angle Θ) $\Theta = 0°$ ($\cos\Theta = 1$) means ideal wetting and maximum capillary action. $\Theta = 90°$ ($\cos\Theta = 0$) means no capillary action and $\Theta = 180°$ ($\cos\Theta = -1$) means ideal water-repellency.



In the case of water-repellency water can only penetrate a pore if sufficient external pressure is exerted or if there is sufficient internal under pressure. Since capillary action is inversely proportional to the pore diameter a water repellent porous material resists to more water pressure the smaller the pores.

2 EFFECTS OF PENETRATION DEPTH

Basically very little penetration of a water-repellent is needed to suppress capillary suction. Indeed, a very superficial treatment will result in perfect beading. However, due to imperfections in the substrate such a treatment will seldom result in maximum possible resistance to water pressure and, therefore, in optimal behaviour from a practical point of view. How much penetration depth shall be realized to achieve maximum resistance to water pressure depends on the pore size (distribution) and on the presence of (hair) cracks and other inhomogeneities in the substrate.

Everything tends to wear. Since wear generally is due to external forces or degradation factors an initially perfectly seeming, but, very superficial treatment will show imperfections at rather short term. Durability calls for at least some penetration depth. In addition, water behind a very thin water-repellent zone will shine through as it were due to the fact that a moist material generally has a darker colour. So, in order to avoid at least moisture stains penetration depth shall be greater the more transparent the substrate. Sand-lime brick for instance is more transparent than clay brick.

Penetration depth, of course, depends on the amount of water-repellent agent absorbed by the material. However, since the agent is only being used, so to say, to cover the pore walls there is no simple relation between the amount of agent needed and the porosity of the substrate. This means that the amount of agent needed to achieve a certain penetration depth shall be determined experimentally.

3 PREFERABLY CLEAN FIRST

Application of a water-repellent agent onto a soiled substrate will inevitably lead to inhomogeneous absorption. In the case of soiled masonry it will show that penetration into the brick will mainly occur through the interface between brick and joint. This will result in very little impregnation in the center of the brick's face. Therefore, soiled substrates preferably shall be cleaned first.

4 APPLICATION TECHNIQUES

Experience shows that it is very hard, not to say impossible, to achieve homogeneous penetration if application is done by roller or painting brush. To achieve acceptable results using such techniques will require more water-repellent. Best results are achieved using so-called flooding or low pressure

airless spray techniques. Airless spraying is favoured in case the substrate shows cracks or a pronounced surface texture as is the case with some hand moulded clay brick.
Application shall be done working bottom-up and preferably in two steps, i.e. doing the job in two succesive runs using about half the amount to be applied in total. This is especially advisable if the application does not follow a facade cleaning. Due to soiling the agent is namely not being absorbed at the same rate by all bricks and joints. In a second run bricks/joints which absorbed less agent in the first run will absorb more in the second and vice versa. This is especially the case if the active agent is diluted with a liquid which is capable of dissolving greasy substances. In case the diluent is not able to dissolve such substances as is the case with water-based agents, it will be hard to achieve acceptable results if the substrate has not been cleaned before.

5 THE CHOICE OF THE TYPE OF WATER-REPELLENT

The various types of water-repellent show different behaviour when it comes to impregnation in substrates showing different pore size (distribution). This is due to the fact that the various agents show different molecular size. Silanes have the smallest size and, therefore, are the best choice in case of a fine porous substrate. Siloxanes are more or less further polymerized silanes. Oligomeric siloxanes consist of shorter and polymeric siloxanes consist of longer chains of silane molecules. So-called silicone resins are fully polymerized. In this order the various types of agent are less suitable for substrates with finer pores.

Unfortunately, smaller molecules go together with higher vapour pressure and thus lead to higher evaporation losses. Therefore, silanes are being applied in higher concentrations which, of course, makes them more expensive. So, for economical reasons the choice of a water-repellent shall also depend on the ease of penetration into the substrate.

Another thing is that water-repellents generally develop their water-repellency only after some chemical reaction. Silanes and siloxanes for instance need to react with water and siliconates (silicone salts) generally develop their water-repellency after reaction with carbon dioxide. These reactions are being influenced by the pH-value of the substrate. Silanes for instance need an alkaline environment and siliconate works best in a slightly acid environment. Silanes, therefore, are preferred for sand-lime and other calcitic materials which, fortunately, is in line with the fact that these materials generally have finer pores. It also has been observed that some agents do not fully develop their abilities in the presence of some salts. It follows that in some cases the suitability of a water-repellent shall be tested on the particular substrate.

