



ASPECTS OF SALT AND MOISTURE TRANSPORT IN RESTORATION RENDERS (PLASTERS) *

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Abstract

There is a need for obtaining more knowledge about renders (plasters) used in restoration because of cases of damage observed in the field. The currently applied and available restoration renders do not always meet the requirements.

By analyzing damage cases it becomes clear that the performance of modern and traditional renders, under salt load is not fully understood. In order to gain a better understanding of salt migration through renders and to promote better practices regarding the application of restoration renders, the European research project COMPASS (compatibility of renders with salt-loaded substrates in historic buildings) was launched. In this paper, preliminary findings from project are presented.

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1 Performance of Repair Renders

The performance of various repair renders has been studied through the analysis of damage cases and laboratory research. In this paper, special attention is paid to the differences in performance in transport of salts of designed restoration renders and traditional renders. The main difference in composition between these two types of renders is the use of light weight aggregates and additives such as water repellents in the designed restoration renders. They are specifically designed to deal with the effects of salts present in the substrate. Normal weight aggregates and no additives are used in the traditional renders. In both cases cement or lime or combinations can be found as binders and sometimes may be even in combination with a pozzolan.

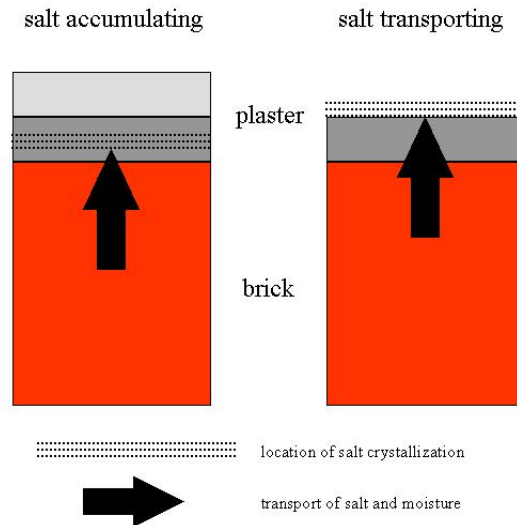


Figure 1 Different working principles are applied to renders to achieve accumulation (left) or transport (right) of salts to the surface as efflorescence in renders

Two different working principles can be distinguished (i) accumulation of salts in the render and (ii) transport of salts through the render to the surface, where it can be brushed off (Figure 1). From the analysis of damage cases where there is typically an appearance of efflorescence at the surface, it can be concluded that traditional renders most often function as transport systems rather than accumulation systems (Figure 2).

The performance of restoration and traditional renders were compared in a laboratory test programme. In the laboratory tests, sodium sulphate and sodium chloride salt distribution was determined for render on brick substrates. The salts were introduced through absorption by placing immersing the brick substrate in a salt saturated water solution to a depth of 20 mm. This follows the Rilem Test MS.A.1. (Rilem, 1998). Subsequently, the specimens were dried unidirectionally under constant conditions of 50% relative humidity and 20 °C by only allowing evaporation from the face of the render. The moisture transport direction was from the substrate to render which is consistent with what occurs in walls. The drying continued until the weight of the specimen was constant.



Figure 2 Damage to traditional render as peeling paint layer and finish coat scaling. Caused by cyclical wetting and drying conditions related to rising damp and rain penetration.

The salt distribution in the test specimen was estimated making use of the hygroscopic behaviour of salt: the quantity of water absorbed is directly proportional to salt content of the specimen. Layers of 3 mm were ground from the test specimen starting from the outer face. The layers were dried at 100 °C and weighed. They were subsequently stored at 93 % RH and 20 °C. The hygroscopic water absorption was determined through weighing.

Table 1 presents some physical data on the two renders. The restoration render appears to have a larger volume of pores, higher water vapor coefficient and lower vapor diffusion resistance than the traditional render. The salt distribution differences between the restoration render and traditional render showed relatively small differences. And in both cases no damage occurred in this test.

Table 1. Physical data for render types.

	Restoration Render	Traditional Render
Pore volume (%)	37	22
Water absorption coefficient kg/m ² s ^{0.5}	0.024	0.017
Vapor diffusion resistance	25.0	36.4

Restoration mortars had greater salt transport than traditional mortars. This should also be possible for renders using traditional materials and may result in less expensive solutions. It should be noted that restoration mortars may have lower strength than traditional cement-based renders and therefore better mechanical compatibility with historic substrates.

