Hydrophobe VII *7th International Conference on*
Water Repellent Treatment and Protective Surface Technology for Building Materials
A.Elena Charola and J. Delgado Rodrigues, Editors
LNEC (Laboratório Nacional de Engenharia Civil), Lisbon: 2014 (141-150)

Adapting hydrophobizing impregnation agents to the object

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SUMMARY: In general, old buildings consume substantially more energy than new ones. In old, historical buildings, many brick-, natural stone and lavishly decorated facades are found that limit installation of outside insulation, hence this is done on the inside during energetic refurbishment of old buildings. As a result, heat hardly gets into the wall during winter. Therefore, when driving rain gets into the facade in winter months, moisture cannot properly dry out. As a consequence, such facades remain wet for a very long time, whilst they are cooling down extremely, which increases the potential of frost damages. A solution is to match the degree of water repellence to the existing building materials and the specific construction with its driving rain load as well as to the properties of the chosen interior insulation. This should be done under the premise to do as much as necessary but as little as possible. One example is discussed to illustrate this approach.

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INTRODUCTION

As a rule, old buildings consume considerable more energy than newly constructed buildings because of poorer insulation. Since many of these old buildings have facades made of brick, clinker and natural stone or ornate render facades, external insulation is often not an option. Consequently, internal insulation is being increasingly used to refurbish these buildings to save energy. If, during the winter months, driving rain finds its way into a facade construction that has been insulated on the inside, it is difficult for moisture to dry out towards the exterior, since the interior insulation does not allow much heat to reach the wall construction and therefore not enough energy is available for the evaporation process. Accordingly, such facades remain damp longer, soak up more moisture and cool off more strongly. This considerably increases the risk of damage caused by frost. Against this background, protection against driving rain is a requirement for most structures that are insulated on the inside and should be taken into account when plans are made to refurbish the building to save energy.

In the case of painted facades, the problem described is usually only of secondary importance since modern facade paints are, as a rule, water repelling and thus effectively ensure that the wall construction does not absorb much moisture.

In the case of stone-faced facades, the problem is far more difficult to control. Different impregnation systems are used to make brick, clinker and eventually natural stone facades water-repellent even against driving rain since this is the only way to realize this on a facade without changing its appearance. However, such a measure must be thoroughly planned to reliably prevent possible subsequent damage caused by insufficient protection or missed areas. A correspondence must be established between the configuration or construction of the structure to be refurbished, a suitable interior insulation system, the driving rain conditions that will act on the building and, if applicable, any other possible causes that allow moisture to enter. This especially applies when thermally refurbishing sensitive constructions such as single-leaf, brick fair-faced masonry work since in this case the suitability of an interior insulation system will greatly depend on the driving rain load. As a rule, in these cases the capillary transport of moisture and therefore the potential for drying towards the inside must be maintained which means that a vapour inhibiting layer cannot be used on the inside.

To be able to size up the situation of such a building, it is necessary to take the external climate and particularly the driving rain load at the location of the building, including its temporal evolvement, into account. For an initial rough estimate, overview maps on driving rain loads exist in several European countries. A closer look requires the use of a hygrothermal simulation programme such as “Delphin” or “WUFI”.

Stone-faced facades with a lot of driving rain (more than 600 ml/m²/y of precipitation) must have suitable driving rain protection. However, just because buildings are assigned to less rain than 600 ml/m²/y does not mean that they are uncritical; they must also be subjected to an exact analysis in regard to their exposure. Calculations show that long-term ‘drizzle‘– usually assumed to be uncritical – often leads to higher moisture content in the concerned building materials than ‘violent’ driving rain loads, i.e., driven by strong wind, which are of shorter duration.

MOISTURE PROTECTION ON STONE-FACED FACADES

Hydrophobization of a stone-faced facade should only be executed as a comprehensive protective measure after all other moisture protection measures have been carried out. Constructional protective measures that protect the facade from rain should be examined and carried out where appropriate. Such measures include roof eaves, covering building elements subjected to heavy rain loads by using wall crowns, dripstones, hood moulds or ledges, etc. It must also be ensured that the concerned masonry work is not subjected to other sources of moisture besides rain, for example, defective roof gutters and drain pipes, rising damp from areas in contact with the ground due to missing or defective waterproofing and draining facilities, leaks in water or sewage leading systems in the building as well as an increased content of salt in the masonry work. In a second step, constructive details must be examined and, if necessary, repaired such as pointing that has detached from the sides of joints, cracks, deeper lying or weathered joints, etc.

