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New Powdery Water Repellents For Dry Mortar Applications

More Than A Durable Protection

ABSTRACT

For many years hydrophobisation agents have been the media of choice in order to protect masonry facades and building surfaces against moisture and destruction by weathering thereby leading to an increased lifetime.
In the beginning, hydrophobizing systems to be applied externally on the final constructed parts and outside structures were the first to successfully enter the market. However, although external hydrophobisation still accounts for the major share in the above mentioned applications, integral hydrophobisation enjoys increasing popularity and accpetance. In other words building protection is already taken into consideration during the actual construction phase. On the other hand dry mortars have gained importance in the construction industry over the past decades as they lead to increased productivity and improved quality. In order to improve product quality and to meet all kinds of specific requirements, dry mortars are modified with polymer binders and special powdery additives such as hydrophobizing agents (water repellents). At present metal salts of fatty acids are widely used as water repellents in dry mortars and represent the largest group of hydrophobizing additives. Particularly in regard to long term performance, metal salts of fatty acids exhibit some weaknesses. With this paper we would like to introduce newly developed powdery hydrophobizing additives. These additives are composed of silane/siloxane blends based on an inorganic carrier to be easily applied to drymix systems. As powdery water repellents they provide superior performance compared to metal salts of fatty acids and are easy to handle and dose. Due to their unique chemical design they provide outstanding water repellence and excellent beading along with true long term performance and sustainably protect buildings and architectural constructions.

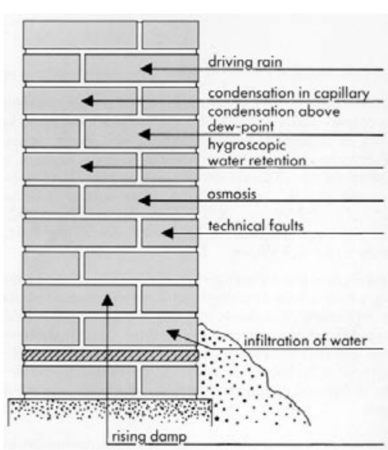

Fig. 1: Ways of water uptake

1 INTRODUCTION

Penetration of water and humidity into facades, buildings and architectural constructions consisting of mortar, concrete, natural stones or bricks is one of the major reasons for damages to their structure and substrate.
Water causes these damages either by direct contact, natural weathering or as a result of insufficient foundation of walls (Fig.1). Additionally, the negative impact of water can even be enhanced as it functions as carrier of water soluble salts or pollutants from air [1].

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Over the past decade building protection has gained much importance and is nowadays often taken into consideration already during the construction phase. This trend is further supported by general technological advancements such as the development of the dry-mix technology. State of the art powdery hydrophobizing additives have become an integral component of various dry-mix formulations. In this regard Goldschmidt's new water repellents provide superior performance in terms of outstanding water repellence and excellent beading along with true long term performance.

2 DAMAGES CAUSED BY WATER-UPTAKE

Most damages to buildings are caused by water e.g. through natural weathering (Fig.2). Air pollutants such as SO_2 or NO_x accelerate the decomposition processes. To suppress, or, even more desirable, to totally prevent the decay of structures building protection in form of waterproofing or water-repellent treatment is used.
Most building materials are porous and water can penetrate into these pores. At lower temperatures this water can freeze to ice (Fig.3). As a consequence cracks may occur within the building material because ice has a larger volume than water.
In nature, this is a common phenomenon, e.g. hard rock turns into sand in the course of time. In the presence of water salts and mineral binders that are contained in the substrate are subjected to conversion.

