BRICKS - WATERPROOFED AND CONSOLIDATED

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ABSTRACT

Of special interest for the users of conservation materials are on one side the possibilities and on the other side the limits of application of commercialy available waterproofing and consolidation products.
Main part of our investigations in the past and now were / are commercially available products for the conservation of bricks.
Aim of the investigations is to find correlations between active substances, the contents of active substances and solvants with regard to the effectiveness of these products on differently treated bricks.

1 INTRODUCTION

For many years manifold investigations on the effectiveness of various materials for waterproofing and consolidation were done in the field of stone conservation. Based on this knowledge requirements on the materials have been formulated.
Waterproofing materials are colourless products solved in organic solvents or in water, which should fit the following requirements:

- reduction of uptake of water by ≥ 70 %
- reduction of water vapour diffusion by ≤ 10 %
- good penetration of the waterproofing material
- hardening of the active substance to a non-sticky consistency
- no alterations of colour on the surface of the building material
- long-standing effectiveness (at least 10 years)
- possibility to repeat the treatment
- compatibility with other conservation arrangements.

The solvent has the function to transport the active substances and to reach high penetration depth.[1,2,3,4,5,6,7]
Organic silicone compounds, as e.g. alkyl-alkoxy-silanes, oligomer siloxanes are the most frequently used products for water repellency.

Consolidation materials should fit the following requirements:

- good penetration depth, at least up to the undamaged core of the building material
- deposition of new, weatherproof binding material
- no formation of damaging by-products
- no alteration or negative influence on the physical properties

(e. g. water vapour diffusion, dilatation)
- no changes in colour on the surface of the building material
- reduction of uptake of water and the penetration of contaminants
- no formation of crusts; formation of an uniform strength profile. [8]

Consolidation materials depositing an anorganic binding material have been deliberately selected.

2 MATERIALS

The investigated brick material is to be charakterized as follows:

- compressive strength:	15 - 30 N/mm²
- uptake of water:	20 - 25 %
- density in raw state:	≈ 1,6 g/cm³
- porosity:	37 - 42 %
- water vapour permeability μ:	6 - 11

These informations imply that the material shows inhomogenities which make the interpretation of the results more difficult.
In a first part of the investigations the effectiveness of 19 waterproofing and 11 consolidation materials has been tested on brick samples of balanced humidity (23 °C, 50 % rel. hum.).
As a result of these investigations 4 waterproofing and 5 consolidation materials (Tab. 1, marked) were selected. Their effectiveness on wet- and salt-contaminated substrates were tested.

TABLE 1 Materials

Nr.	Name	Producer	Composition
Waterproofing Materials			
1	FK 7	Fakolith Farben	silicone micro-emulsion, water
2	*Funcosil SNL*	*Remmers*	*6,7 % siloxane, aliphatic hydrocarbons, mineral turpentine*
3	*W 1311*	*Wacker-Chemie*	*silicone micro-emulsion, water*
4	*Siloxan Fassadenimprägnierung*	*Colformit Rajasil*	*6,7 % oligomer siloxane test benzine*
5	MS Siloxan	HEY'DI	siloxane, solvents
6	Kapillarwassersperre	- " -	alkalidisilicates alkalialkylsiliconates
7	Siloxan-Mikroemulsion	- " -	silicone micro-emulsion, water
8	Fassadenimprägnierung W	Colformit Rajasil	silicone micro-emulsion water
9	Deiterol S	Deitermann	siloxane, aliph. hydrocarbons
10	Deiterol SLF	- " -	silicone micro-emulsion, water
11	FassadenschutzSMK	Coverax	silicone micro-emulsion, water
12	Siloxan Bautenschutz W 290	- " -	6,7 % oligomer siloxane aliphatic hydrocarbons
13	Tegosivin HL 100	Goldschmidt	modified siloxane, cleaner's naphtha
14	Funcosil Hydroimprägnierung	Remmers	siloxane water
15	Baysilone LD	Bayer	siloxane emulsion, higher alkylate
16	Dynasilan BHS 40N	Hüls	40 % isobutyltriethoxysilane ethanol
17	*Dynasilan BHS 40 %*	- " -	*38 % isobutyltriethoxysilane 2 % octylethoxysilane ethanol*
18	Unil 290	Kulba Bauchemie	6,3 % siloxane, solvents
19	Unil SMK	- " -	silicone micro-emulsion, water
Consolidation Materials			
I	Wacker Steinfestiger OH	Wacker-Chemie	75 % silicic-acid ester solvents
II	*Wacker Steinfestiger H*	- " -	*75 % silicic-acid ester silicone, 20 % butanone, 5 % toluene*
III	Steinfestiger OH	Colformit Rajasil	75 % silicic-acid ester ketone
IV	Steinfestiger H	- " -	75 % silicic-acid ester silane, siloxane, ketone
V	Funcosil OH	Remmers	75 % silicic-acid ester ketone
VI	*Funcosil 100*	- " -	*20 % silicic-acid ester aliphatic hydrocarbons*
VII	*Funcosil 300*	- " -	*99 % silicic-acid ester*
VIII	Steinfestiger OH	Coverax	silicic-acid ester, ketone
IX	*Tegovakon T*	*Goldschmidt*	*silicic-acid ester, methyl siloxane, 12 % ethanol, 9% butanone*
X	Tegovakon V	- " -	silicic-acid ester, 17 % ethanol
XI	*Durolith 61*	*Dr. Kremer*	*Li-polysilicate, water*