MATERIAL AND EXAMINATION METHODS

Even though they have been used for decades, the hydrophobizing impregnation of a facade is not a standard measure and may not be generalised as such, since as a rule, preliminary and accompanying examinations to assess effectiveness are necessary. The effect of the impregnation on the construction of the masonry work must also be evaluated which may include a comprehensive analysis of the existing materials and climatic boundary conditions.

The tests presented in the following example clearly show that an evaluation of the effectiveness of an impregnation cannot always be made based solely on the water absorption coefficient (A_{ws}) as required, e.g., by WTA [1]. The measurement of this coefficient is a standard method and defined as such according to EN ISO 15148. However, the application of the standard will not ensure a satisfactory result. This is due to the problem of homogeneity of building materials in regard to their hygrothermal behaviour. If a building material actually is macroscopically homogeneous, then the cumulative moisture absorption of the sample will be linearly proportional to the square root of time. In this case, the Boltzmann Transformation may be used and the A_{ws} value can be determined with sufficient accuracy according to EN ISO 15148 [2].

Brick facades, on the other hand, are not always homogeneous (particularly in historic buildings) because of the way the bricks were fired, previously treated or weathered. Consequently, the water absorption curves are not sufficiently linear and require an informed interpretation.

With automatic measurement of capillary water absorption, the absorption of water is continuously recorded. Measuring intervals can be selected in any frequency up to one second. Contrary to EN ISO 15148, the stop criterion is not after 24 hours but is determined by reaching capillary saturation, the end point of the absorption curve. The course of the curve itself supplies further information such as the influence of layers, cracks and the state of the sample.

In the case of critical constructions in terms of frost damages, adapting the hydrophobization impregnation agent to the material, construction and use is carried out to ensure that driving rain protection also functions. In addition to capillary water absorption measurements, other material parameters such as capillary saturation, saturation until constant weight, change in water vapour diffusion resistance, the course of evaporation and the penetration depth of the impregnation agent are also taken into account.

An example for the evaluation of driving rain-tight materials is provided by the results obtained from various types of bricks in the case of the “Elbe Philharmonic Hall“ in Hamburg. For the evaluation, the following material parameters respectively material functions were taken into account:

$t^{0.5}$ Time of capillary saturation [$s^{0.5}$]

A_{ws} Water absorption coefficient [$kg/m^2s^{0.5}$]

θ_{cap} Capillary saturation [m^3/m^3]

θ_{end} Saturation until constant weight [m^3/m^3]

μ Water vapour diffusion resistance

$W_{m(t)}$ Drying function and potential [$m^3/m^3/d$]

A detailed description of the methods used to determine these characteristic values can be is found in the literature listed [2, 3, 4]. The determination of these values was carried out on the untreated and subsequently on the impregnated material.

CASE STUDY

Elbe Philharmonic Hall, Hamburg

A new landmark is in the making at Hamburg: The Elbe Philharmonic Hall. One of the special challenges of this project is to preserve the approximately 30 metre high existing facade of the old wharf warehouse and to strengthen it for its future utilisation. For this purpose, tests were carried out on bricks from the outer shell. In the first round, the mentioned parameters of the untreated, existing brick were determined. In the second round, the bricks were treated with different impregnation agents and the same material parameters were determined again. Table 1 gives the obtained results, while Table 2 gives information on the water repellents used.