6 THE APPLICATION TEMPERATURE

Chemical reactions generally proceed faster the higher the temperature. Therefore, at lower temperatures there is a risk that the agent develops its water-repellent properties too slowly with respect to the evaporation rate so that after some time it appears that there is no water-repellency at the very surface of the substrate where is it generally wanted the most. This phenomenon has been observed with silanes. Another thing is that rainfall soon after the application can wash away the agent if it has not sufficiently settled itself, so to say. It follows that for practical reasons agents should be preferred which show shorter reaction times.

7 THE BENEFITS AND CONSEQUENSES OF WATER-REPELLENT TREATMENTS

SOILING

If soiling is the result of airborne particles being deposited on a substrate these particles only appear to adhere well to that substrate once capillary forces had a chance to work. So, as soon as capillary forces, due to a water-repellent treatment no longer exist, such airborne particles can easily be washed away from that substrate. The washing action normally comes from rain-water hitting the substrate and being able to flow off thanks to the fact that it is no longer being absorbed. This explains why substrates being treated with a water-repellent tend to stay clean for quite some time. The same holds if there is very little capillary action due to the fact that the substrate is a very dense one or if it is fully saturated with water. However, since the cleaning action comes from the flow of water this effect can only be expected if rain-water is able to reach that substrate and if it can flow off freely. This means that overhang, how beneficial by itself and, therefore, recommendable it may be, spoils this potentially beneficial effect of a water-repellent treatment. In order to keep them satisfied consumers should be told to do themselves some cleaning on such protected areas from time to time.

BIOLOGICAL GROWTH

A discrimination shall be made between superficial growth and plants that have their roots grow deeper into the substrate.

Algae grow only very superficially. They can be considered not to damage the substrate other than in an esthetical way. Mosses send their rhizoids (rootlike organs) into the substrate in order to have them through acid secretion dissolve minerals on which mosses feed. These minerals are mostly calcitic materials so that mosses especially and seriously can attack pointing mortar.

Algae and mosses multiply by spores and these are, so to say, flying around looking for suitable conditions to germinate. Very thin water films seem to suit the purpose. Once spores have germinated they tend to create and maintain the environment they need. Algae mostly come first and prepare as it were the conditions in such a way that also the higher demands of mosses are being fulfilled. Whether algae and mosses can colonize a substrate all depends

on the so-called time of wetness. Sunshine on the substrate shortens this time of wetness and, therefore, is an efficacious means to avoid growth of algae and mosses. It is often thought that a water-repellent treatment can have the same beneficial effect. Unfortunately, experience is that algae and mosses that grew there before the treatment reappear after several years if nothing was changed in order to prevent the substrate from getting extra wet. This is due to the fact that the effect of the treatment decreases in time due to natural wear. This wear most probably is mainly due to ultra violet light and it is likely that also the run off of rain-water has some influence. Fortunately, however, it takes less effort to remove algae and mosses from a treated than from an untreated substrate.
Mosses need more water than algae. Due to this fact mosses may spread out more once a substrate has been treated.
If after a water-repellent treatment the substrate can dry out sufficiently this can be the end of the growth of higher plants. In order to achieve this goal the plants shall, of course, be removed and the substrate be repaired before a treatment is done.

