TEST METHODS FOR THE EVALUATION OF THE IN SITU PERFORMANCE OF WATER-REPELLENT TREATMENTS

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ABSTRACT

TNO, IRPA-KIK and PDM are involved in an EC research project 'Evaluation of the Performance of Surface Treatments for the Conservation of Historic Brick Masonry'.
Among the tasks in this project are:

- to carry out 60 case studies of treated brick masonry monuments, in order to evaluate the performance, to collect knowledge on types of damage, damaging processes and causes of damage and to find out about the relation between treatment and damage;
- to evaluate and improve test methods and eventually develop new methods or procedures.

For two of the test methods, meant to assess the performance and to diagnose the damage, a proposal is presented and discussed.

Keywords: water-repellents, masonry, monuments, performance, damage, test methods

1 INTRODUCTION

One of the objectives of the EC project 'Evaluation of the performance of surface treatments for historic brick masonry' is to propose test methods for assessing the state of preservation of historic masonry, treated with a water-repellent and/or a consolidant.

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The most important aspects are:

- the performance in the course of time;
- the risks of failure and damage.

There is quite some discussion on the use of these products amongst experts in the field of conservation, because of the risks that might exist for historic masonry. It was therefore decided that damage analysis would be a focus point both in the 60 case studies to be undertaken as well as in the analysis methods to be chosen or developed. A standard test methodology should be obtained.

This paper is related to some of the methods used in the EC project for the evaluation of brick masonry monuments treated with water-repellents.

2 TREATMENT AND TESTING OF HISTORIC BRICK MASONRY

The reasons why water-repellent treatments are used may vary:

- to prevent water penetration
- to prevent decay due to environmental influences
- to prevent soiling
- to prevent biological degradation

Test methods to be used should be either non destructive or little destructive. For further laboratory research little destructive sampling is inevitable. Of course destructive testing or sampling in monuments should be as restricted as possible.
Nevertheless little destructive methods may be permitted either in case of necessity, i.e. to prevent substantial damage or in case of diagnosis of damage. In any case the damage due to the testing or sampling should be repaired in a 'decent' way; for brick masonry in monuments, a repair method is proposed in this paper.

Aims of testing
Testing and sampling are performed with the following aims:

- to reach a sound diagnosis of the damage
- to give information on the performance and the quality of the treatment
- to identify the type of product used

