ANALYSIS OF FACADES

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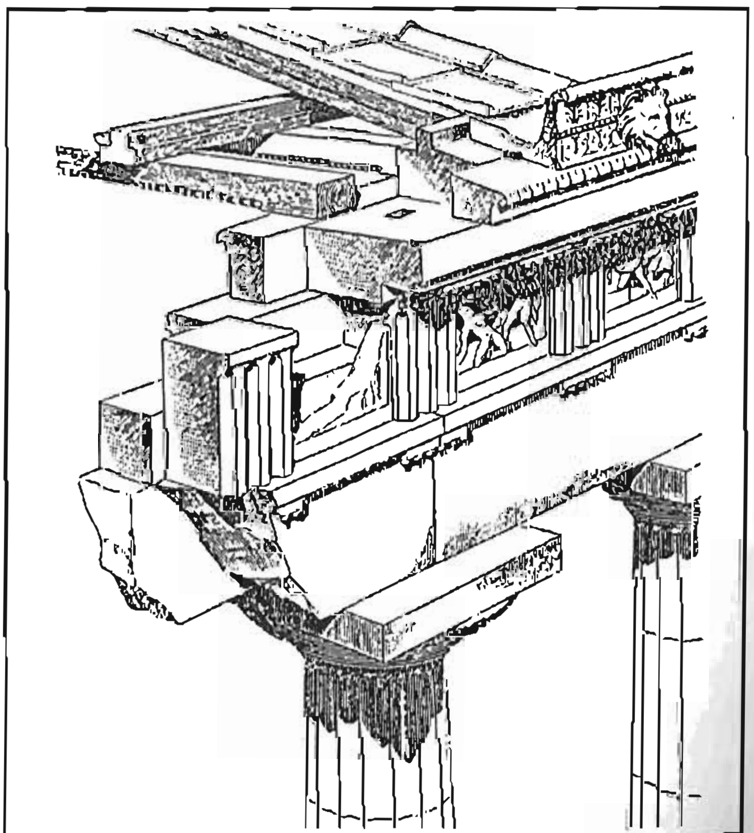
1 INTRODUCTION

Throughout the centuries we have had to learn the hard way how to use the materials around us for building. Master builders learned from each other and passed on their skills from father to son, while to keep in touch with the architectural styles of the day it was necessary to travel to see how others built. A building style would flourish only to merge gradually into the superseding style; Graeco-Roman, Romanesque or Gothic, and so on. A building style would sometimes last for hundreds of years - quite logical of course as in the past it took many years even a century to complete a single building. And since buildings were meant to last, the problem of rainwater had to be closely addressed.