3 METHODES AND RESULTS

For the determination of effectiveness and penetration depth cores (ø = 5 cm; h = 5 cm) were both completely wetted through and soaked on one side. The cores were cut into slices (about 5 mm thick) to determine the depth profiles.

3.1 FIRST PART OF INVESTIGATIONS

WATERPROOFING MATERIALS

Wet penetration depth, uptake of water [%] and uptake of water coefficient w as 24-h-values [$kg/m^2h^{0,5}$] were determined and, on the slices, uptake of water [%] and water vapour permeabilty _ (wet-cup-method) were measured. A futher criterion of selection was the visual alteration of the brick samples.
For all substances the wet penetration depth were about the same, between 10 and 13 mm.
Uptake of water was sufficiently reduced, with the exception of substance 15 (reduction of uptake of water only 50 %).
Water vapour diffusion was hardly changed. But it has to be noticed that variations up to 30 % are normal for the untreated material.
The application of siliconates and silicone micro-emulsions led to visual alterations.
It is remakable that the waterproofing materials containing ethanol, even with only 0,2 % deposited active substances (other waterproofing materials deposited about 6 %) penetrated the cores completely. These samples showed sufficient water-repellent results although the wet penetration depth was comparable to that of the other substances.

CONSOLIDATION MATERIALS

Measurements of the elastic moduli by means of the determination of flexural and torsional resonance frequencies and water vapour diffusion _ appeared to be suitable methods for the determination of effectiveness and penetration depth.
For water-repellent consolidation materials the determination of the uptake of water [%] of the core slices and measurement of the contact angle have to be included.

All consolidation materials (except 15) showed comparable results.
All substances, with the exception of those containing waterproofing components, led to visual alterations as white blooms.

3.2 SECOND PART OF INVESTIGATIONS

For these investigations several substances were selected (marked in Table 1) because of their good results in the first part of investigations and their different compositions.
The brick cores were treated with moisture contents, pottasium nitrate (nitrate samples) and a gypsum/bassanite/halite-combination (gypsum samples) before entering the waterproofing / concolidation process.

WATERPROOFING MATERIALS

The effectiveness was determined by means of uptake of water [% or kg/m²], penetration depth and water vapour diffusion. Besides, experiments on the hygric dilatation behaviour and the durability against sodium sulphate were caried out.
Uptake of water [% or kg/m²] and contact angle proved to be suitable methods for the determination of effectiveness and penetration depth. Measurements of the water vapour diffusion on the slices proved to be unsuitable for the determination of penetration depth, since the tested substances did not influence the vapour diffusion significantaly. The requirement not to reduce the water vapour permeability more than 10 % is assessed to be unrealistic, because untreated material already showes variations of up to 30 %. The wet penetration depth only shows the minimum penetration depth, but the real penetration depth can not be determined with that.
On wet substrates (50 % wetness of the samples) all tested waterproofings showed the same effectiveness as on substrates of balanced humidity (23 °C, 50 % rel. hum.).
Best results achieved using *W 1311*(aqueous) and *Dynasilan BMS 40 %* (containing ethanol). In contrast to certain statements in the literature [9] that ethanol compared to test benzine and aliphatic hydrocarbons causes worse penetration depth on natural stones, on wet substrates the highest material deposition and best effectiveness could be proven.
On waterlogging bricks only with *W 1311* a close-to-the-surface water-repellent effect could be found out.
Problems appeared with the impregnation of salt-contaminated substracts.
The reduction of capillary uptake of water could hardly be proven, as during the experiments salts were solved from the samples. Therefore, in spite of the storage in water the samples became lighter. This effect was not observed with the respective untreated sample. By means of measurements of contact angle in all salt-contaminated samples a negative influence on the waterproofing effect could be found.
The hygric dilatation of the gypsum samples treated with *Siloxan-Fassadenimprägnierung* and *Dynasilan BMS 40 %* was determined in comparison to the untreated gypsum sample - 0-sample (Fig.1 and Fig 2). The 0-sample showed a low, continnous shrinkage caused by salt-solving processes.