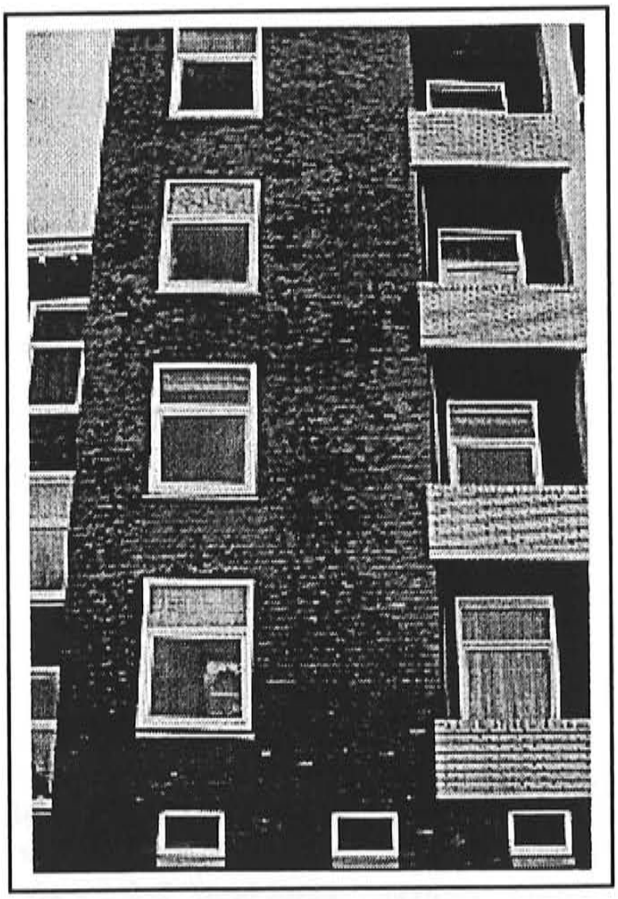
THE DISSOLVING PROPERTIES OF RAIN-WATER

Clean rain-water is almost saturated with carbon dioxide. The pH-value of natural rain-water is 5.6. Although carboncarbonate is little soluble in water free of carbon dioxide it dissolves much better in water saturated from carbon dioxide. This is due to the formation of carbonbicarbonate which is 200 times more soluble than carboncarbonate. Natural rain-water, therefore, is highly aggresive to calcitic materials among which cement and lime containing materials like pointing mortar and concrete and also some natural stones. Acid water, in addition, contains among other dissolved gases sulphur oxides from which sulphuric acid is formed. The pH-value of acid rain in The Netherlands can be as low pH 3, the yearly average value being pH 4.5.
As can be easily demonstrated by the acid rain test developed by TNO Building and Construction Research pointing mortar shall be of a very good quality which in fact means sufficiently dense and, as a consequense, contain sufficient binder to resist the aggressive effect of acid rain. In the same test it can be demonstrated that a water-repellent treatment can provide an amazingly effective protection to pointing mortar, sand-lime brick and comparable materials. In the same way it can be expected that a water-repellent treatment can provide calcitic stone an effective protection against the formation of black crust.
It has also been demonstrated that sanding of natural sandstone and powdering of weakly burnt clay brick is the result of the dissolution by acid rain of the binder that acted as a sort of adhesive for the inert particles and that this effectively can be prevented by a water-repellent treatment.
Chloride can dissolve calciumcarbonate. Due to this effect pointing mortar which appears durable elswhere can be damage on relatively short term near the sea side. Therefore, newly erected masonry near the sea side should be treated with a water-repellent. However, with newly pointed old masonry near the sea side one should be careful as will be explained in the following chapter.

EFFLORESCENCES AND STAINING

Porous materials contain constituents which are more of less water soluble. At drying pore water more or less saturated with these constituents comes to the surface by capillary action. After evaporation the constituents remain on the surface of the substrate and become more or less visible. If the soluble constituents are salts what becomes visible is called efflorescence. If the efflorescence consists of coloured substance the term is coloured efflorescence or staining [1].

FIG. 1
Moisture stains due to improper application of a water-repellent.



If the water evaporates underneath the surface the pore water constituents are deposited there and do no longer become visible. In such a case one speaks of hidden or crypto-florescence. That can be considered a beneficial effect and, since a water-repellent zone effectively prevents water from coming to the surface a water-repellent treatment can be an effective measure to cope with stains and efflorescences. However, if the crystallizing salt is able to develop high pressure sometimes severe damage can be done to the substrate since then flakes as thick as the impregnated zone can be pushed off. This is referred to as spalling. Sodium sulphate is such a damaging salt. Sodium chloride, however, is rather harmless in that respect. Nevertheless, severe damage was done to clay brick when a building very much near the sea was treated with a water-repellent in order to cope with water penetration. The same happened to masonry which was treated after it had absorbed quite some table salt which was used as a deicer. In the case of the building near the sea each time a layer came loose a thick white crust containing sea salt was found behind it. It should be recognized that sea salt next to a lot of sodium chloride contains some sodium sulphate as well. The same risk exists if the substrate contains sodium sulphate or when this salt gets into the substrate after the treatment for instance as a result of rising damp. So, in such instances, care shall be taken. It is wise to perform some crystallisation tests on samples taken from the substrate to be treated. In the case of the masonry containing quite some deicer the weakly burnt clay brick suffered from powdering.

That 'weakly burnt' should be stressed because clay brick is less vulnerable the better it is burnt. Therefore, at the sea side onlywell burnt brick shall be used.