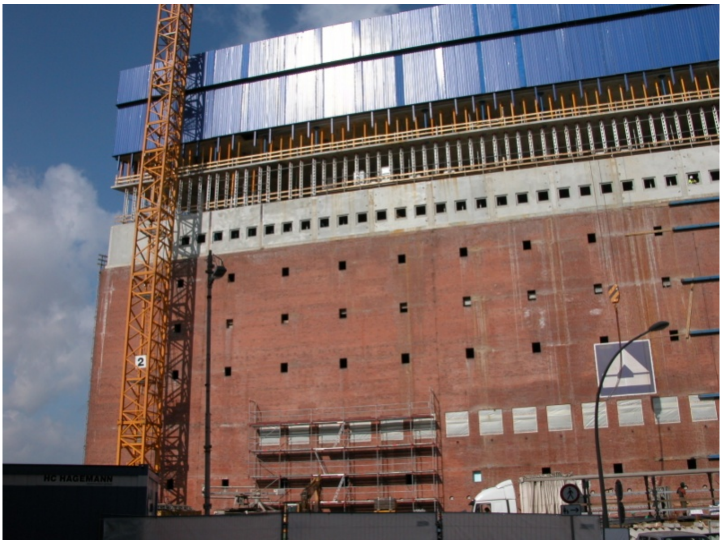

Figure 2. Existing facade of the Elbe Philharmonic Hall, now under construction, which was formerly Wharf Warehouse A. [Remmers]

Table 1. Mean values of measured results of brick samples from the Elbe Philharmonic Hall before and after the impregnation measures using different hydrophobization agents (water absorption coefficient: Aws value, capillary saturation: θcap, saturation until constant weight: θend, water vapour diffusion resistance: μ-value and the time capillary saturation is reached: $t^{0.5}$) [7].

Treatment	$t^{0.5}$ [$s^{0.5}$]	A_{ws} [kg/m²$s^{0.5}$]	θ_{cap} [m³/m³]	θ_{end} [m³/m³]	μ [-]
Untreated	21.7	0.1890	0.191	0.197	23.93
SNL	21.3	0.0027	0.003	0.121	21.87
WS	101.2	0.0414	0.191	0.195	27.49
FC 10	227.6	0.0211	0.173	0.180	21.94
FC 30	61.3	0.0020	0.006	0.005	22.54
FC 40	20.8	0.0051	0.005	0.014	22.27
FC 50	20.1	0.0321	0.034	0.036	23.72
FC 60	171.5	0.0026	0.008	0.013	18.81

Table 2: List of agents used for the tests, their active ingredients and concentrations.

Product Name	Abbreviation	Description	Concentration
Funcosil SNL	SNL	fluid, solvent-based, Silane/Siloxane	7 % w/w
Funcosil WS	WS	fluid, water-based, Silane/Siloxane	10 % w/w
Funcosil FC pro C10	FC 10	crème, Silane	10 % w/w
Funcosil FC pro C30	FC 30		30 % w/w
Funcosil FC pro C40	FC 40		40 % w/w
Funcosil FC pro C50	FC 50		50 % w/w
Funcosil FC pro C60	FC 60		60 % w/w

Concerning the A_{ws} values, a significant reduction of water absorption in all cases was observed. There were, however, clear differences, depending on the impregnation agent used. In regard to capillary saturation, two of the samples had practically the same values as the untreated samples. Water vapour diffusion resistance (µ-value) remained practically unchanged, as shown in Fig. 3. The water vapour diffusion resistance of individual samples from the brick masonry work of the Elbe Philharmonic Hall before and after treatment with different hydrophobizing agents are shown. It can be clearly seen that a hydrophobizing impregnation does not have a significant influence on diffusion resistance.