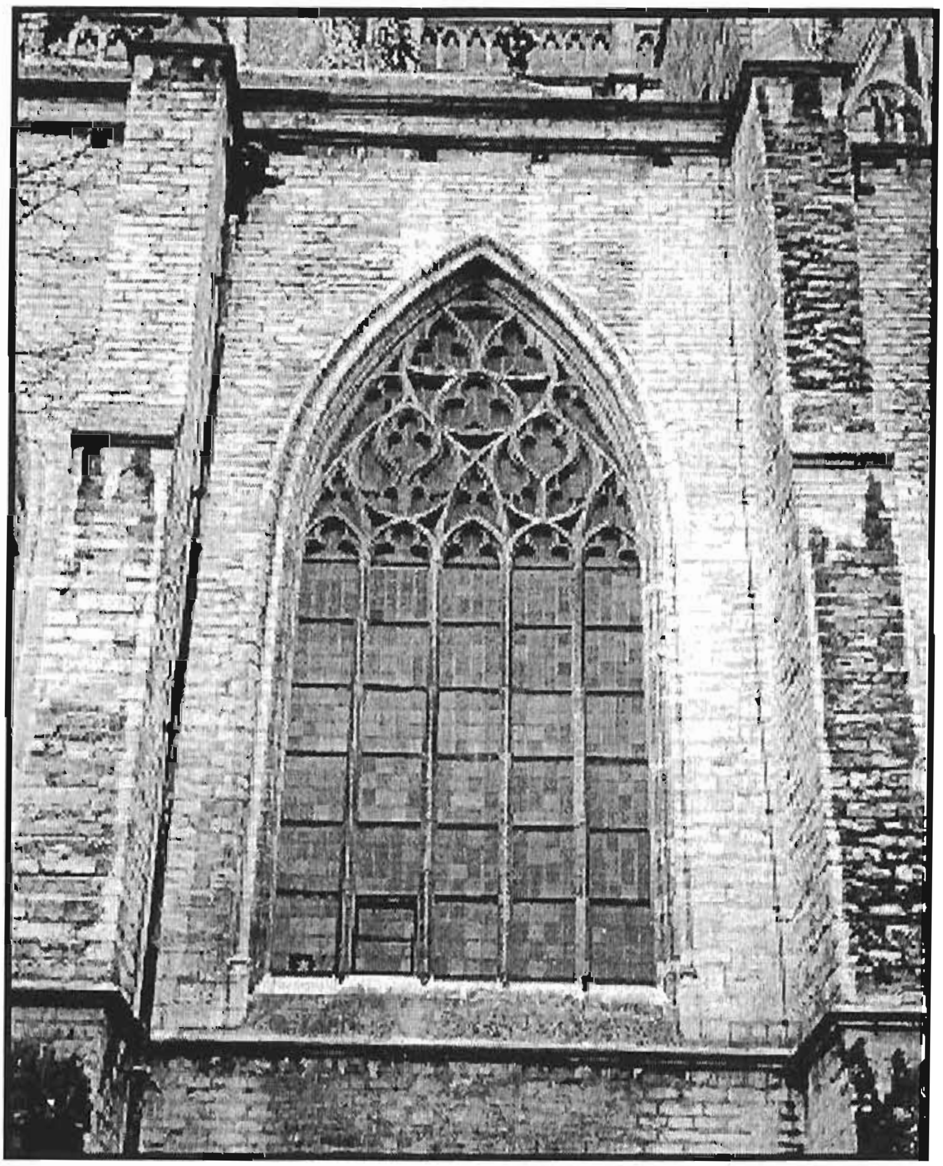
Water is the prerequisite for everything that lives but water also causes things to change. If the influence of water can be contained, a building will last much longer. For instance, its facade should be water-repellant and every good facade should visibly demonstrate certain principles. These are:

- to cover the upward-facing stone surfaces
- to divert water from the facade
- to drain the collected water to places not in contact with te facade.

A building's design and its detailing were partly based/are still based on these fundamental principles. For example, one feature of the Doric order is its sloping roofs which ensure that water is conveyed to the gutters. The gutters have finely detailed spouts which throw the rainwater clear of the building. Moreover, the architrave under the gutters is protected by a multi-cornered canopy which does not allow the water to flow in any other direction but downwards, while we see that closed building elements are placed in a recess, e.g. tympans.



The Gothic style clearly demonstrates the attention given to the protection of facades and to drainage. Stone-made Gothic windows project from the wall surfaces and are detailed in such a way that water is thrown clear. The window sills slope sharply and also project from the wall surface, allowing the water falling onto the glass surfaces to be thrown clear of the facade immediately. The filigree ornamentation is well-rounded and bevelled in form to ensure that water is not given the chance to remain on the stone for any length of time. A comparable technique is used in constructing flying buttresses. Not only are flying buttresses sharply inclined on the upper side but are also equipped with crockets that give Gothic buildings their subtlety and delicacy but more importantly, prevent excessively large flows of water from forming. Water spouts are now substantially larger in size and project from the facade for a considerable distance, throwing water at a considerable distance from the surface of the facade. The vertical stone work is always protected.

