CROSS-SECTIONAL WATER-REPELLENT TREATMENT OF REPAIR MORTARS
EXPERIENCES FROM LONG-TERM BEHAVIOR

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1 INTRODUCTION

Water-repellent treatment of coatings such as paints and lacquers is generally understood to result in the formation of droplets which run off the surface. Waterrepellent treatment on facades serves to protect them from rain, preventing the penetration of water into the building material. The "hydrophobic" nature of surfaces treated in this way causes the formation of beads of water. The water cannot penetrate into the coating, or can only do so to a minor extent.

This beading effect can also be achieved on mortars (=thick coatings), which are subsequently treated with a water-repellent agent, e.g. siloxanes or siliconate solutions.
This extreme water repellence is however not always desirable, as it can also be disadvantageous to buildings. Moisture can only travel through highly waterrepellent zones by water vapour diffusion. Thus, for example, moisture behind waterrepellent surfaces can lead to damage if the moisture does not dry out rapidly enough by water vapour diffusion before the frost period.

For this reason, no attempt is made to achieve beading effects with water-repellent mortars. On the contrary, the aim is to reduce the water intake of these thick coatings by slowing down their absorption properties: the wettability of the inner surfaces is reduced, and a large part of the suction effect of the water-bearing capillaries is thus removed. The capillaries can convey small quantities of water for short distances. The penetration of water through the mortar structure as a whole is however prevented in that no complete capillary permeation takes place. Protection from rain can thus be achieved without a "beading" effect.

The german standard DIN 18550 distinguishes, depending on the exposure class, between water-retardant and water-repellent mortars. The criterion is not the beading effect on the surface, but rather the effective water absorption of the mortars:

water-repellent	$w \cdot s_D \leq 0{,}2\ kg/(m \cdot h^{0,5})$ $w \leq 0{,}5\ kg/(m^2 \cdot h^{0,5})$ $s_D \leq 2{,}0\ m$ (DIN 18550)
water-retardant	$w \leq 2{,}0\ kg/(m^2 \cdot h^{0,5})$ (state of the technology)

EN 998, Part 1 (1993 draft), the future European standard for rendering and plastering mortar with mineral binders, also distinuishes between three requirement classes, depending on the capillary water absorption:

W0	not specified
W1	w ≤ 2,0 kg / (m^2 . $h^{0,5}$)
W2	w ≤ 1,0 kg / (m^2 . $h^{0,5}$)

Repair mortars (in Germany called "Sanierputze") are special mortars with specific functions on structures, in particular in renovation and restauration: Repair mortars are special dry factory mortars which have to have the following characteristics in accordance with WTA specification 2-2-91. - The charateristics are to be demonstrated by type tests at recogniced testing institutes. So proofed products can be declared "Sanierputz WTA".

small, but still present capillary **suction** (W_{24} > 0,3 kg/m^2, water penetration in the mortar after 24 hours < 5 mm)
good **water vapour diffusivity** caused by high porosity (μ < 12)
high **salt storing capacity** in air pores and capillary pores
high **salt and freeze-thaw resistance**

Two topics are now to be addressed:

1. The development of repair mortars: water-repellent additives
2. Salt and moisture ingress into repair mortars

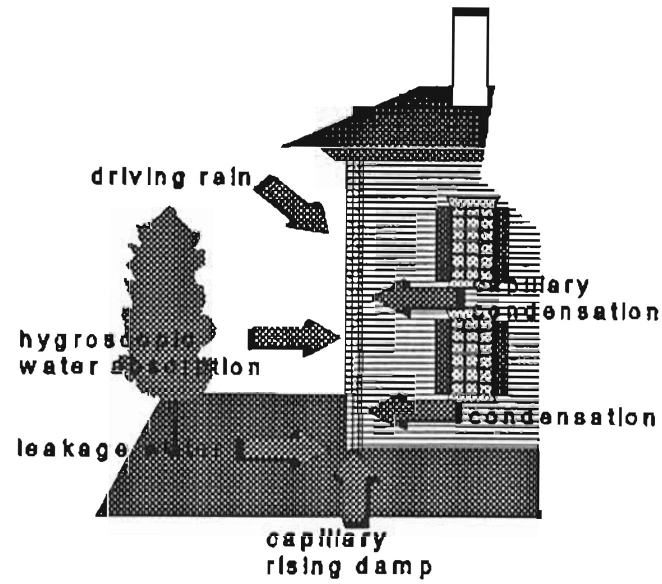
But before some remarks to the use of repair mortars. Moisture can penetrate into masonry in various ways:

a. in the liquid phase by driving rain, leakage water, capillary rising damp

b. in the gas phase by condensation, capillary condensation, hygroscopic salts

Salts are only absorbed by masonry via the liquid phase, and conveyed withing it in accordance with the moisture flow and concentration potential.