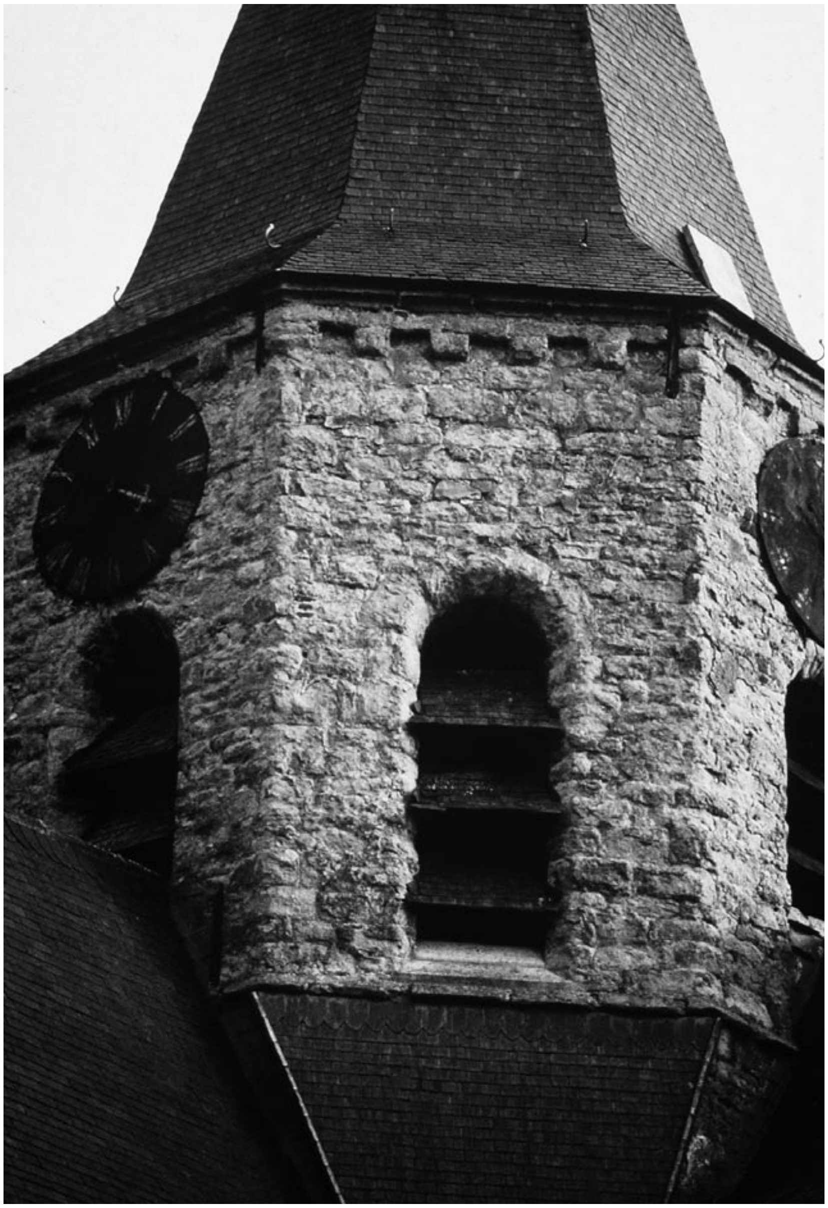


Fig. 2: Damages through weathering

Undesirable consequences of water ingress
- Cracks due to water freezing
- Efflorescence
- Transport of salts (corrosion)
- Dirt retention
- Peeling off of decorative coatings
- Rising/penetration dampness
- Reduced insulating properties

Fig. 3: Freeze / Thaw damage

In order to effectively control humidity in the masonry, different water absorption mechanisms need to be considered. Construction defects, destroyed joints, cracks and non-existing insulation give access to moisture. Via defective or non-existing horizontal insulation, moisture can rise in capillary form in the masonry. Capillary action (Fig.4) in the porous substrates leads to a fast and high water uptake in masonry. This process is accelerated through the condensation of air humidity when the temperature falls below the thaw point in cold areas, as well as the condensation of water vapour when the temperature rises above the thaw point.
Infiltration of ground water might additionally occur in the basement area if insulation is insufficient.
Salt blooming is the most apparent moisture-induced damage. Salts which are contained in the building material are dissolved by penetrating water and reach the surface where the water evaporates and the salts crystallise. Salts in the masonry are hydrophilic centres which may cause damp zones.

The volume of certain salts increases by reversibly absorbing crystallisation water.
Damages to the surface and the interior of the masonry, where crystallisation pressures cause structural cracks, are the consequences. Through these cracks water penetration is accelerated, thereby increasing the damp zones and becoming an ideal medium for the development of micro-organisms which may further worsen the damage.
Moisture in the masonry may cause paints and renders to peel off, mainly due to freeze/thaw stress. Moreover, powdery surfaces as well as the cracking of joints and stone surfaces reduce the strength of the masonry. Reduction of the heat insulation and thus increased costs for energy are secondary effects.

To summarize: Water is one of the major causes for structural damage to building materials in the course of time. The results range from total destruction to expensive restoration of the affected buil-

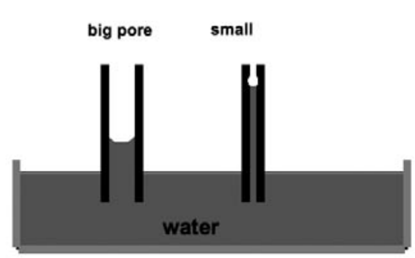


Fig. 4: Capillary action

dings. The attack of mould and fungus is not only unpleasant but also poses a health risk.