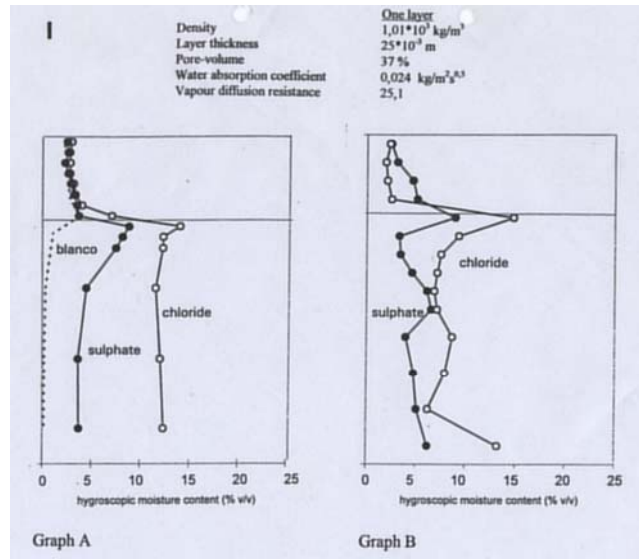


Figure 3a Salt distributions in brick substrate and a restoration plaster layer. (from Wijffels, 1997)

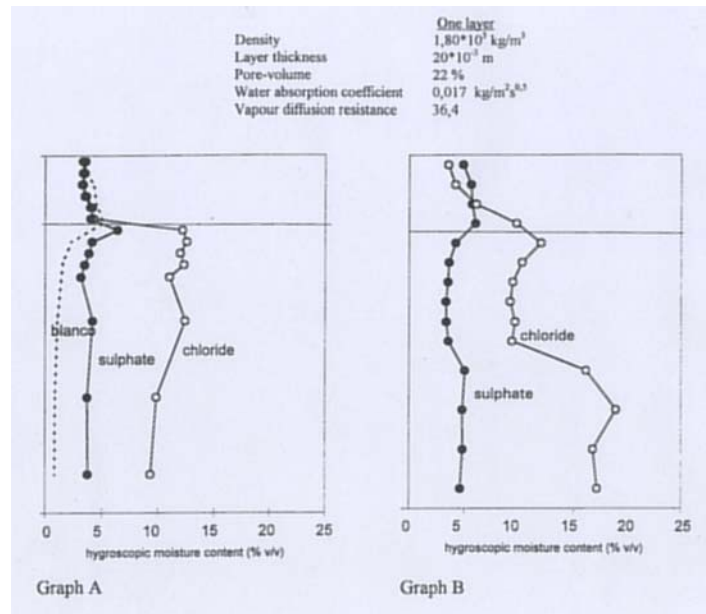


Figure 3b Salt distributions in substrate (brick) and traditional render.

2 A Design Attempt

An attempt was made to design a render with better salt transport characteristics using only traditional materials without additives. Based on the objectives in Table 1, two render compositions were chosen and subsequently tested.

Table 2 Requirements, aims, and expectations

Requirements:	
	<ul style="list-style-type: none"> ▪ One coat application ▪ Use 'gap'-graded sand (0.5-1 mm) ▪ Binder not too strong (cement lime 1:4) ▪ Not too binder rich (binder:sand approx. 1:3.5) ▪ Mix in the pigment (no paint) ▪ Good bond with the substrate
Aim and expectations mix design	
	<ul style="list-style-type: none"> ▪ Allow transport of salt solution ▪ Adequate void space in case of salt crystallisation in the render ▪ Accept necessity of brushing away efflorescence ▪ Accept some material loss from the plaster near the surface with time

The chosen render compositions by volume were:

- cement:lime:sand: = 1:4:24 (binder: sand = 1:5)
- cement:lime:sand: = 1:4:10 (binder:sand = 1:2)

Two substrates with very different porosity and moisture absorption characteristics were chosen for the renders (calcium silicate brick and Bentheim sandstone) Their hygric properties are shown in Table 3.

Hygric properties of the substrates appear in Table 3. The calcium silicate brick appears more porous and less dense than the sandstone, but has a lower water absorption coefficient.

Table 3 Hygric characteristics of substrates.