FIG. 1
Moisture intake of masonry



Moisture intake of masonary

Repair mortars are not a cure-all for all these causes of damage, even if they are sometimes used to counteract all moisture phenomena:

- They are not demoisturising mortars, for they conduct moisture fundamentally by water vapour diffusion, and to a subordinate extent by capillary action. This however also means that they are slower to dry by almost a power of ten than absorbent mortars. Damp rising and migration by capillary action is only combatted to a minor extent if at all.
- Repair mortars, like standard water-retardant and water-repellent mortars, prevent the ingress of driving rain and splash water.
- Repair mortars counteract all phenomena in which moisture can enter masonry in the form of water vapour, by moving the dew point into the mortar and covering hygroscopic areas.

Repair mortars are used so universally for renovation purposes because they cover up moisture damage. They do not combat most causes of such damage, but hide it more or less permanently, because they are highly resistant to damp, freeze-thaw and salt attack. As a result, they produce a dry and visually attractive surface for the builder, which can if necessary be worked over with coatings open to water diffusion.

2 THE DEVELOPEMENT OF REPAIR MORTARS: WATER-REPELLENT ADDITIVES

The reduced water absorption of repair mortars is achieved by two mechanisms:

1 Breaking up of capillary action by the inclusion of air pores
2 Hydrophobic constitution of the mortar

In the hydrophobic constitution of repair mortars, a thin line has to be tread between too much and too little water repellence: To a small extent, capillary absorbencyc W_{24} still has to be maintained (>0.3 kg/m^2), but water must not penetrate deeper than 5 mm after 24 hours,

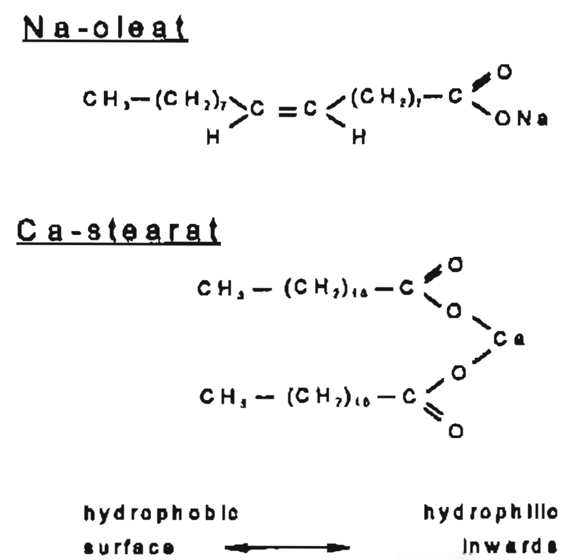
The aim is firstly to ensure that a low level of capillary water transport in the mortar is still possible, so that salts can crystallise out of the masonry substructure in the mortar, and secondly to use the capillary component to speed up the drying process. This is counterbalanced by the necessity for the moisture, and therefore also the salts, not to reach the surface through the mortar too rapidly, thus causing optical and mechanical damage there.

Repair mortars with these characteristics can be manufactured, and have been available on the market for around 20 years. Development of such materials is predominantly based on practical experience. The transport phenomena have not yet been finally clarified, however, and require further research work. Studies on such transport phenomena are currently in progress, for example at the Fraunhofer Institut for Construction Physics in Holzkirchen, and these have produced interesting results but are not as yet complete. The final results will be presented when available by Dr. Kiessl and his staff, and can be used in future for the systematic setting of properties in the further development of repair mortars.

With their components of binders, aggregates particulary in the fine grain range and chemical additives, repair mortars form a complex system of mutually dependent constituents. The binders, pore formers, hydrophobic agents, water retaining agents and processing aids must not have an adverse effect on each other.

The hydrophobic agents used are as a rule metallic soaps, such as sodium oleate, calcium stearate, zinc stearate, etc.

FIG.2
Common hydrophobic agents



Common hydrophobic agents

The actual additive to be used depends on the system as a whole. Certain types react badly with some binders. Calcium hydroxide, for instance, which is added in small quantities to almost all mortars to improve machinability, can have highly disruptive effects.