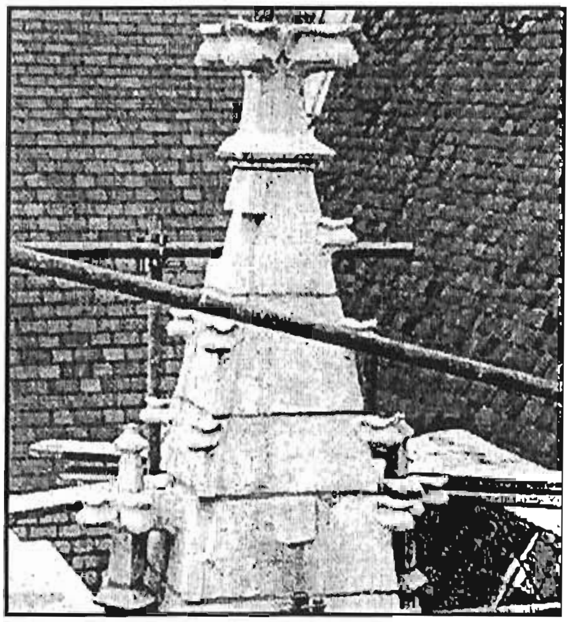


In later centuries we see, particularly in Holland, how wood and subsequently brick emerged as important building materials.
We see the "spout" gable with its slanting surface causing water to be diverted from the horizontal shoulder areas (for the same reason, additional structures to the sloping parts of Gothic buildings distributed the flow of water), and the "step" gable with its horizontal covering, although the seam between the protected horizontal brickwork and the vertical brickwork was rather vulnerable; the later "scrolled" gable, "neck" gable and "corniche" gable dealt more effectively with this problem.

1500 1520 1550 1558 1594 1615 1620
uit:koninklijke oudheidkundig genootschap

In comparison to the gradual development of the various styles in the past, and the relatively few building materials in use (brick, plaster, wood, lead and glass), developments are so rapid nowadays that a new style emerges virtually every five years. Today's rapid developments are partly stimulated by the enormous range of products and components now available and partly by the much higher demands made by a building's users regarding the need to economise on energy and materials. But in this century particularly - due to our use of cement - we see many examples of buildings in which the fundamental principles have been abandoned. Our knowledge of them has been forgotten while our schools neglect to teach the subject adequately. It is as though we are having to learn from bitter experience all over again; the learning process is sidestepped because the next building style has already been proclaimed.

Lessons must be learned from our analysis of facades. Those components that regulate water flows and that have disappeared or been damaged, should be restored before resorting to hydrophobation - often most essential.



2 WATER

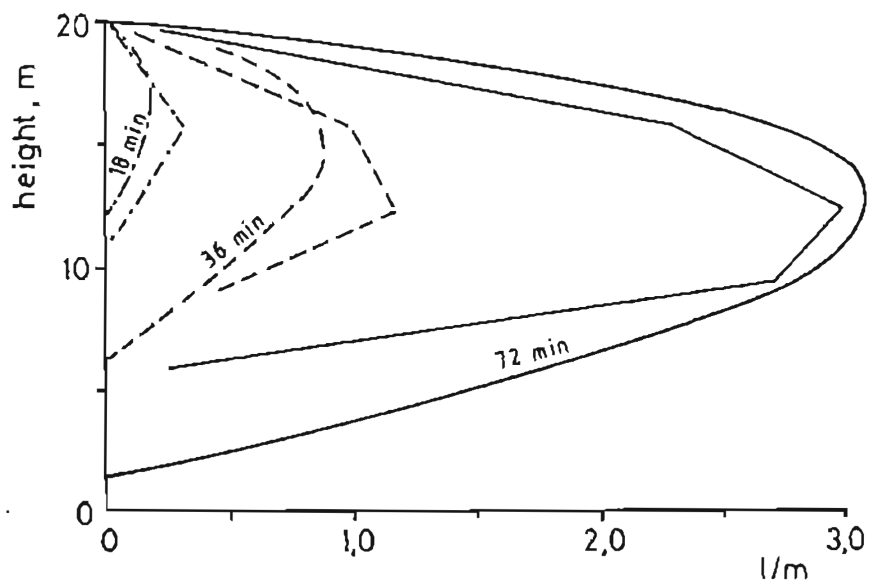
Water can be found in facades in various forms - as vapour (gas), liquid or solid matter. Of vital importance is the way in which solid matter collects in or on facades.
We differentiate the following forms:
- from outside to inside
- from inside to outside
- from above to below
- from below to above

All these forms involve the facade's capillary system.