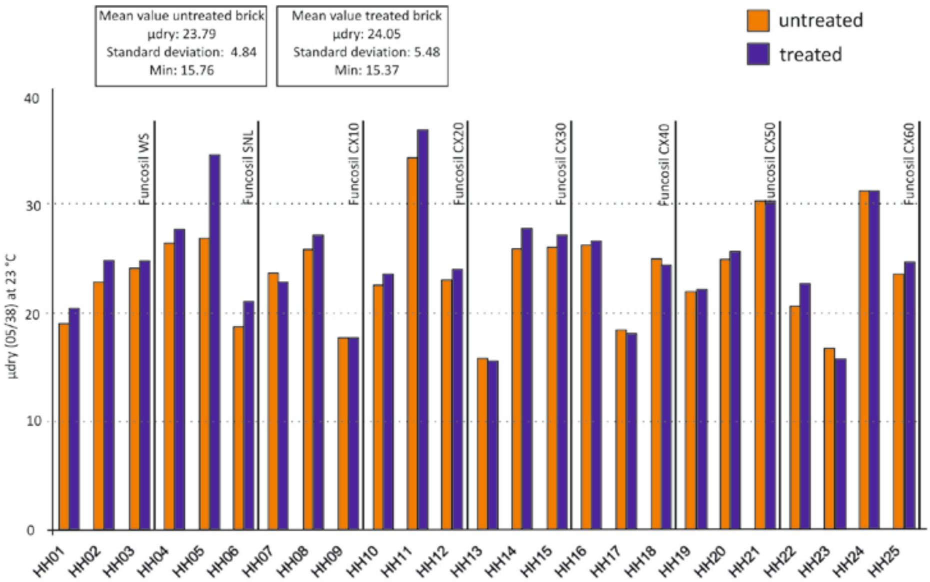

Figure 3.Water vapour diffusion coefficient µdry (dry cup test 05/38 rel.hum.) at 23 °C of brick samples from Elbe Philharmonic Hall each untreated and treated with different hydrophobization agents [7].

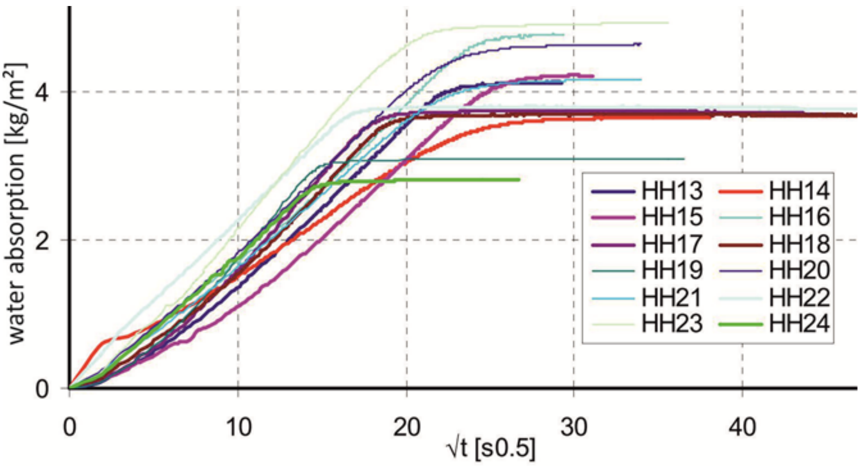

Figure 4. Function of capillary water absorption of brick samples treated with different hydrophobizing impregnation agents from the Elbe Philharmonic Hall in Hamburg [7].

The capillary water absorption curves show great differences, depending on the impregnation agent used. Due to their non-linear curve, they indicate inhomogeneity of the hydrophobized materials (Figure 4). In regard to the values of capillary saturation, two of the impregnation systems achieved practically the same values as untreated samples. Water vapour diffusion resistance (μ-value) remained nearly unchanged.

ADVANTAGE OF ADAPTIVE HYDROPHOBIZATION

To assess the effect of hydrophobizing impregnation agents on the drying properties of brick material, impregnation creams with different concentrations of an active ingredient (silane) (10 %, 30 % and 60 % w/w) were applied to the surface of a brick. After saturating the samples with water through the untreated surface, the samples were sealed in such a manner that evaporation could only take place through the impregnated surface [3].

On the basis of the drying curves (Fig. 5) it can be seen that the impregnation agent on the test sample has an influence on the degree of saturation of the sample (water content at time "0"). The lower the active ingredient content, the higher the volumetric degree of saturation is in the beginning. With 10 % active ingredient, 0.27 m^3/m^3 of water is in the samples, with 60 % active ingredient, only 0.22 m^3/m^3.

The samples with 10 % active ingredient gave off water the fastest. After just 3 days they showed less moisture than the other two samples. The further drying curve showed: The higher the active ingredient content, the lower the effective return transport of water. Since the entrance of moisture into masonry work cannot be completely ruled out even when the hydrophobizing impregnation measures have been carried out with the greatest care and the entire construction is intact, the effectiveness of impregnation should not be formulated stronger than necessary, particularly in critical cases.