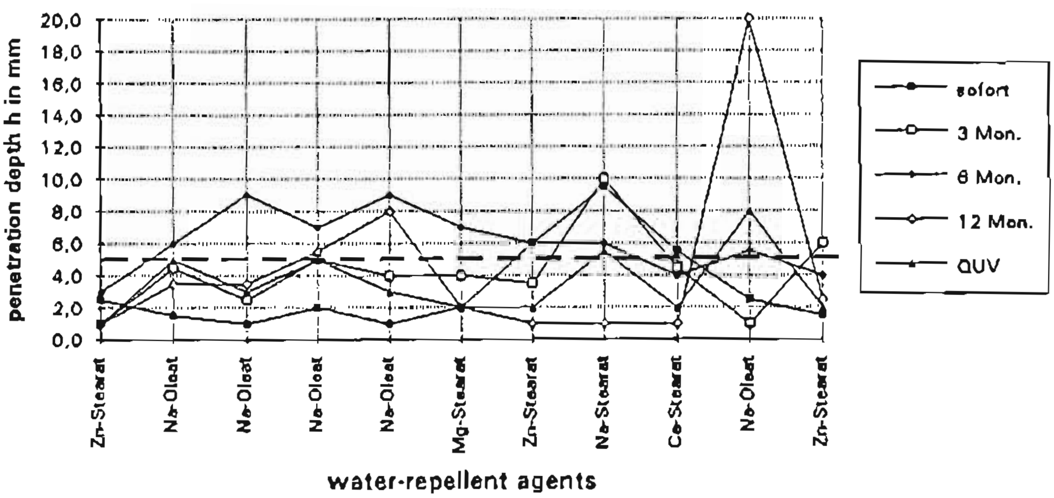
With some additives, also, the water-repellent properties develop late, or diminish very rapidly. Both these factors are disadvantageous to the durability of repair mortars. Too slow an establishment of water-repellent properties can, for example, lead to the permeation of salts at an early stage and the resulting damage. In contrast, a permature deterioration of water-repellent properties can allow salts to reach the surface of the mortar rapidly again, producing the familiar mortar damage there.

The important criteria are a rapid establishment of hydrophobia and long-term, continous water-repellence by the mortar: repair mortars should develop their waterrepellent properties as rapid as possible, in order to prevent penetration of salt solution deep into the mortar. If moisture enters the repair mortar at an early stage, salt is deposited in the capillaries and pores through which the moisture flows. The cross-sectional water-repellence of the repair mortar which is normally required is not established, and damp spots initially appear on the surface, followed by salt blooms, even after intermediate drying. It is therefore necessary to achieve an extensive drying of the repair mortar immediately after application, in oder to guarantee the capillary-hydrophobic properites of the mortar.

How do the effects of various water-repellent agents differ? Let us now consider a series of studies performed since 1993, in which the long-term effects of various hydrophobic agents from several manufacturers have been tested in different concentrations, in order to derive information for own recipes.The specimens were made up in the laboratory to a basic recipe and exposed to an industrial atmosphere, facing west. The specimen were examined after 28 days' storage, after 3, 6 and 12 months' exposed weathering, and after QUV-storage.