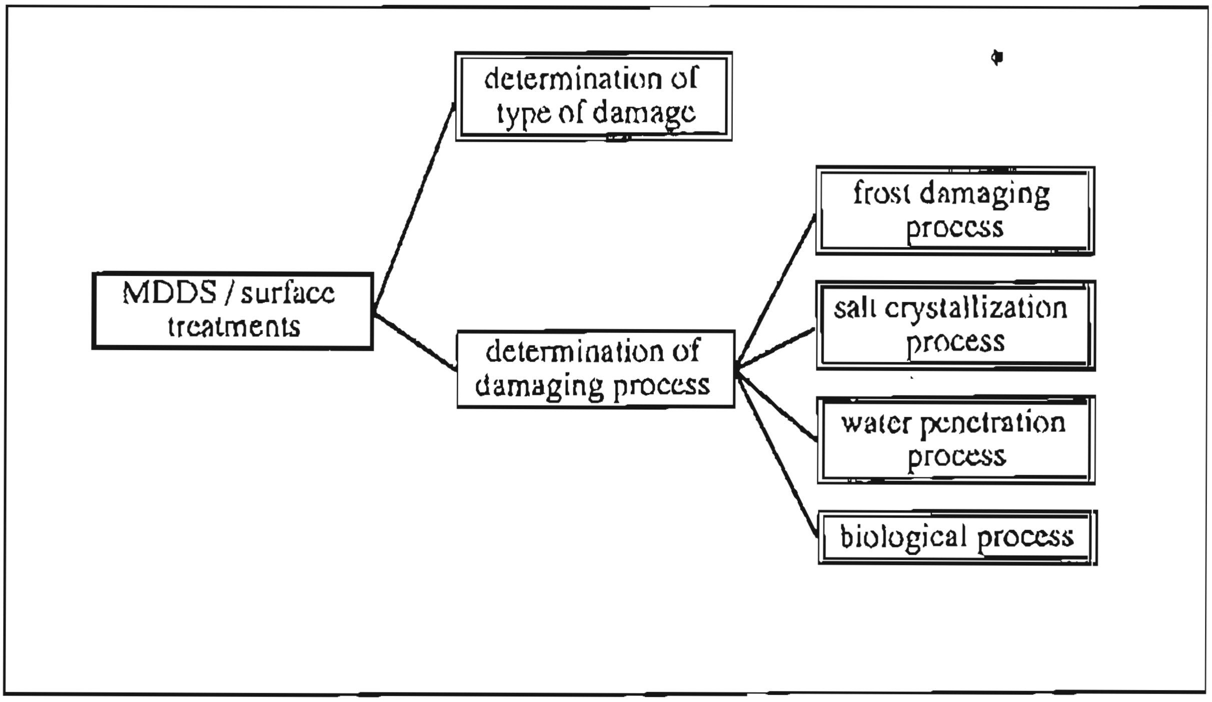
3 DIAGNOSIS OF DAMAGE RELATED TO WATER-REPELLENT TREATMENTS

Damage generally is the result of a combination of factors on several levels. A good approach to describe damage and its causes is to define damaging processes. This approach is used here and was based on an EC research-project that resulted in the Masonry Damage Diagnostic System (MDDS). The MDDS is a Knowledge Based System (or expert system) meant for the diagnosis of damage to historic brick masonry [HEE95]. In this approach damage is contributed to for example a physical or chemical process, whereas circumstances, environmental influences, material quality etc. are defined as conditions allowing the process to take place.
It was agreed with the EC that knowledge, resulting from the case-studies in the project 'Evaluation of the Performance of Surface Treatments for the Conservation of Historic Brick Masonry', would be made available to the MDDS.
An analysis of the case-studies showed that four processes are responsible (either on their own or in combination) for damage to treated masonry:

- frost damaging process
- salt crystallization process
- water penetration process
- biological process

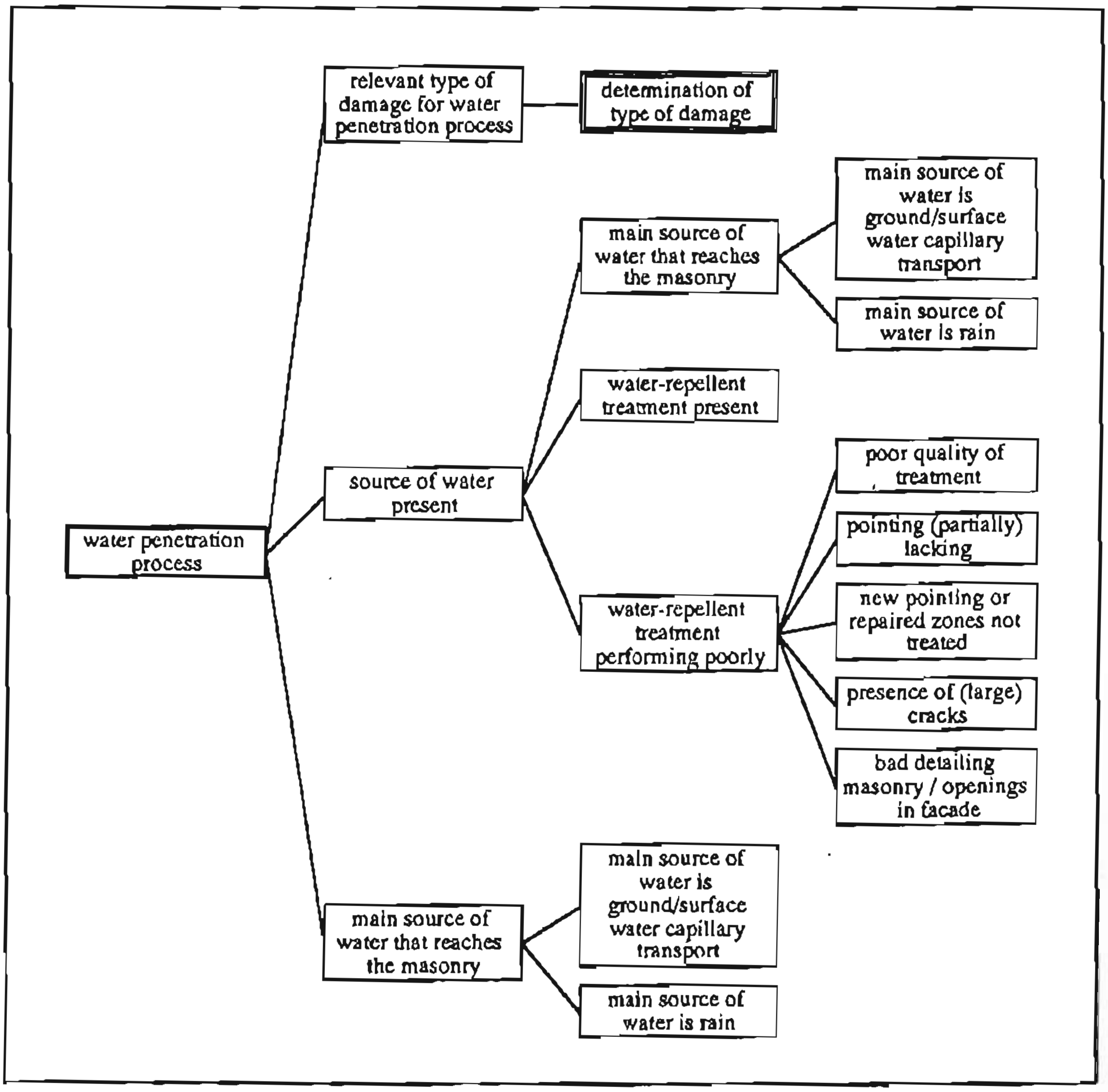
All processes are related to the presence of water (see fig. 1).