	Units	Calcium silicate brick	Bentheim sandstone
Free water absorption	% v/v	22.0	15.6
Bulk Density	kg/m ³	1898	2036
Total porosity	%	28	23
Water Abs. Coeff	Kg/m ² .s ^{0.5}	0.09	0.73

The two renders were applied on the two substrates. Three replicates were made. The specimens were subjected to the Rilem salt resistance test (Rilem, 1998) where sodium sulphate and sodium chloride salts were introduced by absorption, then subjected to an accelerated salt crystallisation test, involving drying and wetting cycles. The appearance of efflorescence on the surface of the test specimens was evaluated as a function of time (Figure 4).

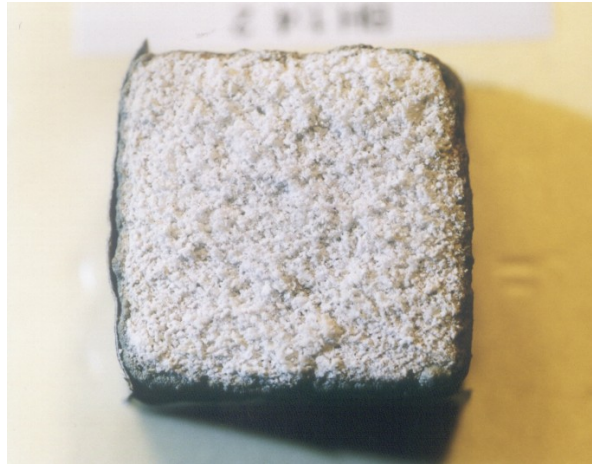


Figure 4 Salt efflorescence on a test specimen. This specimen was given a rating of 5, indicated the specimen is completely covered.

Table 4 shows that the efflorescence varies as a function of the type of substrate and time. Significant efflorescence on the render on the calcium silicate substrate appeared after 5-6 weeks. Efflorescence appeared on the render on the Bentheim sandstone substrate almost immediately.

Table 4 Classification of salt efflorescence on test specimens after accelerated testing.

	Feb. 18	Feb. 25	March 4	March 11	March 19	March 25	April 1
Kzs 1:2	1	1	1	1	2	4	4
Kzs 1:2				1	1	4	4
Kzs 1:2					2	3	3
Kzs 1:5					1	3	3
Kzs 1:5					1	2	3
Kzs 1:5				1	1	3	3
BH 1:2	3	3	5	5	5	5	5
BH 1:2	3	3	5	5	5	5	5
BH 1:2	3	3	5	5	5	5	5
BH 1:5	5	5	5	5	5	5	5
BH 1:5	5	5	5	5	5	5	5
BH 1:5	5	5	5	5	5	5	5

Scale used to evaluate degree of efflorescence

1: small quantity of surface area →→→ 5: completely covered surface

kzs: calcium silicate substrate

BH: Bentheim sandstone substrate

3 Observations

The influence of the type of pore structure of the substrate on salt transport in the test specimens is significant. The influence of the substrate on the salt transport is more substantial than the influence of binder to sand ratio of the render type (the 1:2 and the 1:5 mortar).

The transport of the salts through the Bentheim sandstone-render combination was faster than expected. To obtain a better idea about the differences in moisture transport behaviour between the designed traditional (lime-cement) render and restoration plaster, the water absorption rate of the two from a free water surface was determined (Figure 5).

Figure 5 shows that the moisture absorption of the restoration (salt transporting) render is much slower and the amount of absorbed water considerably lower than the experimental render. While water repellent admixtures are often cited to account for this behaviour, in this case the restoration render studied did not contain water repellent.

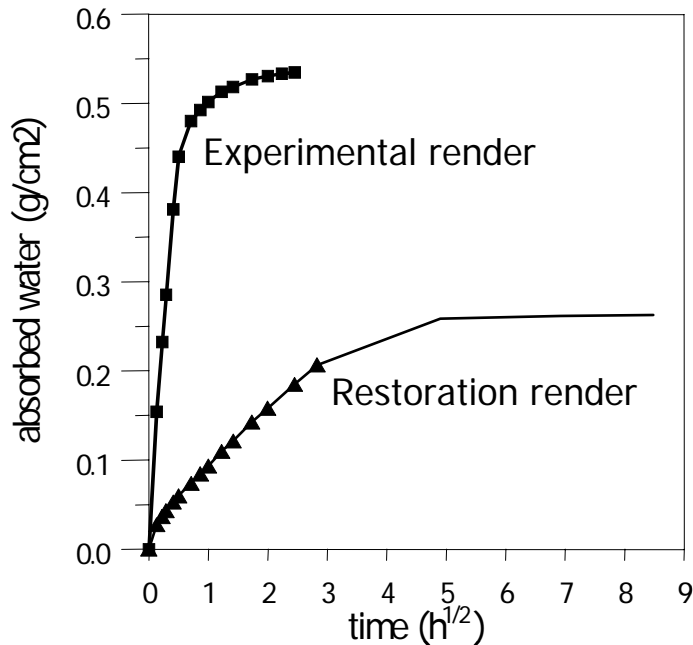


Figure 5 Comparison of the moisture absorption from a free surface by the experimental render and the restoration render.