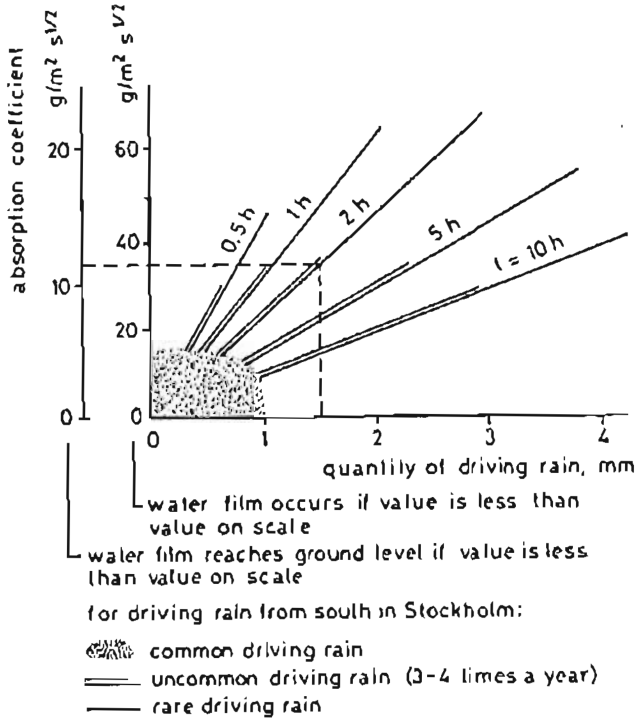
FROM OUTSIDE TO INSIDE

The first question to address is how water - rain, for instance - arrives on and in a facade. The problem has been considered by many researchers but the field tests conducted by the Swede, Oscar Beyer, have proved to be the most informative. Most water collects at the corners and upper edges of a building; hardly any on the surface of the vertical facade just above the ground level since the direction of the rain drop is then practically vertical. This also means that more water is collected at the extruding parts of the facade closer to the ground level. Water collected by the building is partly absorbed into the pore system and partly flows away over the facade. The porosity of the stone will determine whether the water can flow away and whether this flow can, for instance, reach ground level. A decisive factor is the uniform permeability of the joints and also whether the wall is homogeneous or whether various types of stone have been used.

The figure below shows an example of the magnitude of the rainfall run-off streams during a shower of rain, with a high and uniform driving rain intensity. It can be seen that it took about a quarter of an hour in this case before rainfall run-off began to appear and that the run-off then gradually increased as te wall material was moistened. Despite the fact that powerful driving rain continued for more than 1 hour, the run-off never reached ground level.



The next figure on this page shows the influence of the absorption-coefficient of an external wall material on the rain run-off streams which result from driving rain of different types and frequences.
t indicates the duration of the driving rain in hours. The figure shows that rain run-off rather often occurs on concrete walls but usually affect only the upper parts of the wall.



Just as important is the relationship between the amount of water present and the porosity of the stone, because, if the saturation level is exceeded in winter, the situation can become critical. These effects become greater in relation to the size of a building. Water freezes and expands. This expansion can be much, much greater - even one hundred times greater - than expanding stone. If at all possible, water and ice will avoid the pressure that builds up and seep into the pores where lower pressure prevails.
In 1912, Hirschwald found that a critical situation arose if 80% of limestone became saturated, while the situation was even more critical in finely porous stone with pores of < 10U than in coarsely porous stone. This 80% saturation level is not valid for every type of stone; French limestone ranges from 70-100%.

To analyse facades and architectural decorations, stone is removed from the facade and subjected to a freeze-thaw cycle under laboratory conditions. It is saturated up to 80% under vacuum and then subjected to a freeze-thaw regime. If stone stands up to this treatment it can safely stand the ravages of time. However, we do not feel this method of simulating reality a correct one. Moisture is absorbed into the centre of the stone and is reasonably correct for extremely porous material and such components as brick chimneys. However, properly detailed limestone absorbs much less as was found in tests carried out by the Belgian firm, R.M.T. prior to cleaning the church of Our Lady of Breda. The procedure was as follows: spray facade for several hours to soak the dirt then clean facade with an adapted JOS system causing the minimum amount of material loss. Samples were then taken immediately and the carbide method used to measure their humidity content. It was found that despite the intense "rain" treatment, moisture had not penetrated into the core of the stone. We feel that freeze-thaw tests under laboratory conditions only correspond with reality for very small-sized components. Hence, what is a good testprocedure for brick is not yet good enough for natural stone.

A	B	C
% [m/m]	% [m/m]	impession during drilling
<0.5	*	- hard - dry
0.5	0.5	- quite soft - wet / dry
3.0	1.0	- soft - wet

Table 12.4c: percentage of moisture absorbed after cleaning
Method M.R.T.
Column A: drilling depth 0 - 50 mm
Column B: drilling depth 50 - 100 mm

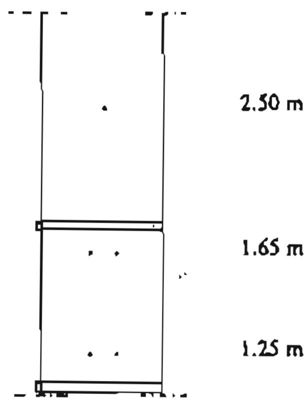


fig. 12.8: head of Buttress 1 with drilling holes

* Remark: moisture measurements with carbide samples occured about 2 hours after cleaning.