FIG.1
Determination of damaging process(es) in relation to surface treatments on monuments. Table tree from the Masonry Damaga Diagnostic System (MDDS)



Within each damaging process the conditions are defined for which the treatment may contribute to (or influence) the occurrence of damage. This does not mean however that the treatment is directly responsible for the damage: other circumstances (like repointing after the treatment, resulting in local water penetration, or poor workmanship) may be responsible. An example of the description of one of the processes in terms of the MDDS is given in fig. 2 for the water penetration process.
Conclusions on the performance of treatments and the causes of damage in 60 European brick masonry monuments mentioned in chapter 1, will be published elsewhere.

FIG.2
Table tree of the water penetration process. The circumstances leading to a relation between treatment and damaga are taken into account. Source: the Masonry Damage Diagnostic System (MDDS).



4 TEST METHODS

4.1 GENERAL

The complete set of test methods that were selected ranges from visual inspection to sampling for further laboratory analysis. The test methods selected still need further elaboration. The try-outs in the case studies and discussions among the members of the project team will eventually lead to a proposal for a Standard or a RILEM Recommendation.

Overview of the selected methods:

1. visual inspection of damage
2a. spraying water, using a wash bottle
2b. spraying water on a wider area
3. Karsten pipe
4. pointing tester (mainly for the evaluation of consolidation)
5. core drilling
6. profile drill (mainly for the evaluation of consolidation)
7. moisture profile
8. identification of products applied on masonry

In the EC project the testing is carried out both on damaged and non-damaged substrates. This enables sound conclusions on the causes of damage and the role of the treatments.
The Karsten pipe (3) and the core drilling (5), will be further discussed here.

4.2 KARSTEN PIPE

Aim and limits of the Karsten pipe
The aim of the Karsten pipe is to give an objective measurement of the rate of water absorption of treated and not-treated stone and brick masonry.
Some of the limits of the method are:

- the way of applying of the sealant in order to have a test area of a con stant seize; fig. 3 (KIK) is showing the influence of the contact surface on the amount of water absorption;
- the test surface being so small (i.e. 5 - 7 cm^2), to have a sound idea about the general performance of a treatment, the Karsten pipe should be used together with the spraying of water (2a and/or 2b).

Therefore the EC project deals with the improvement of the method for water absorption measurements with the Karsten pipe.

Backgrounds of the method
The Karsten pipe was developed at the end of the fifties, to measure the

water absorption of natural stone [KAR83]. Later the device was used for measurements on brick masonry and the efficiency of water-repellent treatments [RIL87].
The stem of the pipe is calibrated in ml or in mm. The bowl is provided with a rim to fix the device to the surface of the wall, making use of a suitable sealant.

There are two different procedures in use:
a. filling the pipe to a certain height and measuring the water absorption over a certain time. This procedure is applicable to treated and untreated surfaces [RIL87].

b. Filling the pipe stepwise, determining the height of water column (i.e. the water pressure) that causes a clear water absorption.

ad a.
As water pressure has a certain influence on the absorption rate, some theories state that water should be added after a certain drop in water level in order to keep the pressure constant. However most building materials have a relatively fine pore system and therefore a very high suction potential, which implies that once suction has started, there will be practically no difference between free water absorption and water absorption under a pressure of up to about 100 mm. Therefore the adding of water can be considered superfluous.

Some materials may develop their normal suction rate only after some time; therefore the first minutes should be neglected. According to several researchers for example the volume of water absorbed between 5 and 15 minutes is to be measured, neglecting the first 5 minutes.

Old treatments: surface absorption
According to [WEN89] measurements with the Karsten pipe, may result in water absorption parallel to the surface due to the ageing of a water-repellent treatment. The effect is visible in a circular spreading out of the water.
It is deduced theoretically that water absorption in the latter case will be a linear function of time, whereas the normal in depth absorption will be parabolic. It is therefore proposed to do a sufficient number of readings of water absorption versus time during the test, in order to obtain a graph that enables to evaluate the type of water absorption.
From a practical point of view the proposed procedure is very time consuming, both due to the long time span (70 minutes) and to the impossibility to perform several measurements at the same time.
The approach is interesting, the method however is considered very time-consuming and therefore hardly applicable for testing in situ.