4 NMR measurements

The observed differences in moisture and salt transport as a function of the substrate were studied in more detail using the Neutron Magnetic Resonance (NMR) technique. The specimens are cylindrical with a diameter of approximately 2 cm. The test set-up is shown in Figure 6. Before drying, the test specimen is immersed the same salt solution used for the testing described above. salt solution. (This is a different starting condition from the RILEM test described above which was from the base only). The drying is initiated by an air flow with a relative humidity of 0% and acts on the specimen at the face of the render specimen.

The moisture distribution in the specimen with the Bentheim sandstone-render at 0h and 10h shows that the Bentheim sandstone clearly dries faster than the render (Figure 7).

Figure 8 shows the moisture distribution in the calcium silicate brick-render combination after 0 and 10 hours. The plaster dries faster than the calcium silicate brick substrate. Another observation from the

test was that drying of the calcium silicate substrate was significantly slower. These results are in accordance with the results presented in the previous section).

An important conclusion is that the differences in drying behaviour can be related to the differences in pore structure of the plaster and the substrates. For an adequate performance of the plaster, a proper matching of the pore-size distribution of the plaster with the masonry appears to be required.

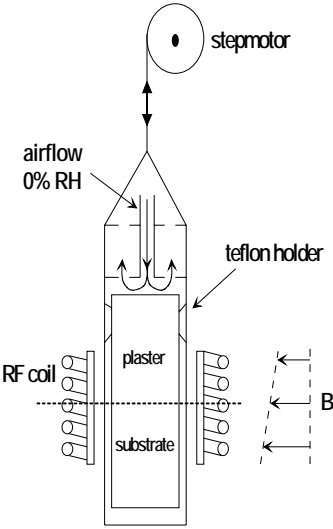


Figure 6 Set-up for drying experiments. The Teflon holder with the sample is moved in the vertical direction by means of a step-motor. The signal from the nuclei processing around the magnetic field B is received by the RF coil.

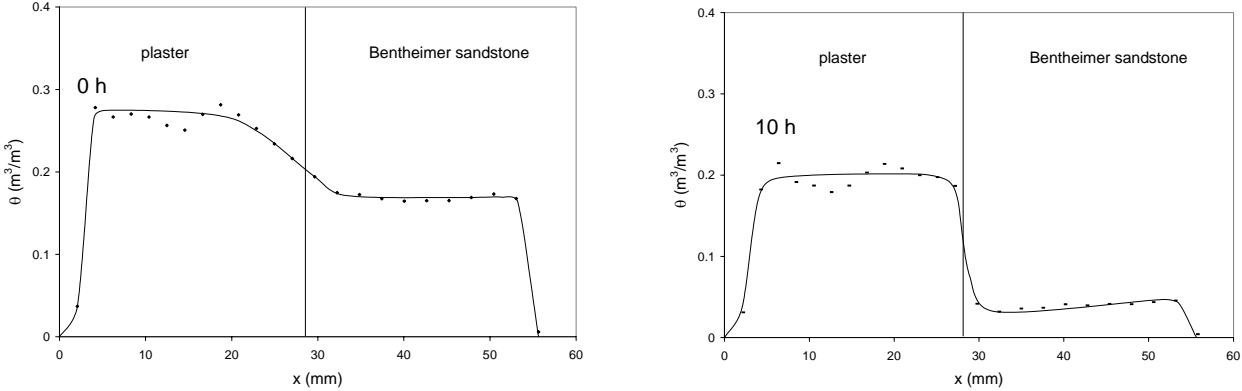


Figure 7 Moisture distribution over cross section of plaster / Bentheim sandstone combination at the beginning of the test (0h) and after 10 h.