8 SALT SWELLING

Some clay bricks have extremely high sulphate contents. In very wet conditions the sulphate may migrate to the pointing mortar and/or to the laying mortar. Depending on the type of cement and the use of lime ettringite and/or gypsum may be formed. These minerals are hydrates which means that they include water into their crystals. Their volume is larger than the one of the original constituent. This may cause the mortar to swell which may give rise to various types of damage [2,3,4,5].

FIG. 2
Soiling photographed 10 years after the facade was cleaned and treated with a water-repellent. Soiling occurs where due to detailling rain-water is prevented from washing the brickwork.

In a case where the high sulphate content of the brick is known one can choose for a mortar giving the least of risk. Of course the masonry shall be properly designed, i.e. it shall be properly coped and detailing shall be such that no concentrated down flow of water will occur. In addition, in order to reduce the risk to an absolute minimum the masonry shall be treated with a water-repellent.
In some instances damage comes by surprise. It then manifests itself at the most risky location, e.g. a non-coped garden wall. This wall may be lost, but, as long as the facades show no sign of damage there is no reason to replace them as well. A water-repellent treatment shall be considered.
Recently brick made of clay rich in pyrite (iron sulphide) contained over 1% water-soluble sulphate (SO_4).

FIG. 3 Weathering of weak pointing mortar.

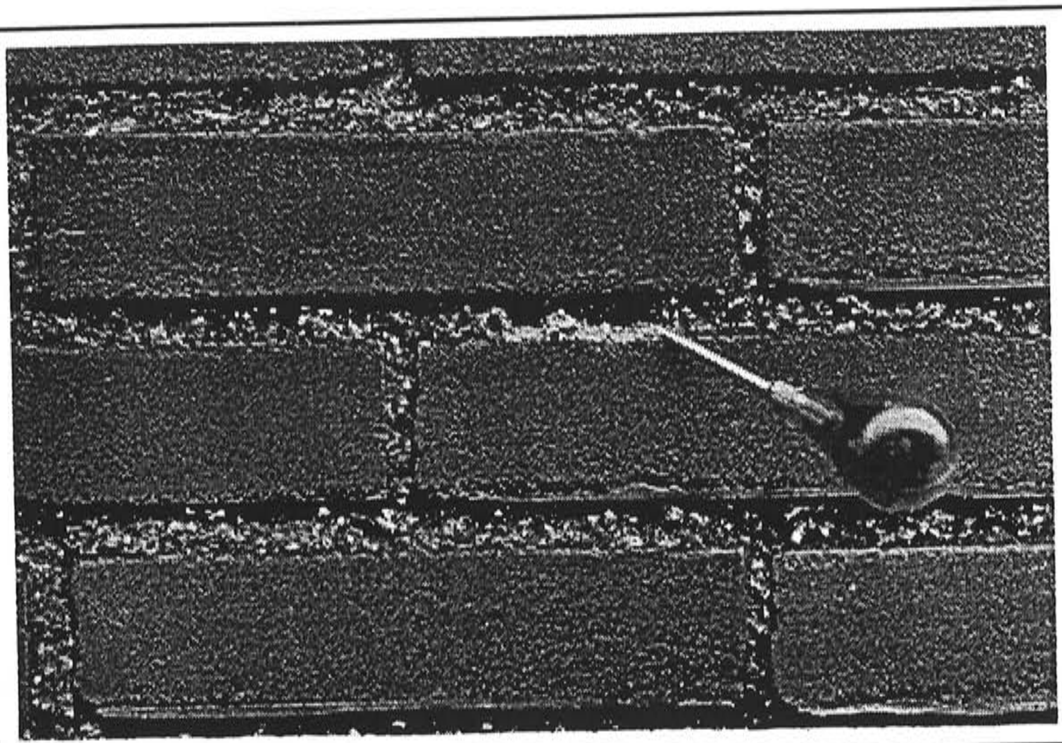


FIG. 4
Spalling after a water-repellent treatment due to crypto-florescence of airborne sea salts which accumulated in the brickwork before the treatment was done.