The swelling that appeared with water-repellent samples is not caused by the presence of salts.
By means of the crystallisation test with sodium sulfate [10] on waterproofed samples of balanced humidity a very good resistence against sodium sulfate was found. No damaging of the samples appeared.
Therefore, the waterproofing does not only give a water-repellent protection but also prevents salt from penetrating into the building materials.

CONSOLIDATION MATERIAL

For the determination of the effectiveness the different properties were measured according to the first part of the investigations. Besides, the cristallisation test with sodium sulfate was carried out on impregnated samples of balanced humidity, and the hygrig dilatation (Fig. 1 and Fig. 2) was determined on gypsum samples treated with waterproofing consolidation materials.
It was found that there are considerable differences between consolidation materials with and without waterproofing additives.
For the determination of the penetration depth of waterproofing consolidation materials measurements of uptake of water [%], water vapour diffusion, contact angle and elastic modulus on core slices are suitable .
The penetration depth of consolidation materials without waterproofing additives could only be determined by means of the water vapour diffusion and elastic modulus.
On salt-contaminated samples measurements of the elastic modulus proved to be useless.
Wacker Steinfestiger H and *Tegovakon T* cause a reduction or a delay of the water suction. The contents of water and salts in the brick samples has a less unfavourable effect on the impregnation results when using *Tegovakon T* instead of *Wacker Steinfestiger H*.
With increasing wet of the substrate the amount of deposited impregnation material decreases.
At a wet of sample of 50 % the water-repellent effect of *Tegovakon T* is good over the whole sample depth.
Even on waterlogging substrate with the ethanol-containing *Tegovakon T* a penetration depth of 5 mm could be achieved.
The aqueous Li-silicate solution always showed the worst penetration depth.
A salt-content always implies an unfavourable influence on the impregnation results.
By means of the crystallisation test it was found that consolidation materials with water-repellent effect increase the resistence against sodium sulfate solution. Consolidation materials without waterproofing additives do not lead to a better resistence in comparison to the 0-sample.
Dilatation and weight change behaviour when stored at climate conditions was only tested on the gypsum samples which had been treated with waterproofing consolidation materials.

With increasing humidity *Tegovakon T* causes intensive swelling effects. Samples treated with *Wacker Steinfestiger H* show the same behaviour as the 0-sample. This results is caused by the different additives.

Especially *Funcosil 300* and *Durolith 61* show a unfavourable influence on visual properties.

Fig.1: Hygric dilatation [mm/m] of treated and untreated bricks, depending on relative humidity [%]