3 PROTECTION AGAINST WATER – HYDROPHOBIZING AGENTS

Being aware of all the damages that can be caused by water and moisture the requirements for a good protection can be described as follows:

- Reduction of water absorption
- Effective protection from heavy wind and driven rain
- High penetration depth of the water repellent
- Prevention of efflorescence
- Protection against de-icing salts
- Reduction of dirt build-up
- No adverse effects on the appearance of the substrate
- No significant reduction of the vapour permeability

Although many different types of water repellents are available in the market, for the last decades silicone based products as silicone resins, silanes and organomodified siloxanes proved to be the best solution. No other chemistry fulfils simultaneously as many of the above mentioned requirements.

With respect to concrete structures impregnation with silanes/siloxanes based water repellents strongly reduces water penetration which is the most important measure. Such products may be used as 100 % product, dilution in white spirit or as environmentally friendly aqueous emulsion. Due to the difference in surface tension between water (72 $mN\ m^{-1}$) and silicones (22 $mN\ m^{-1}$) water cannot penetrate into the impregnated areas. In contrast to other water repellents silicone based products do not negatively affect the permeability (openness of pores) and the air exchange (breathability) of building materials [2].

For façade impregnation hydrophobizing agents can be applied by means of flooding, airless spraying techniques or with rollers and brushes. These are post completion techniques which means that the finished architectural structure is being treated. Although external treatment still accounts for the major share of hydrophobization applications, integral hydrophobization enjoys increasing acceptance. In other words building protection is already taken into consideration during the construction phase e.g. via appropriate dry mortars formulations.

4 HYDROPHOBIZING AGENTS IN DRY MORTAR FORMULATIONS

Nowadays advanced dry mortar products are available to the construction industry. In contrast to job-site mortars modern drymix mortars are produced in special factories. Drymix technology can be described as highly controlled process of pre-blending and batching of all the necessary ingredients. Over the past decades drymix technology has been displacing the job-site technology since it provides numerous advantages which are crucial for modern and efficient construction works. Different types of mortar can be produced with well-defined properties to achieve reproduceable performance of high quality. Only water needs to be added at the site. A high level of consistency and reliability is achieved

and the overall construction process becomes more productive and cost-efficient [3].
Although precise market data on production and consumption of dry mortars is hardly available, consumption for Western Europe was estimated to be approximately 30 – 40 10^6 t/a in 2001 with the trend to further increase. Main growth is projected for Eastern Europe, South America and Asia.
Raw materials comprising the components of a dry-mix formulation are mainly binders, fillers, chemical additives and pigments. Typical additives applied in dry-mix formulations are cellulose ethers, plasticizers, thickening agents, air entrainers, defoaming agents and hydrophobizing agents. Of course this list is not exhaustive and others might be added. As for the other additives, too, to incorporate the hydrophobizing agent into the drymix mortar, it is advantageous to have them in solid form so that dosage, mixing and homogeneous distribution can be guaranteed. Well known as powdery water repellents for drymix mortars are low cost systems based on stearates or oleates with only moderate performance and limited durability.

For superior hydrophobicity and durability high performance water repellents based on blends of silane/siloxane eventually in combination with organic components were developed. Since the active matter of powdery additives itself often is of liquid nature it is converted into a powder by "attaching" it to an inorganic carrier such as silica, carbonates or talc to make it easily applicable to dry-mix systems.
Silane/siloxane based powdery water repellents provide superior performance compared to metal salts of fatty acids and are easy to handle and dose. Due to their unique chemical design they provide outstanding water repellence and excellent beading along with true long term performance resulting in sustainable protection of buildings and architectural constructions. The areas of applications include their use in drymix for masonry mortars, high cement content mortars, renders, plasters, tile grouts and joint fillers.

Advantages of powdery water repellent agents:

- Outstanding water repellence
- Excellent beading effect
- Durability
- Very good free flow behaviour
- Stability against alkalinity (pH in mortar formulation is above 9)
- Easy to handle and dose

5 PERFORMANCE DATA OF POWDERY WATER REPELLENTS

There are numerous methods described e.g. in the European Norms on designed mortars which can be applied to test specimen to evaluate their water repellent properties. For this paper test specimen were prepared using our newly developed high performance powdery water repellents and tested for their beading and water up-take behaviour, which yields a valuable insight into their hydrophobizing characteristics.
Four different products, Additives 1-4, were subjected to the test program and compared to a dry mortar formulation without water repellent (Table 1).