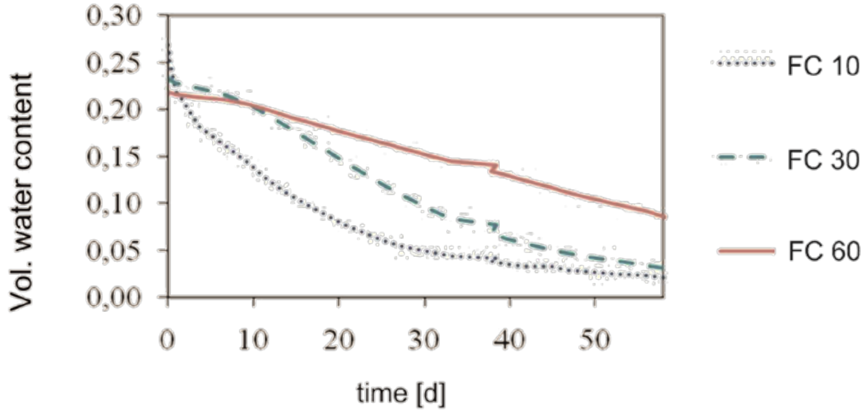

Figure 5. Drying curves of brick samples impregnated with different concentrations of the same hydrophobizing agent. Shown here are mean values from tests with impregnation creams formulated with the same active ingredient at three concentrations (10 %, 30 % and 60 % w/w) [7].

ADAPTATION OF A HYDROPHOBIZING IMPREGNATION AGENT

To optimise a hydrophobizing protection system, the material parameters of the building need to be determined as well as the climatic boundary conditions while construction details must also be examined. The required parameters should be determined in a laboratory first and transferred to a hygrothermal, numeric simulation programme such as Delphin (simulation program for the calculation of coupled heat, moisture, air, pollutant, and salt transport, produced by the TU Dresden [8]). Afterwards, taking into account the information gained at the building site and from plans regarding construction, existing materials, geographic location, usual climatic conditions and, if applicable, planned interior insulation, corresponding simulation calculations can be carried out. The sequence for adapting the hydrophobizing impregnation agent to the construction will be shown in the following flow chart (Figure 6) [5].

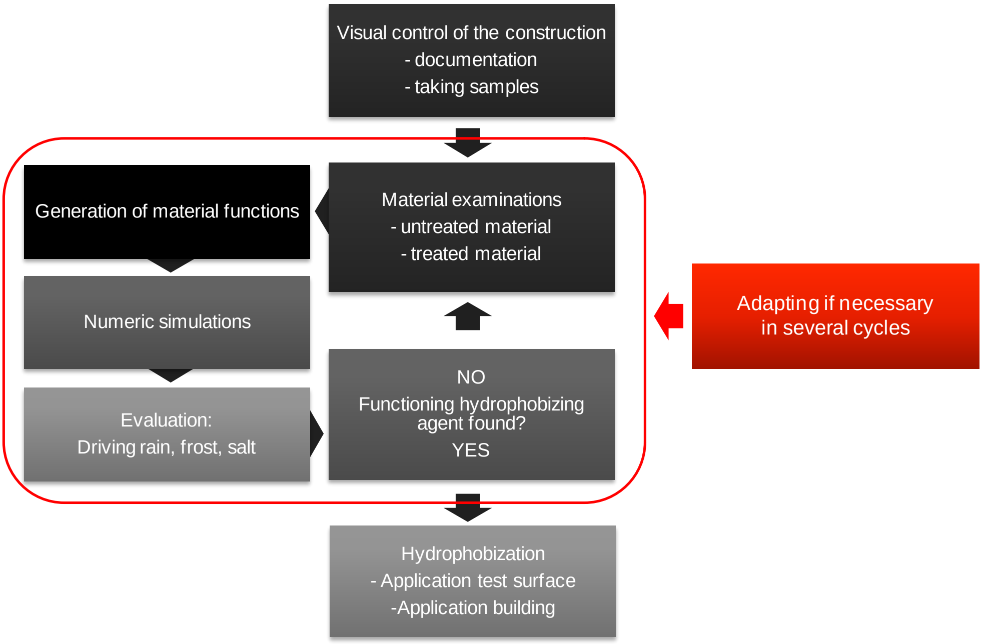

Figure 6. Diagram showing the approach used to adapt a hydrophobizing impregnation agent to a specific object [5].