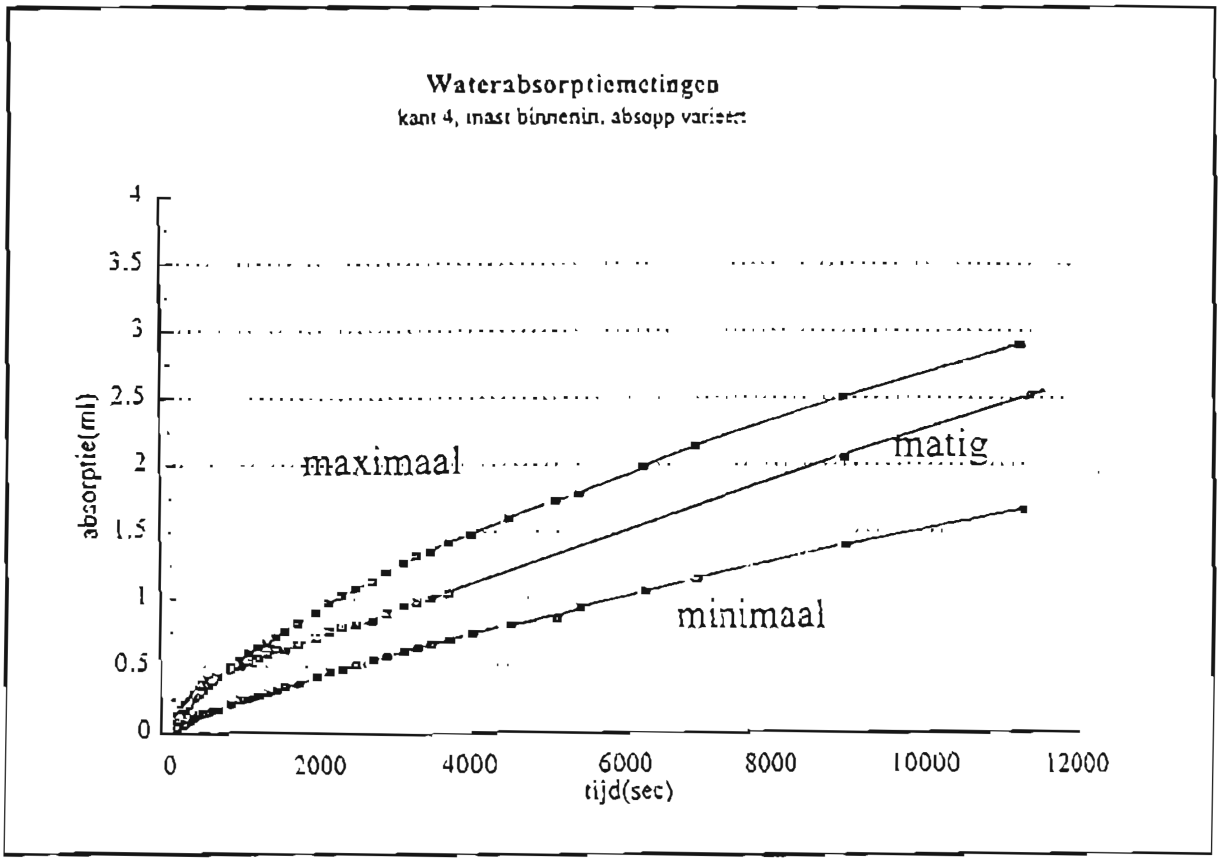
ad b.
Measuring the water pressure that can be resisted.
The main aim of a water-repellent treatment is to prevent penetration of rain water. Wind that is driving rain towards a facade exerts a pressure. As rain drops arriving at the masonry surface with the velocity of the wind have a

higher energy than the wind, because of their higher mass by volume, the water-repellent zone of the masonry should resist a certain water pressure.
A static wind with a speed of 140 km/h perpendicular to a surface exerts a pressure of 92 mm water column (9.2 N/mm^2) on that surface, this apart from the effect caused by the higher energy of the rain drops.
Measuring the water pressure that can be resisted could also be interesting.

Generally it is assumed that if the water-repellent is able to resist a pressure of ca. 100 mm water column, no rain water penetration occurs. For the most commonly used Karsten pipe in The Netherlands and Belgium (see also [RIL87], the highest level of the pipe (indicated with '0') corresponds with a height of approximately 98 mm (distance between indication '0' and the centre of the bowl).
Using longer, specially designed Karsten pipes it was proved (measurements TNO Building and Construction research) that recently treated brick may resist sometimes water pressures of more than 200 mm, whereas recently treated modern joints may resist water pressures of 50 to 150 mm (end joints are in the lower range, bed joints generally in the higher range).
However for the evaluation of longer existing treatments it is considered sufficient to know whether the treatment will resist 100 mm water column or not.