Table 1: Characteristics / Chemistry:

	Additive 1	Additive 2	Additive 3	Additive 4
Active component	Siloxane	Alkoxysiloxane	Modified silanes/ siloxanes	Alkoxysilane and stearates
Carrier	Calcium carbo-nate	Silica	Silica	Silica
Appearance	White powder	White powder	White powder	Slightly yellowish powder

Preparation of test specimen

In order to test the individual hydrophobizing agents they were incorporated in standard drymix formulations as subsequently described. The formulations were used to prepare test specimen e.g. mortar blocks as shown in Fig.5.

All solid components of the dry mortar formulation (Table 2) were premixed, including the cement, sand, filler, the water repellent (dosage = 0.2 - 0. 5 %; referring to the total amount of dry material) and other additives. To this premix 3/4 of the total amount of water is added under continuous stirring in a Hobart-Mixer. After complete addition of water stirring is continued for additional three minutes. From each formulation four test specimen were prepared. No release agents were used on the mould to avoid any interference. Before testing these specimen they were left for 2 days at 23°C and 90% relative humidity and for further 26 days at 23°C and 50% relative humidity.

Water-uptake according to UNI 10859 (similar to DIN 52617)

The test specimen were dried in an oven and then kept on a water saturated polyurethane soft foam (density 25-30 g/l). The water absorption is determined in mg/cm² by weighing the specimen after 10 min, 20 min, 30 min, 60 min, 4 h, 6 h, 24 h, 48 h, 72 h. The higher the water absorption the worse is the performance regarding water repellence.

Test results

The beading performance of the individual hydrophobizing additives is shown in following table. For comparison a test specimen not containing any water repellent (control) was tested and beading performance was rated 6 meaning that the water droplet was totally adsorbed. In general the beading

Test formulations

Test specimen were prepared according to standard formulations for tile grouts, standard plaster and render.

Table 2: Standard Formulations

Tile Grout

Component	parts
Cement 42,5 R	35
Sand 0 - 0,04 mm	60
Carbonate filler	5
Cellulose fibers	0,6
Water repellent	0,25
Water	25

Standard Plaster

Component	parts
Cement 42,5 R	13
Sand 0 - 0,04 mm	70
Calcium hydroxide	10
Carbonate filler	5
Cellulose ether	0,1
Cellulose fibers	0,6
Dispersible polymer	1
Water repellent	0,20
Water	25

Standard Render

Component	parts
Cement 32,5 R	25
Sand 0 - 0,04 mm	75
Water repellent	0,25
Water	15

Table 3: Evaluation of Beading Performance

To determine the beading effect a 0.5 ml water droplet is being placed on the specimen's surface and removed after 10 minutes. The beading effect is proportional to the wetted area left by the droplet on the specimen's surface. The performance is rated from 0 to 6.

Mark	Comments
0	no water-droplet can be placed onto the surface
1	no wetting of the surface after removal of the water-droplet
2	approx. 50 % of the contacted surface is wetted
3	the contacted surface is totally wetted
4	little darkening of the contacted surface. approx. 10 % of the water-droplet is absorbed
5	darkening of the contacted surface, approx. 50 % of the water-droplet is absorbed
6	the water-droplet is totally absorbed

effect was more pronounced in tile grouts. While Additive 1,2 and 4 show only moderate beading behaviour in the render and plaster, the beading behaviour of Additive 3 is excellent in all three formulations.

Water uptake

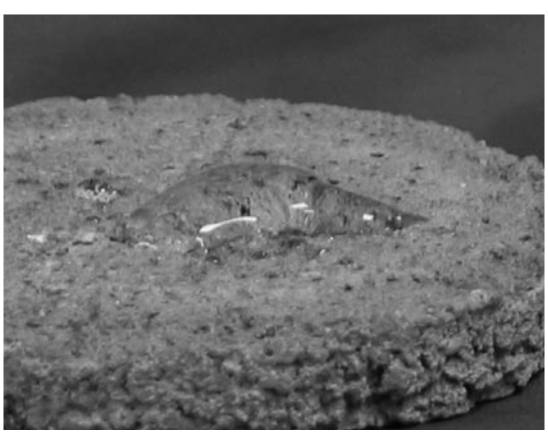
In Figures 8-10 the water up-take over a period of 48 h is shown, again for comparison a test specimen based on a standard formulation not containing any hydrophobizing agent (control) was used.
The tile grout control specimen (Fig.8) started immediately to absorb water reaching a plateau due to total saturation already after 4 h. For Additive 1 the saturation was reached after about 24 h. With Additives 3 and 4 even after 48 h the water up-take was still as low as approx. 50 % of the maximum uptake.