FROM INSIDE TO OUTSIDE

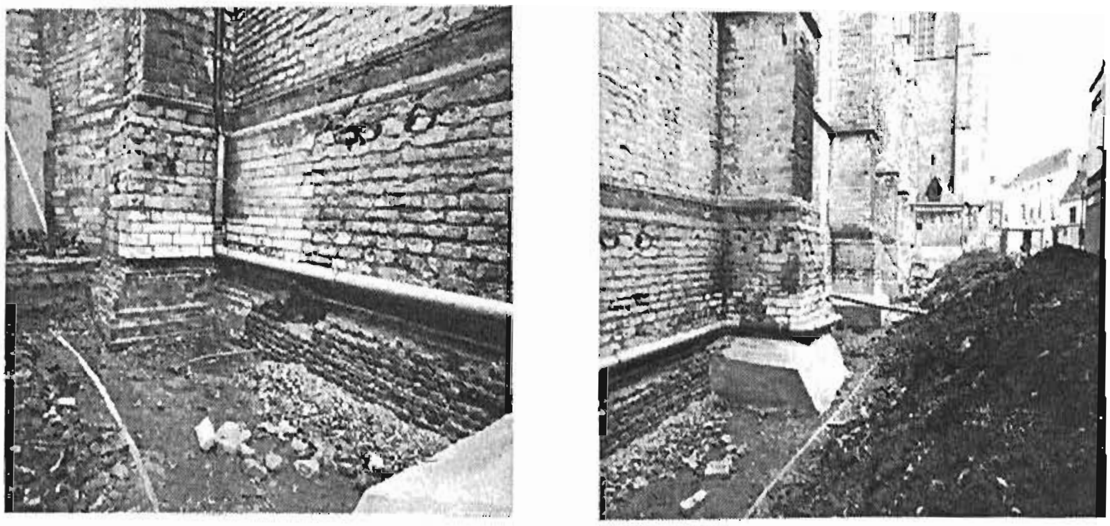
Pressure changes cause damp to move to areas with a lower pressure, usually from inside to outside. Then, if the temperature is low enough for the relative humidity to reach 100%, it condenses to water. In pore systems containing fine pores, water is able to condense at a relative humidity of 70-80%. Hence, the more open the surface of the stone on the outside, the easier it is for moisture inside to evaporate on the outside of the facade. Applying layers to the outside of the facade to reduce its permeability is risky. If possible, moisture production on the inside should be decreased to prevent problems occurring on the outside of the facade.

FROM ABOVE TO BELOW

This can occur if the fundamental principles are not adhered to. It can also occur through lack of maintenance, which is usually the case. It should be treated once the water has settled and evaporated and the situation is back to normal. Cracks in walls should be closed and of course the origins of the cracks traced and dealt with. In many cases, the cracks are caused by the entire bearing system structure behind the facade, such as a non-insulated concrete roof mounted on a brick wall or a detailed structure behind an undetailed facade.

FROM BELOW TO ABOVE (RISING GROUNDWATER)

The base of the facade absorbs moisture from its surroundings. The flow of moisture then saturates the bottom of the wall causing water on the inner and outer surfaces of the wall to evaporate. Hence, the relative humidity of the air on the inside increases, causing moisture to be transported from inside to outside, higher up the wall. Often enough, darker discolourations on a wall's surface are visible signs of rising damp. In any case, moisture can be measured.