Proposed procedure Karsten pipe
For the use in the case studies to be undertaken it was agreed that a combination of two methods would be applied:
to start with a step by step method is followed in which the highest level of a standard Karsten pipe is reached in 5 steps. After each step a period of at least 1 minute should be respected, before the next one is made. The step in which a clear water absorption occurs should be indicated. Step 5 corresponds with a water pressure of approximately 98 mm (method 1).
If no clear water absorption occurs, part 2 of the procedure, reading the absorption (ml) after 5, 10 and 15 minutes should be followed (method 2).
A form was developed to register the results (see fig. 4).
In this way differences in performance can be clearly observed and the applicability of both methods can be evaluated.
Finally the measuring results should be expressed as ml/(5-15 min) and the opening area or contact surface should be determined.

FIG.3
Water absorption measurements (KIK) with the Karsten pipe (maximum height 98 mm). The contact surface was varied by different ways of application of the sealant.



Practical advises

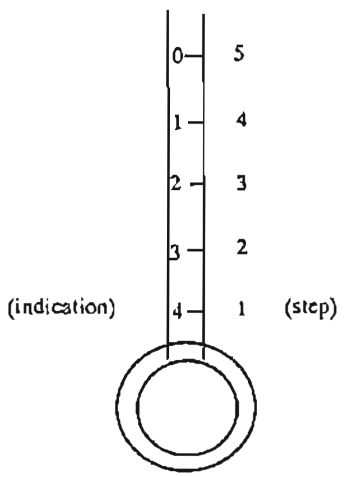
It is proposed to use a standard Karsten pipe with a known opening area. The sealant should be applied in such a way that it is always present in as thin as possible a layer on the inner surface of the opening of the bowl. In that way the area will be the maximum possible and practically always rather equal, which is, compared to the common practice until now a very clear step forward; see also fig. 3.

The pipe should be placed on a sufficient number of bricks and also on a number of brick-mortar combinations.

Apart from that it is advised to make use of the methods 2a. and or 2b. (spraying of water), which will allow the necessary general impression of the performance and of the ageing of the treatment.

FIG.4
Form used for Karsten pipe measurements in case studies.

Project									
method 1	location / description of position pipe								
step (indic)									
1 (4)									
2 (3)									
3 (2)									
4 (1)									
5 (0)									
method 2 minute									
5 min									
10 min									
15 min									



Karsten pipe with steps / indication

4.3 CORE DRILLING

This method is proposed, together with the moisture profile as one of the essential tests for assessing the cause of damage to treated masonry.

Aims and limits of the method
Sampling is performed in order to:

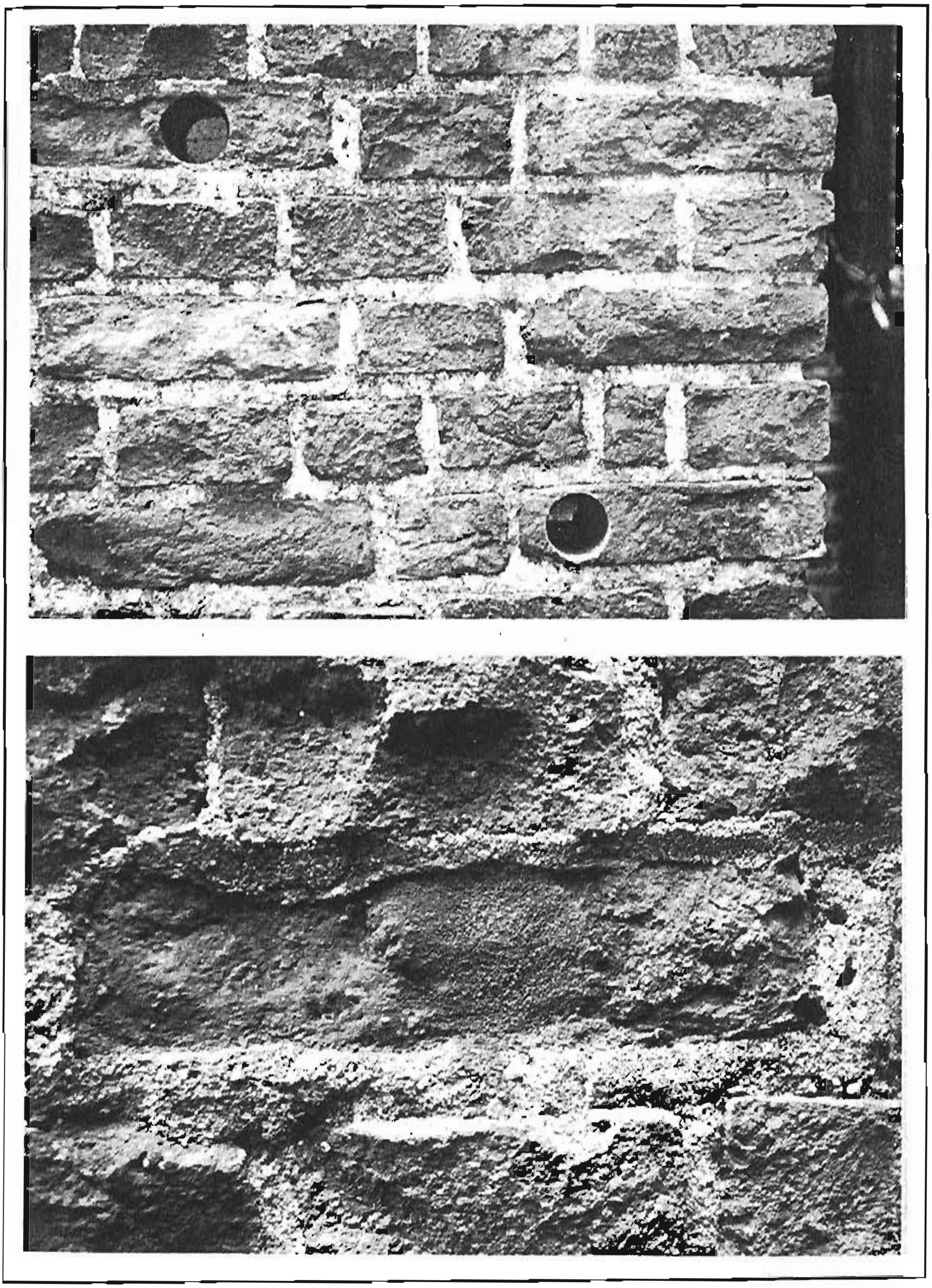
- determine the in depth-penetration of a surface treatment;
- study the eventual damage and damage depth, using thin sections and petrography;
- test the possible destructive effect of salts that might be present in the materials;
- test the frost-thaw receptivity of the treated material(s).