Fig. 5
Test specimen for water up-take measurement were placed on a water saturated PU-foam. The specimen in the upper half is untreated whereas the specimen lower half is treated with Additive 3 powder.

As for the plaster specimen (Fig.9) the water uptake generally was much faster reaching the full load for the control already after about 10 minutes. However none of the tested additives was able to

Table 4: Beading effects of the tested hydrophobizing Additives 1-4.

Additive	Tile Grout	Standard Plaster	Standard Render
Additive **1**	2	5	3
Additive **2**	3	5	5
Additive **3**	2	1	1
Additive **4**	3	5	5
Control	6	6	6



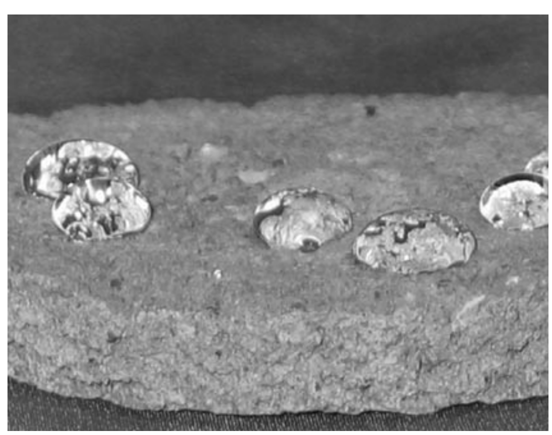


Fig. 6 (left): Beading effect with Additive 2

Fig. 7 (right): Beading effect with Additive 3

prevent the fast up-take of capillary water. For Additive 3 the final level was about 100 mg lower compared to the control.

For the standard render (Fig. 10) a clear differentiation of the water up-take properties could be determined between hydrophobized and untreated specimen, as well as in between the different hydrophobizing additives. While Additive 1 reduces the water up-take only to a minor extend in comparison to the control, Additive 4 and especially Additive 3 dramatically not only delay the water up-take but also decrease the up-take within 48 hrs to 50 mg compared to > 300 mg for the control.

Durability of the water repellent effect

These results clearly demonstrate that hydrophobizing agents delay the water up-take and volume take-up. However, the performance largely depends on the individual additive applied. For economical reasons it is desirable that water repellence is durable to achieve long lasting protection of buildings and architectural structures.

In the trials the Additive 3 was compared against a standard stearate soap in order to compare durability behaviour.

For this purpose water up-take tests were repeated four times with the same tile grout test specimen. In between the cycle the specimen were dried until constant weight at 80°C in the oven. The results are given in Fig.11.

The sample treated with stearate soap showed an acceptable behaviour in the first water uptake measure. The uptake was effectively delayed and the final value of approx. 125 ml was much lower than the control (320 ml) after 72 hrs.

However after the fourth cycle the protection of the test specimen against water up-take was more or less completely gone.

In contrast to the behaviour of the stearate soap, Additive 3 did not only show a slightly better water uptake protection in the first cycle but also kept this excellence behaviour until cycle four and even longer.

The reason for the decreasing performance of the stearate soap can be explained with the wash-out phenomenon of the active material which is after several cycles no longer present and no performance is being obtained.