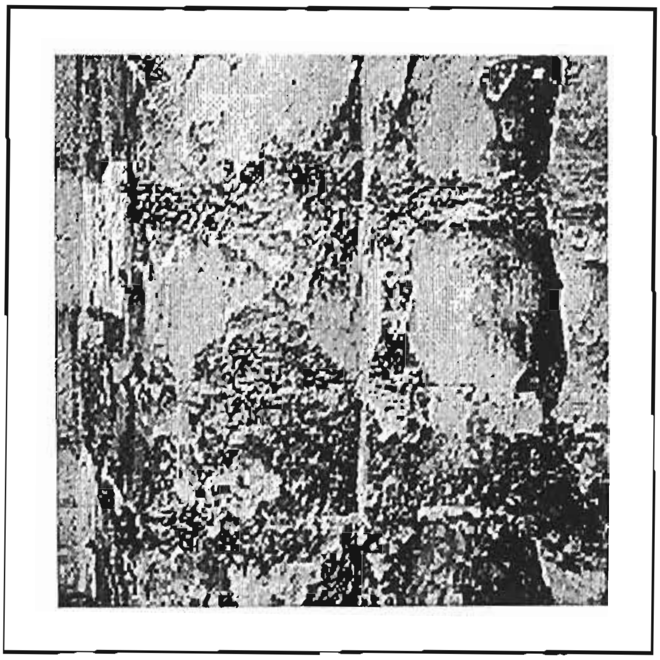


Before deciding on other measures, the upward flow of moisture should be halted. Rising groundwater is often caused by leaking drain pipes or other systems to convey water to the base of a building. A drainage system, installed at ground level, would absorb and drain off water at the base of the facade. In the past, financial factors meant that the base of a building was constructed differently to the rest of the building. In that case, protection is essential.

3 HOMOGENEITY

Nothing is homogeneous. The effects of sun, wind and rain are different for every facade. As we have already seen, certain parts of a facade can be severely affected by moisture and other less so. A facade is constructed of stones comprising thinner (walls) and thicker parts (corners, pilasters, etc.) with open and closed parts. Mortar is used to form the stones into a wall. Stone and mortar have different characteristics which change over time. The environment can induce chemical reactions, causing gypsum to form on the stone, while the mortar pH can fall.

On those areas subjected to much rainfall, the gypsum is washed away to expose the white limestone but where there is less exposure to rain, the gypsum remains visible as a black layer because combustion products in the air, "black smoke", cover extremely large surfaces, making the white colour of the gypsum invisible. Since gypsum and limestone have disparate characteristics, differences in tension will cause the growing layer of gypsum to crack and even curl up. Water is no longer able to flow easily away causing it to remain longer in as well as behind the gypsum. The gypsum is as blotting paper on the hard stone. A layer of gypsum that begins to curl should be removed before other measures are taken. The method of removal should take the base material into consideration including the pointing and, as has already been mentioned, care should be taken that as little of the original material as possible is lost.



The analysis of a facade can also give information over the history of the building and the facade itself. Buildings are subjected to many changes. They are altered, enlarged and renovated. Stones are replaced which causes the moisture management to change. Furthermore, joints are cleared out and repointed with cement mortar joints instead of the original lime mortar. Rainwater falls onto the stones and is absorbed by them. Under the law of gravity the water should then settle into the joints but they are now impermeable. It can often be observed how an unsaturated piece of stone is frozen out of its impermeable joints.

The method for refilling joints nowadays is with a mixture of trass, lime, sand and some cement. It would be even better if an hydraulic lime mortar was used as this is more suitable for traditionally-constructed historic buildings and has far superior characteristics. Traditional lime mortars are more permeable and more flexible than cement mortars. The best possible result is to achieve a porous performance that corresponds closely to that of the surrounding stone. It is important for the joint to adhere to a healthy stone surface. This means, by definition, the removal of any gypsum crusts. Damage that was not at first visible will now very well will be. In some cases, large cavities form behind the joints and it should be expected that they contain water. (Van Stigt, 1993: "You cannot hydrophobate a basket"). Also essential is the joint form. Opting for vertical surfacing results in vulnerable joints and the considerable risk of trapped moisture. Joints are vulnerable and should be as small as possible. When being restored, joints should follow the form of the stone as this is the most effective way of controlling water flow.