Limits of the method are that the method is destructive and that repair of the damage is necessary.

Procedure
In situ
The method involves generally wet drilling of cores with a diameter of ca. 50 mm.
Both brick or brick/pointing combinations may be sampled.
Samples are selected near the damaged area, preferably undamaged parts of bricks showing already damage and/or bricks that by aspect are closest to the damaged ones.

Repair
Brick cores of the same diameter prepared in laboratory and finally a mixture of drilling powder and a ready mixed mortar are used to fill the holes almost invisibly. See fig. 5.

FIG.5
Brick masonry wall of a monument showing the holes (diameter 50 mm) due to drilling; after repair.



In laboratory
After drying, the following tests can be carried out:

1. Penetration depth and effectiveness of the treatment.
   The penetration depth of the treatment is determined by wetting the cores. The treated part will remain dry. Measuring the penetration depth at 3 locations will give the mean penetration depth.
   Further the Karsten pipe (see 4.3) can be applied (see fig. 6) and theresults obtained can be compared with those in situ.

2. Salt crystallization as cause of damage.
   Water absorption is allowed to take place from the backside of the core, whereas the sides are sealed. Evaporation and possibly subflorescence or even efflorescence may take place near to the outer face of the sample. For a number of cores drilled in the case studies, this test has been perfor med (see fig. 7).

FIG.6
Use of the Karsten pipe on brick cores in laboratory.