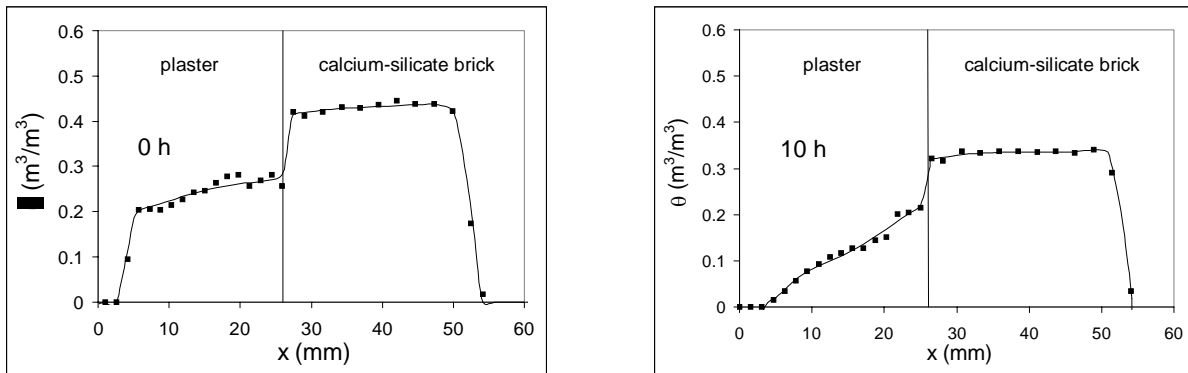


Figure 8 Moisture distribution over cross section of plaster / calcium silicate brick combination at the beginning of the test (0 h) and after 10 h.

5 Porosity

For an understanding of moisture transport in knowledge of the porosity characteristics of the render is essential. In particular, data on the pore size distribution will assist the interpretation of transport phenomena.

The results of the NMR measurements are discussed using pore size distributions determined by mercury intrusion Porosimetry (MIP). The Bentheim stone has coarse pores with high peak at pore diameter of $\sim 30 \mu\text{m}$. The calcium silicate brick has predominantly fine pores with peaks at ~ 12 and $0.01 \mu\text{m}$ (Figure 9).

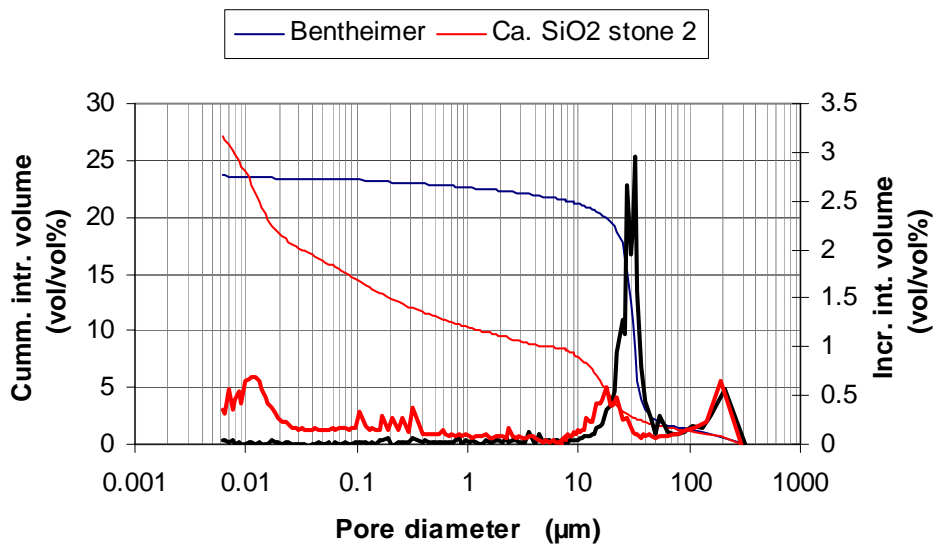
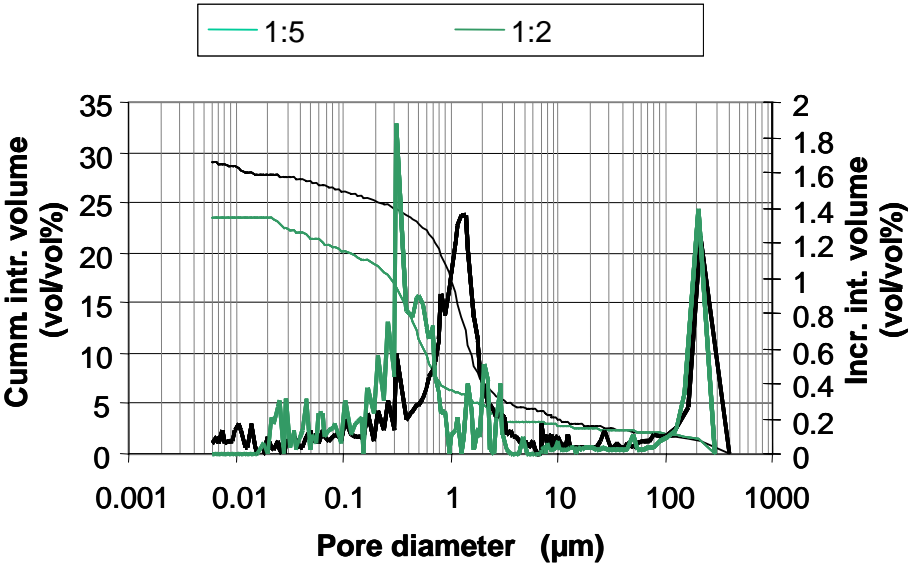