The first step consists of inspecting the building site. This should include comprehensive photographic documentation of the facades, measurement of moisture on selected and exposed areas, taking sample materials and doing a visual analysis of the damage on the facade. The photographic documentation should include photographs of the object from all directions as well as particular details such as cracks in the masonry work (cracks in the brick, cracks in the mortar, settlement cracks) or strong moisture penetration. In addition, brick shapes and sizes, biological growth and efflorescence (salt, gypsum, lime) should also be documented.

Bricks from the building are required for material examination in a laboratory. For this purpose, both undamaged as well as damaged bricks should be taken. If possible, these bricks should be taken from areas of the facade that have different weather conditions. In the first round of laboratory examinations, material parameters such as the A_{ws} value, μ value, λ value, gross density and evaporation curves are determined on the untreated, existing material. With the aid of these parameters, specific material files can be created for the Delphin simulation programme and calculations made based on existing materials, depending on geographic location, climatic conditions and makeup of the construction. This allows an assessment of the hygrothermal behaviour of the initial construction to be made.

In the second round, the A_{ws} value, μ value, λ value, gross density and evaporation curves are again determined but now on the impregnated material. Different impregnation agents are used. With the newly created material files on the hydrophobized brick with the favoured impregnation agent, comparative simulations are then carried out. Based on the simulation calculation, the interaction of the applied surface protection with the masonry work construction can be determined. Further refurbishment measures such as a planned interior insulation, can also be taken into consideration when calculating. The best possible impregnation agent is then selected based on the results.

The effectiveness of the impregnation agent mainly depends on the constructional state of the facade or building and can only be ensured on facades that are structurally intact. Constructive possibilities for reducing the entrance of water must be carried out. If the required constructional measures are observed, the impregnation agent selected can be applied to a test field approx. 2 m² in size. This field is then used to optimise application in regard to quantity of impregnation agent per surface and the application method.

LONG-TERM CONTROL AND MAINTENANCE

The active ingredients used today in hydrophobizing impregnation agents form polysiloxane resins. These are extremely resistant protective substances which are practically indestructible except through normal weathering of the building material. Control of the effectiveness of treatment by measuring the absorption of water and, if necessary, refreshment treatment is advisable since joint material may detach from the sides of the joints and fine particles of dust that are deposited on the facade over the course of time can impair the effect of the impregnation agent.

- Because of fluctuating temperatures and the resulting, unavoidable shrinkage and expansion processes in facade building materials, it is not really possible to prevent joint material from detaching from the joint-sides. These flaws constitute areas where hydrophobization is missing, and therefore their development should be monitored and when necessary, the joints must be repaired [6].
- Once the hydrophobization agent has reacted, it is practically indestructible but over time the surface becomes covered with fine dust particles that are hydrophilic, causing the water repelling effect of the fresh hydrophobization agent to disappear after a while. When it rains, the moisture content of this thin, superficial zone can become quite high because this moisture cannot penetrate into deeper areas. Since it is not possible to reinstate the water repelling effect by cleaning, it is recommended to refresh the hydrophobization of the surface every 7 to 10 years, depending on exposure [6].

With average loads, controls carried out about every 5 years should be sufficient; shorter intervals may be advisable if the building is subjected to stronger weathering. Control and maintenance contracts for the time after the hydrophobizing measures have been carried out are recommended.

CONCLUSION

Facade constructions that are insulated on the inside show clearly lower cross-section temperatures in winter than they had before they were insulated. To reliably prevent a risk caused by frost, the entrance of moisture into the facade construction through rain must be reduced. On stone- or brick-faced facades, this can be achieved by applying a hydrophobizing impregnation agent. Especially in the case of sensitive structures, the active ingredient content of the hydrophobizing agents used can be adjusted (adapted) to the building materials to be impregnated. Within the scope of interior insulation measures, the driving rain tightness of the facade must be assessed, integrated into the plans and, if possible, ensured over the long-term through a maintenance contract.

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