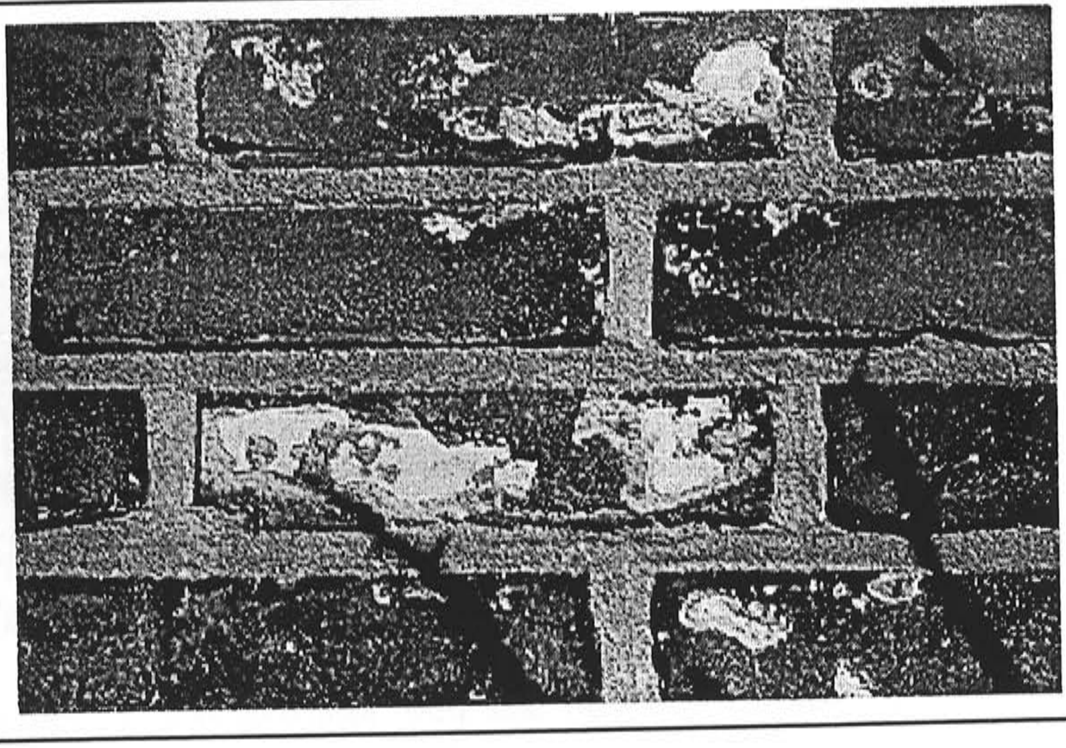
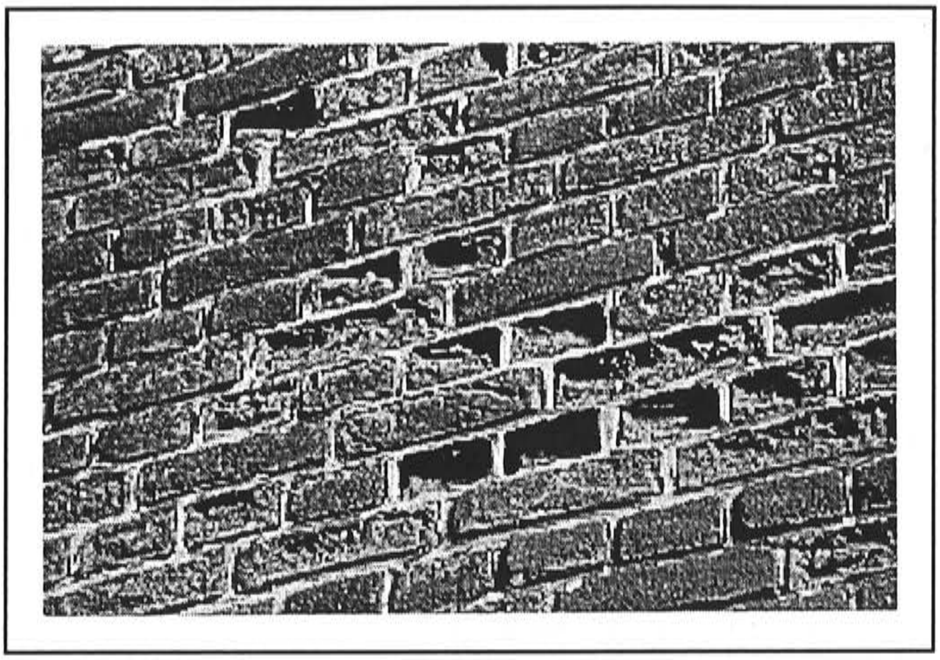


FIG. 5
Powdering of soft mud bricks very much near the sea. Harder bricks are more durable.