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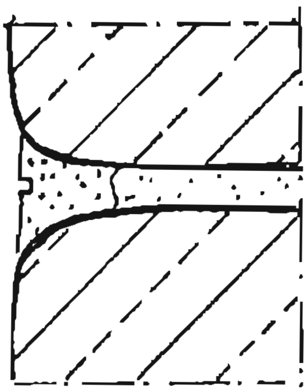
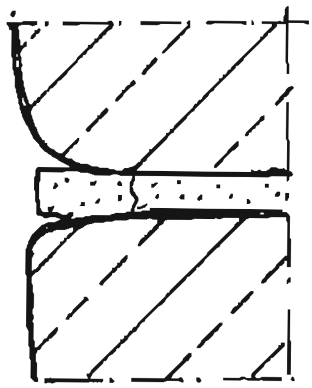
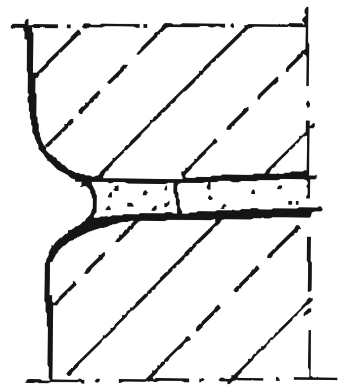
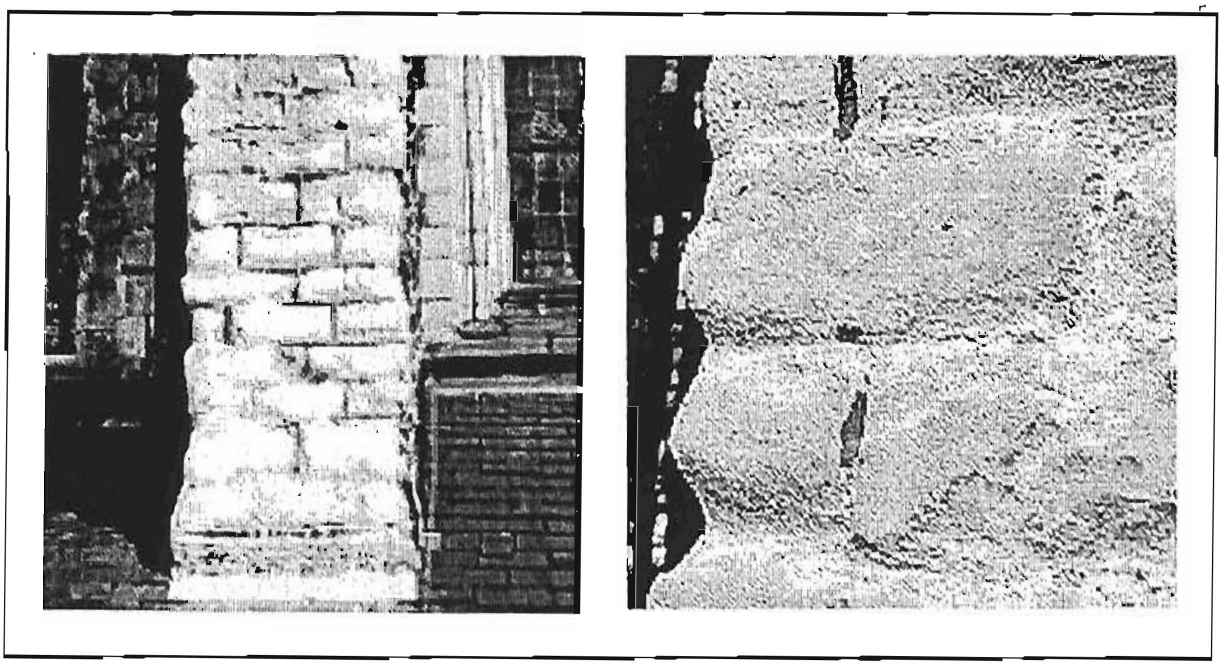


jointform expensive and vulnerable



jointform simple and good allows quick drying out





4 CONCLUSION

The decision to use hydrophobation to reduce the effect of water on the facade can only be taken after applying a range of possible measures. Furthermore, such a decision should be based on a clear understanding of the moisture conditions of a facade. To achieve controlled water run-off, the original detailing has to be restored (or detailing improved) and in doing so, particular attention has to be paid to the homogeneity - but especially the permeability - of the facade.

The interrelation between stone and mortar joint is important as well as the interrelation between the stones that are used, while joints must be repaired with a material in relation to the stone.
Rising damp, the main factor causing damage, has to be curbed or eradicated entirely. If salts are present in a facade, research is essential to determine whether the application of a water repellent agent will cause damage.

Once the decision to use hydrophobation has been made, decisions also have to be made over the material, the amount per square metre, the method and the specialised firm to undertake the work. It will not harm the quality of the work if the operation is regularly monitored.

When deciding to use hydrophobation as the final step to remove water from a facade, the effect on the water run-off over the facade should also be examined as parts of the building never previously exposed to water will now be reached by the water flow.

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