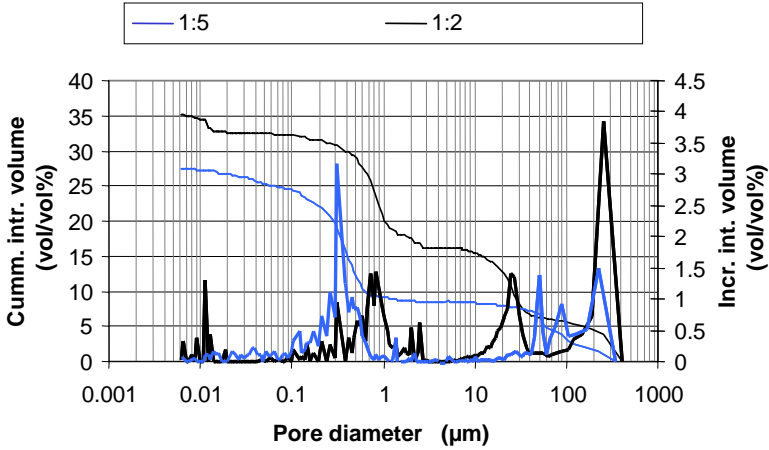
Figure 9 Pore size distribution of the Bentheim sandstone (with high peak at about $30 \mu\text{m}$) and the calcium silicate (with peaks 12 and $0.01 \mu\text{m}$)

Figure 9 shows the pore size distributions of the Bentheim sandstone and the calcium silicate brick.

The pore size distributions of the renders are shown in the Figures 10a and 10b. Striking is the influence of the substrate on the pore content and the pore size distribution of the renders. The pore volume of the renders applied on the calcium silicate brick is clearly higher (27 to 35%) than of the renders cast on the Bentheim sandstone (24 to 29%). This can be understood taking into account that the calcium silicate brick withdraws less moisture from the plaster when it is first applied. Subsequent evaporation of the excess moisture in the render leaves more voids.



a)



b)

Figure 10 (a) Pore size distributions of 1:4 (1.5) and 1:2 render applied on the Bentheim sandstone and (b) pore size distributions of 1:4 (1.5) and 1:2 render applied on calcium silicate brick

Figure 10 also shows differences in pore size distributions between the 1:5 and 1:2 renders. These differences can be attributed to the different binder/aggregate ratios. The slopes of the cumulative curves show that renders on the Bentheim sandstone are slightly finer.

The differences in pore size distribution of the two separate series of renders are less significant than those of the substrates. This leads to the observation that the differences in moisture transport, as found in the NMR measurements, are predominantly due to the differences in substrate.

The pore size distribution may provide information on expected capillary moisture movement (if no additives are applied). The pore sizes of the Bentheim sandstone are always coarser than the renders. This means that in the presence of moisture and capillary contact between substrate and plaster, moisture will move from substrate to render with finer pores. The Bentheim sandstone substrate dries faster than the render, as the capillary supply of water requires less energy than the evaporation of water from the render.

In the case of the calcium silicate/render combination, the situation is the reverse. The capillary attractions by the finer calcium silicate pores is so high that moisture will, if possible, move from the render to the substrate. Drying of the render through evaporation will eventually result in the transport of moisture from the calcium silicate brick to the render.

6 Conclusions

Significant differences in drying indicate that requirements applicable to the renders depend on the characteristics of the substrate. For instance, to diminish as much as possible transport of salts to the surface of the render in the calcium silicate brick/render combinations, one should choose a render with coarse pores.

In case of the Bentheim sandstone/render combinations, slowing the salt/moisture flow may be achieved by using a render with fine pores.

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