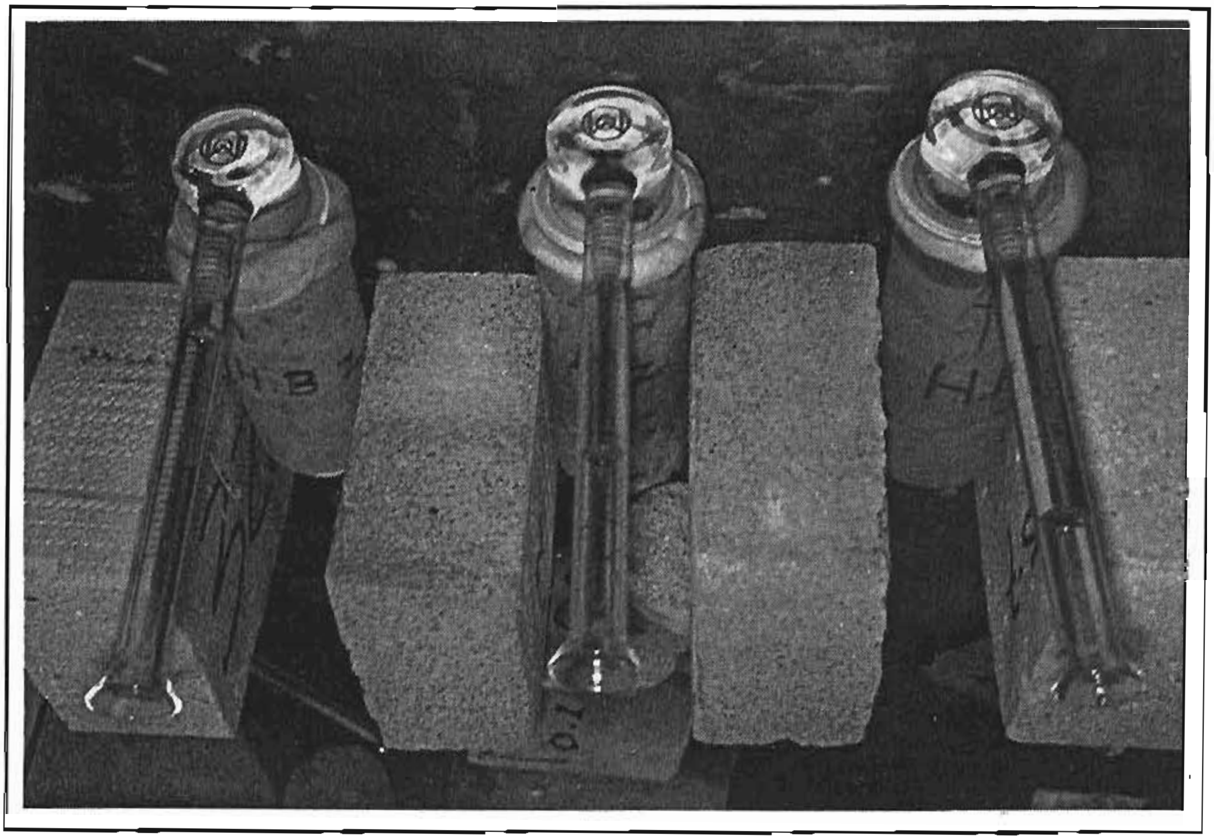
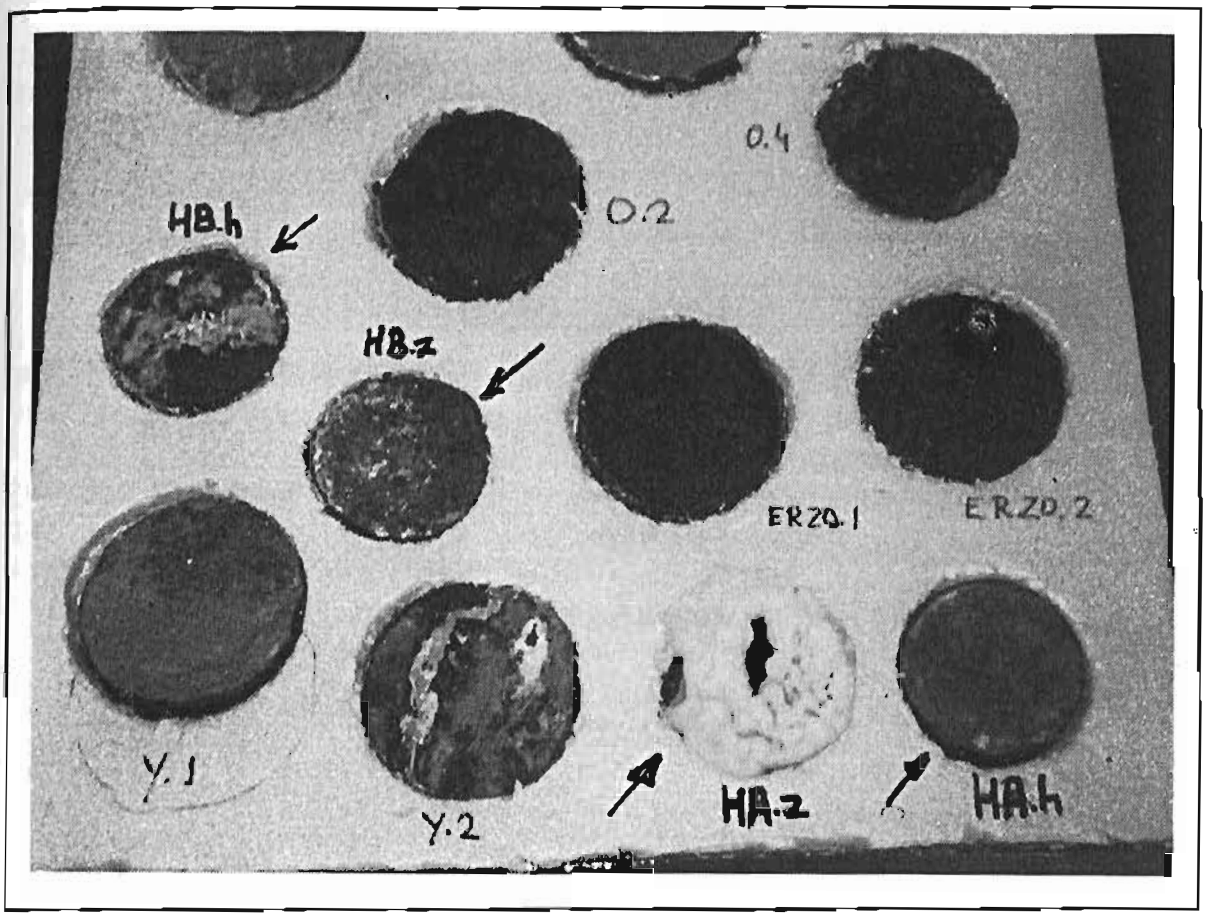


FIG.7
Cores from several case studies, on which water absorption from the backside of the brick has been allowed. The cores coded HA.z, HA.h, HB.z and HB.h originate from the case study described. Especially HA.z shows a large quantity of salt crystallizing at te surface.