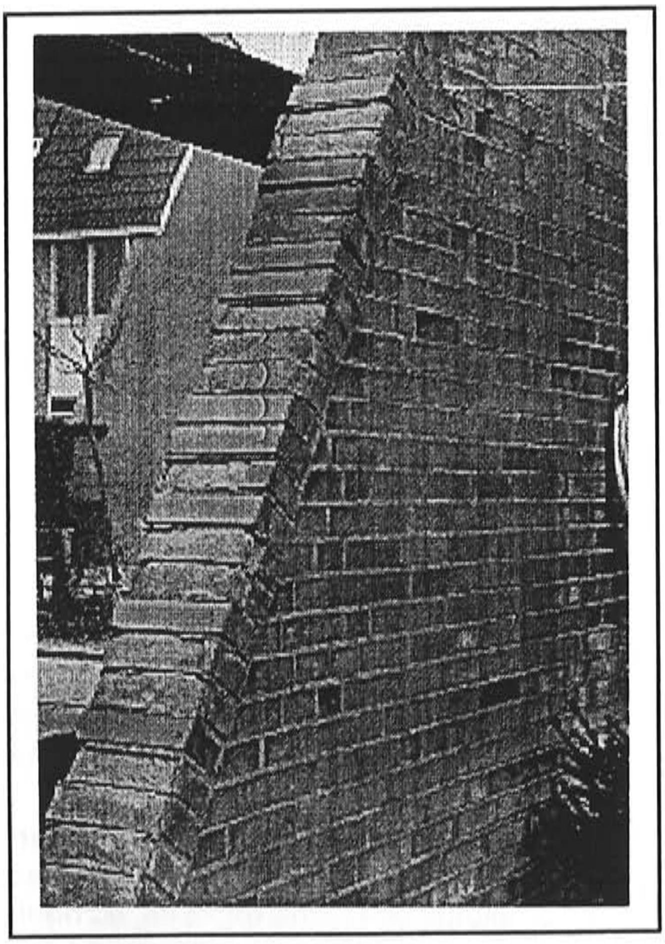
The brick showed blueish-black cores due to lack of oxigen in the brick during the firing process. The brick appeared capable of rusting and produced extreme magnesium sulphate efflorescences. After about three quarter of a year non-coped garden walls started bowing on their top and the brick could be taken away by hand. The facades were tested for their soundness and found allright. It was decided to clean the facades and preserve them by means of a water-repellent treatment. Knowing the risk crystallisation tests were done in order to firstly select a suitable water-repellent and secondly to see if there was any risk of spalling.
Surprisingly, no satisfactory results were obtained using three types of water-based water-repellents. Very good results, on the contrary, were obtained using siloxane in white spirit and also with siloxane in alcohol. The alcohol-based product was also tried because the building society wished to avoid the use of white spirit if possible. The water-based product behaved well on the red parts of the brick, but, not on the blueish-black parts which maximally contained the sulphate.

Cleaning was done by wet powder blasting. In order to prevent new efflorescences at drying the facade was first made water-repellent. Cleaning was very succesful. No damage was done to either the brick or the pointing and the facade was still beading after the cleaning action. No new efflorescences appeared.

9 FROST DAMAGE TO BRICK OR MORTAR

In cases of frost damage to either the brick [6,7] or the (laying) mortar [8] masonry seldom is so badly damaged that it should be replaced entirely. Repairing the damaged areas without taking measures to protect the spared parts is not very wise since experience shows that other parts of the masonry can be affected in following winters.

FIG. 6
Frost damage to the most exposed bricks. After replacing the bricks-on-edge the spared part clearly needs to be protected from getting too wet.



In case of damage to the brick all bricks shall be tapped with a hard object and judged for their sound. All bricks producing hollow sound shall be replaced and all of the pointing shall be repaired. Next all of the masonry shall be cleaned and treated with a water-repellent.
In case of frost damage to the mortar all masonry showing any sign of loss of adhesion shall be replaced. Next, both the new and the spared masonry shall be cleaned and treated with a water-repellent. Here too, of course, everyting shall be done to avoid the ingress of water.

FIG. 7 Frost damage to both pointing and laying mortar.