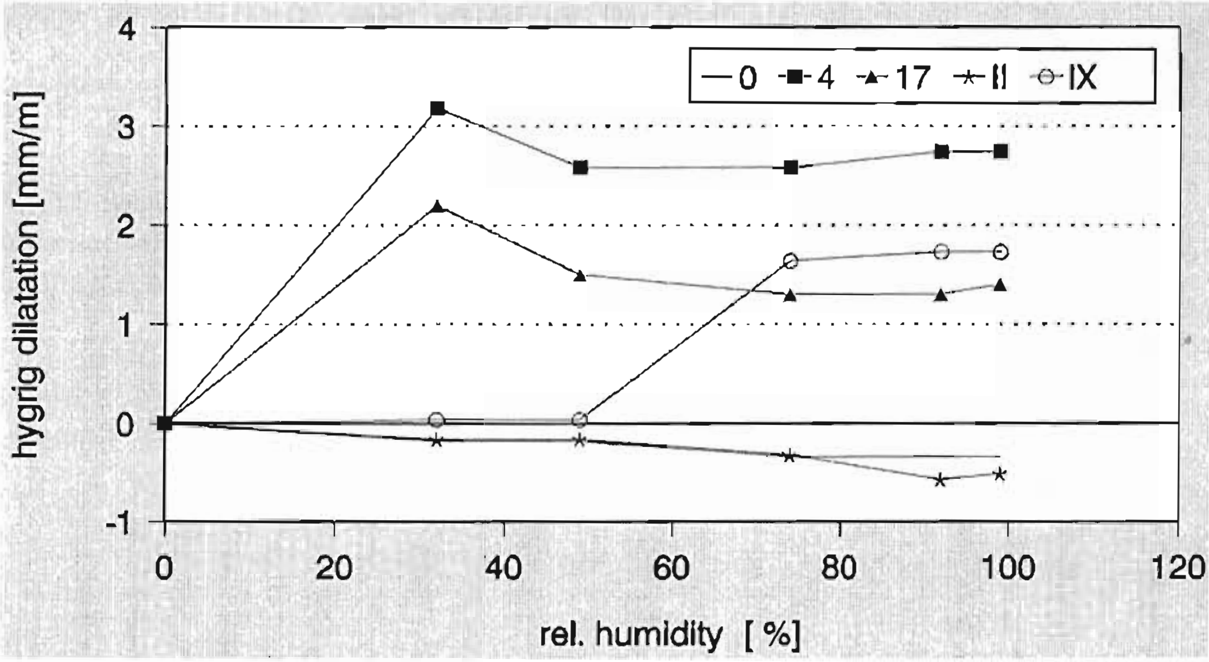
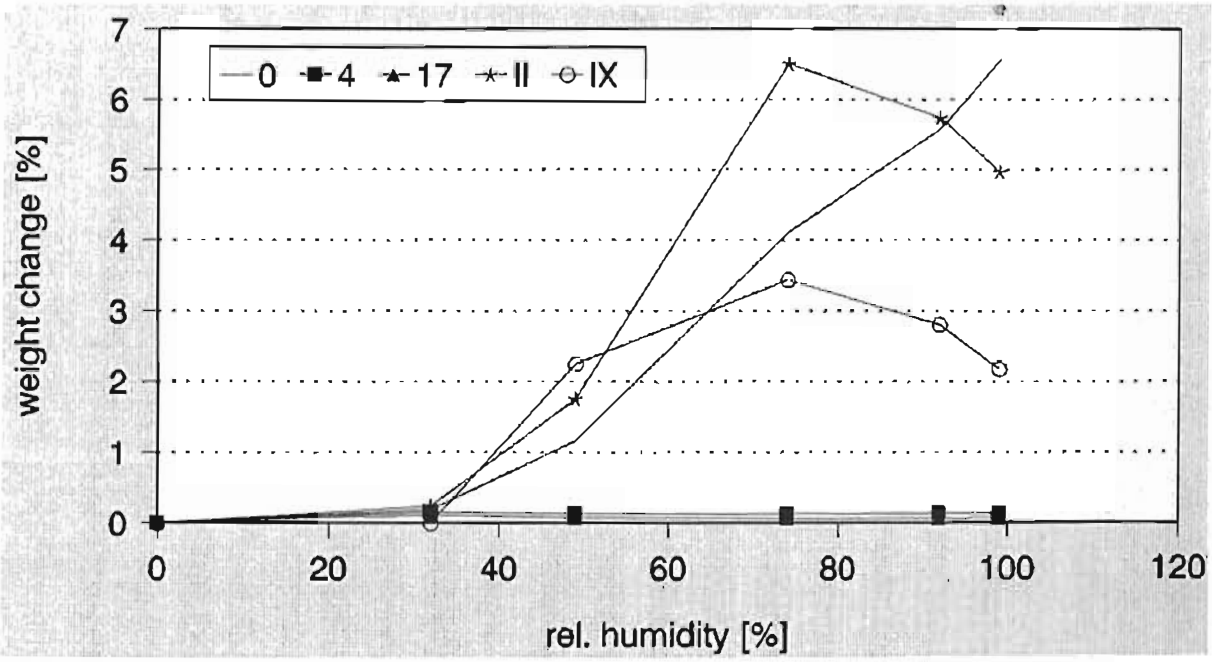


Fig.2: Relative weight change [%] of treated and untreated bricks, depending on relative humidity [%]



4 CONCLUSIONS

The way investigations stand at the moment general conclusions concerning the correlations between active substance, content of active substance and solvent with regard to the effectiveness of the impregnation material can not yet be drawn.
On dry, salt-free bricks the impregnation materials bave comparable penetration depths and effects (except 15).
Based on our experience impregnation materials containing ethanol - followed by the aqueous substances - show even at high substrate moisture the best penetration depth and effectiveness.
Impregnation of waterlogging and salt-contaminated substrate should not be carried out.
Waterproofing always leads to an improvement of the resistent against salts.
Special attention should be drawn to the hygric dilatation of impregnated bricks.
The experience discribed in [11] that impregnation materials containing silane or siloxane lead to swelling effects at climate storage conditions can be confirmed. That is probably caused by the reaction of these active substances to polysiloxanes in the structure.

Our investigations show that the effects of impregnation materials on various substrates are different, and the application of test areas on the building material to be impregnated should still be imperative.

We still are at the beginning of systematic investigations.

5 REFERENCES

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