Fig. 8: Water up-take of hydrophobized tile grouts

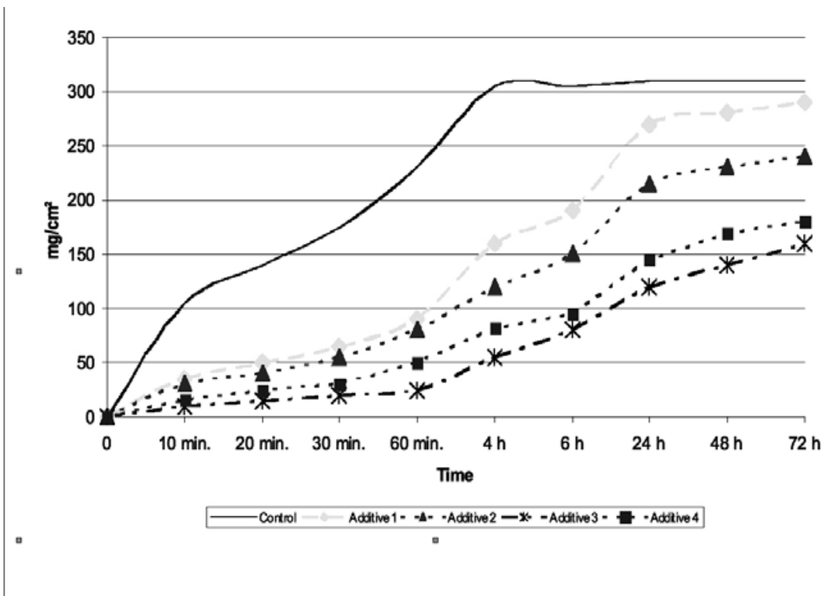
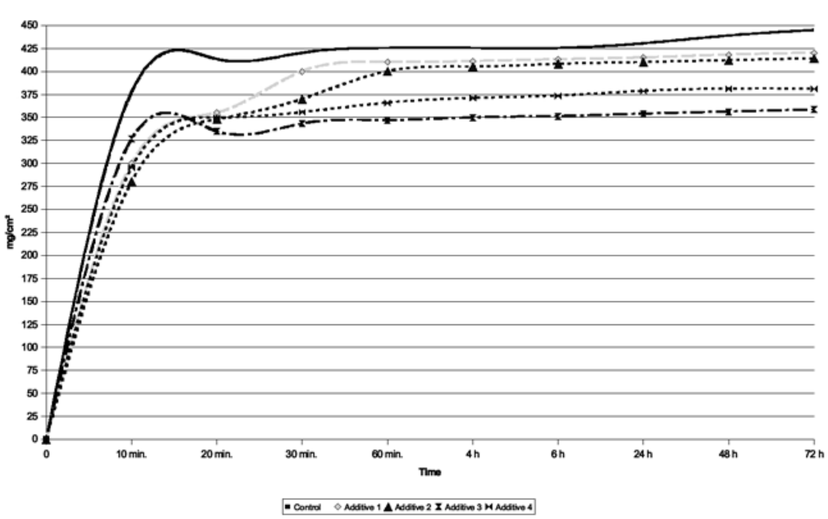


Fig. 9: Water up-take of hydrophobized standard plasters



The newly developed powder products provide mortars with outstanding long time resistance against penetrating water. In contrast, fatty acid derivatives, e.g. stearates or oleates, do not exhibit any durability and will suffer performance losses due to wash out processes.

6 CONCLUSION

Goldschmidt's newly developed powder products provide durable protection against water penetration, thus preventing buildings and architectural structures from decay related to water ingress. One can select the product that best meets the specific requirements for an individual application. The hydrophobizing agent based on modified silanes/siloxanes is the superior water repellent for dry mortar formulations being universally applicable and providing excellent water repellence as well as outstanding beading performance.

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Fig. 10: Water up-take of hydrophobized Standard Renders

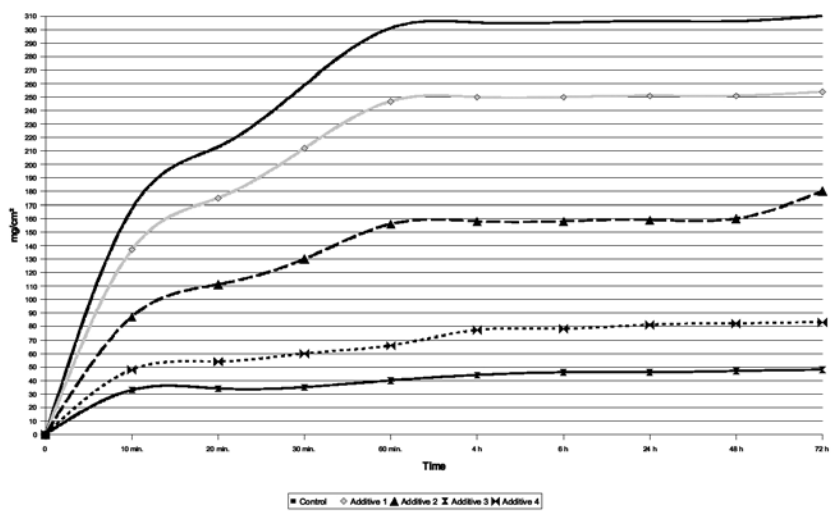

Fig. 11: Water up-take of treated tile grouts over several test cycles