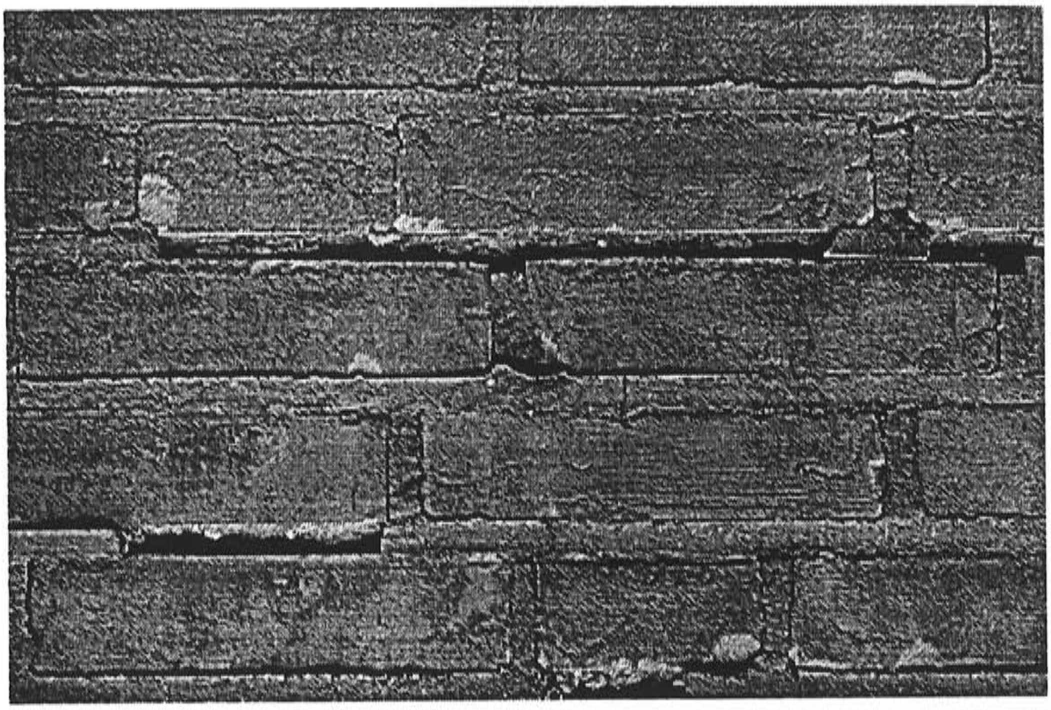
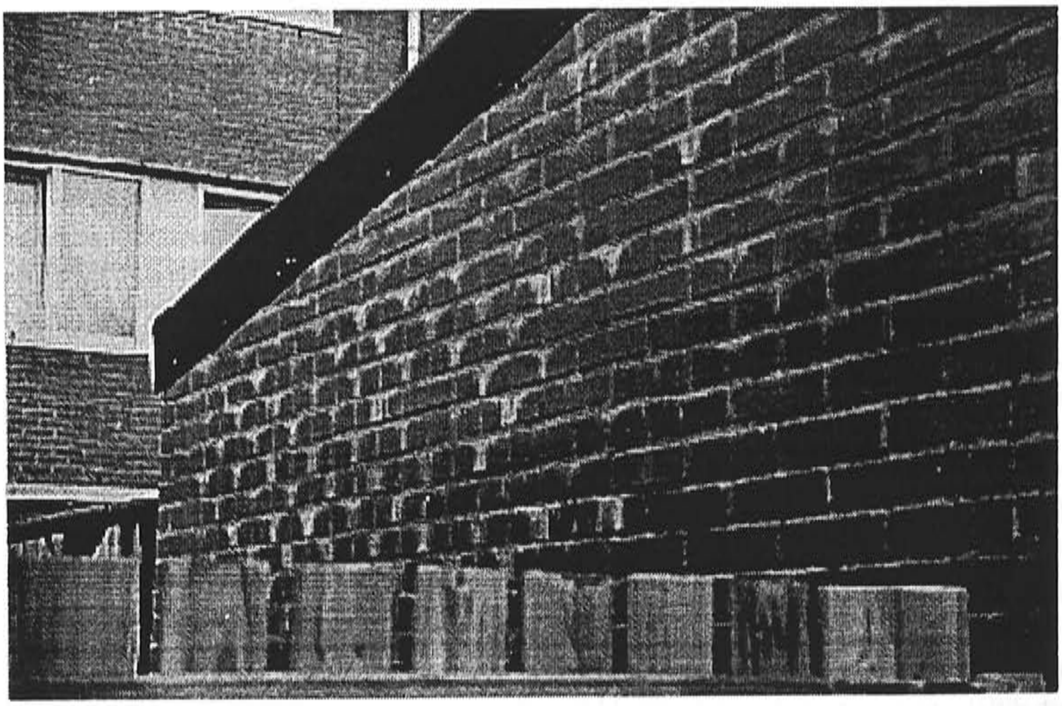


FIG. 8 Leaching of laying mortar constituents.