3. Frost resistance.
   Normal procedure: uni-directional freezing (acc. to NEN 2872), following full vacuum impregnation with water. This test has not been performed yet in the framework of the case studies.

5 PROVISIONAL RESULTS GAINED IN CASE-STUDIES

For one of the case studies the results of both methods described in chapter 4 are given and their contribution in damage diagnosis is explained. The object concerned is the Reformed Church of Harderwijk. The church was treated with a water-repellent (1975) and is showing several types of damage like sanding, scaling and biological growth (algae).

5.1 KARSTEN METHOD

The method was applied both in situ on the walls of the church and in the laboratory on cores drilled from the walls. The combined results from both test series offer interesting data for the diagnosis of the damage.
The measurement results are given in fig. 8. In situ both brick and pointing have been tested. Cores were only drilled from the brick; the cores indicated HA.z and HB.z were taken from bricks with an already decayed surface. Cores indicated HA.h and HB.h were from visually sound bricks.

Results

- the pointing (in situ) and the already decayed brick (in lab) showed the highest water absorption;
- it is clear from comparing method 1 and method 2 that even when the wall is resisting step 5 (method 1), there still may exist rather big differences in the performance of the treatment (method 2);
- if the treatment is clearly failing, than both methods would show this (pointing h=0.75m and core HB.z);
- the higher absorption of HB.h compared with HA.h was mainly due to a little zone in the surface of the core, where the application of the treatment obviously had failed: it was visible from behind that water entered the material via that spot;
- tests on cores may provide useful extra information on the quality of the treatment;
- the water absorption measurements yield together with data on the moistu re content of the masonry (not discussed in this paper) important results for the diagnosis of the damage.

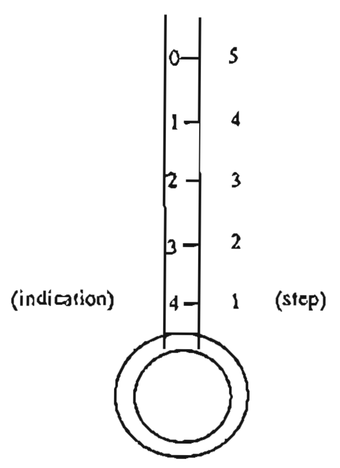
5.2 SALT CRYSTALLIZATION TEST (SEE FIG. 7)

The tests on the cores for the assessment of salt crystallization are still running; the test is performed by water absorption at the backside of the treated brick; is this way the salts that are possibly present in the cores will be activated and salt crystallization at or near the surface is stimulated.

Fig. 7 shows that from the described case study both HA.z and HB.z and HB.h have salts indeed.

FIG.8
Example of a filled in form of Karsten pipe measurements, both in situ and on cores in laboratory.

Project	Reformed Church Harderwijk								
method 1	location / description of position pipe								
step (indic)	in situ brick 1.50 m	brick 1.50m	point. 1.30m	brick 1.80 m	pointing 0.75m	cores brick HA.h	brick HA.z	in lab. brick HB.h	brick HB.z
1 (4)	✓	✓	✓	✓	✓	✓	✓-	✓	✓--
2 (3)	✓	✓	✓	✓	fails	✓	✓-	✓	✓--
3 (2)	✓	✓	✓	✓		✓	✓-	✓	✓--
4 (1)	✓	absorpt.	✓	✓		✓	✓-	✓	✓--
5 (0)	✓	in surface	✓	✓		✓	✓-	✓	✓--
method 2 minute									
5 min	seal part leaking	0.3	0.42	0.15	2.6	0.01	0.68	0.2	2.5
10 min		0.7	0.93	0.23	4.5	0.04	1.32	0.4	3.3
15 min		1.11	1.32	0.25	fully	0.06	1.82	0.6	4.0
diff.		0.81	0.90	0.10	>> 2.0	0.05	1.14	0.4	2.5



Karsten pipe with steps / indication

5.3 CONCLUSIONS

The first results of the crystallization test, together with the relatively high water penetration that may occur via the pointing and via other local shortcomings in the water-repellent layer as described in chapter 5.1, form an important step in the diagnosis of the damage and the assessment of the role of the treatment.
Frost tests to be performed will complete the research on the samples. Together with the set of tests given in chapter 4.1 a sound procedure for the assessment of the performance and of the diagnosis of the damage is available.

6 FUTURE

The methods described will be further improved during the execution of the project and may result in a RILEM Recommendation or a proposal for a European standard for the assessment of the performance treatments.
On the basis of the research and of the case studies a 'Decision model' for the choice of treatments for historic brick masonry will be made.

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