10 LEACHING OF MORTAR CONSTITUENTS

As long as mortar is not carbonated it is vulnerable to leaching of both lime and alkali silicate. Pointing mortar normally gets fully carbonated in a few weeks, but, it may take years for laying mortar to carbonate. The carbonation rate depends on the possibilities for carbon dioxide to diffuse into the mortar. Here the density of the brick plays an important role. So, the denser the brick the longer it takes to carbonate the mortar. In addition, lime containing mortars, of course, take more time to cabonate than pure cement mortars.
Cleaning using chemicals is not always succesful. This, no doubt, is due to the fact that one has to deal with a mixture of carbonate and silicate. Wet powder blasting, however, can do the job.

As long as the mortar is not sufficiently deep carbonated, there is quite some risk for new leaching to occur, especially when the leaching concerns the laying mortar. Therefore, one should make oneself clear about the real cause of the leaching and check for carbonation depth. In quite some cases a water-repellent treatment shall be considered. Very satisfactory results have been obtained.

11 WATER PENETRATION

Due to imperfections in the laying of the bricks half brick masonry shall be considered unable to keep water from penetrating. However, whether this provides for a problem depends on the situation.
Provided that the inner leaf of a cavity wall is virtually air tight the air pressure in the cavity is more or less the same as it is on the outer side of the outer leaf. In case the inner leaf is not air tight there will be a draught of air through the wall and this indicates that an air pressure difference over the wall exists which represents a driving force for water transport through the outer leaf and principally also in the direction of the inner leaf. When water reaches the inner leaf this can provide for a clear case of water penetration. Experience shows that air tightness of the inner leaf is a very important feature. Therefore, inner leafs shall be rendered, at least at the cavity side. In The Netherlands this can be done thanks to the fact that it is normal practice there to first erect the inner leaf. In Belgium, on the contrary, first the outer leaf is built.

Barns and garages in The Netherlands are normally built with half brick thick walls. This provides for a very unfavourable situation since normally there will be over pressure at the rainy side and under pressure at the opposite side. So, building a barn or garage the mason shall work very carefully so as to fully fill all the space between the bricks with mortar. Especially the vertical joints ask for extra care.
Windmills are built in solid masonry some 40 cm thick as an average over their height. Because of their slope they maximally catch rain-water. Windmills, therefore, at least at young age generally suffer badly from water penetration. In order to cope with that problem windmills are frequently rendered on the

rainy side. Fortunately, last centuries. So, old windmills had suffucient time to get water tight as a result of soiling. Therefore, care shall be taken not to clean an old windmill when it is being restored. When bricks have to be replaced both the new bricks and the pointing shall be artificially soiled and made water-repellent.
Practice has shown that water penetration problems almost never can be coped by just replacing the pointing mortar. Provided that the pointing is allright, however, cavity walls and windmills suffering from water penetration can be made 'water tight' by a suitable water-repellent treatment. With half brick thick masonry, on the contrary, water-repellent treatments rarely work out satisfactory.

12 CEMENT ETCHING OF WINDOW PANES

Rain-water penetrating the outer leaf of a cavity wall is a normal phenomenon. However, the amount of penetrating water shall be kept to a minimum and the water that reaches the cavity shall not reach and run over the window panes. Unfortunately quite often, due to improper design, cavity water does run over the window panes and then causes so-called cement stripes. These are very hard to remove, if ever, so that enormous quantities of window pane have been replaced. Often, unfortunately, with the very disappointing result that the story repeated itself.
Here too, if possible, measures shall be taken to prevent cavity water from running over the window panes. In most cases a water-repellent treatment must and will do the job.

13 CONCLUSION

Water-repellent treatments can prevent soiling for at least quite some time. Growth of algae and mosses, however, can be prevented for only a few years. As soon as such biological growth again manifests itself a very superficial retreatment mostly will be enough to keep algae and mosses away for another few years.
Water-repellent treatments can also prevent efflorescences. However, this may introduce the risk of spalling. Coloured efflorescences or staining can be treated succesfully and without any risk.
Functional damages like salt swelling, frost damage to bricks or mortar, water penetration or cement etching of window panes can be prevented or prevented to develop any further.
In fact, in quite some cases a water-repellent treatment is the only measure one can take to reduce the risk of further development of a damage to a minimum. In all cases, however, one should fully understand the nature and causes of the damage. The help of an expert can reduce the risk of taking the wrong measures.

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