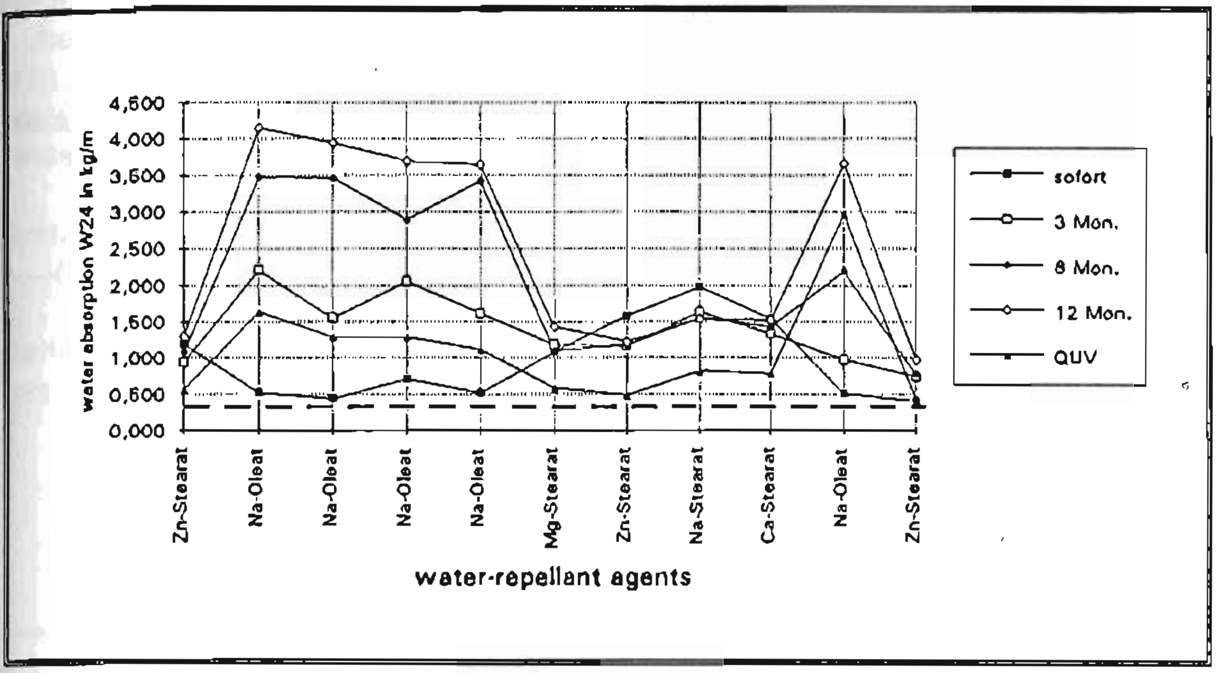
FIG. 3A

Efficiency of different water-repellent agents (water penetration depth h)



It can fundamentally be noted that sodium oleates achieve a very good early water repellence, but their hydrophobic properties diminish in the course of time from the surface inwards, as witnessed by the higher water absorption on long exposure. The hydrophobic effect throughout the cross-section is however not decisively impaired. With stearates, the situation is different: these exhibit weaker water-repellent properties at the start, but are significantly more durable and thus produce longer and more intensive water repellence at the surface.

FIG. 3B
Efficiency of different water-repellent agents (water absorption W_{24})



The results show that individual tests have to be performed for every recipe to determine which water-repellent agent will, in conjunction with the binder used, be as effective as the requirements of WTA specification 2-2-91 even after a period of years. Quick tests have not proven successful to date.

The action of the water-repellent agents has been studied by GORETZKI et al (1993) and KAISER et al (1995) using scanning electron microcopy. GORETZKI et al (1993) studied the distribution of zinc stearates in the mortar with SEM-EDX element distribution. They found a homogeneous distribution of the active substance. There are thus stearate deposits bringing about the water-repellent action of the mortar both on the surface of the air pores and on the walls of the capillary pores.

In the capillaries, these stearate coatings reduce the suction effect; in the air pores they hinder the confluence of surface films. Water droplets with high boundary angles of friction form via water-bearing capillaries (see KAISER et al,1995). As the water droplets dry, salts grow out through the capillaries.

3 SALT AND WATER INGRESS IN REPAIR MORTARS

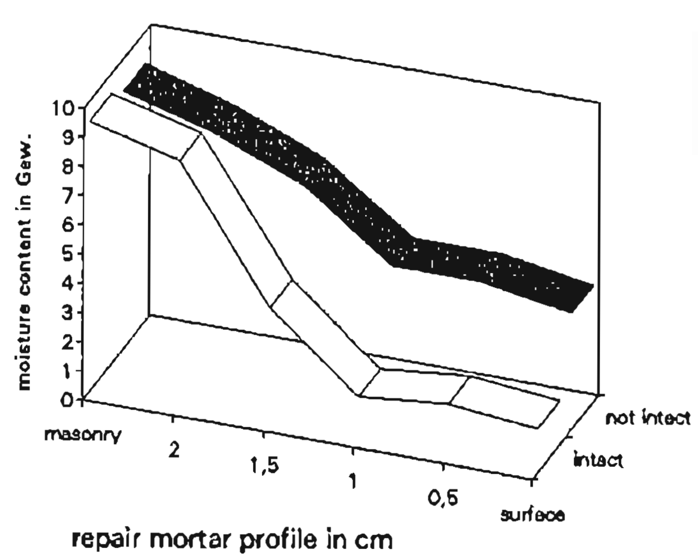
These experience values for moisture ingress determined from theory and laboratory experiments can now be demonstrated on the basis of two practical examples. The salt ingress rates and concentration profiles are also examined.

a) A residential building constructed around the turn of the century in Marktredwitz (renovated with repair mortar in 1978, approx. 17 years ago)

b) A backfilled wall of the Monastry in Waldsassen/Oberpfalz (renovated with repair mortar and other mortars in 1985, approx. 10 years ago)

The typical moisture profile for a repair mortar is presented in the first example. Nearly the whole area was in function ("intact"). Only at a few positions we found salts permeation to the surface ("not intact").

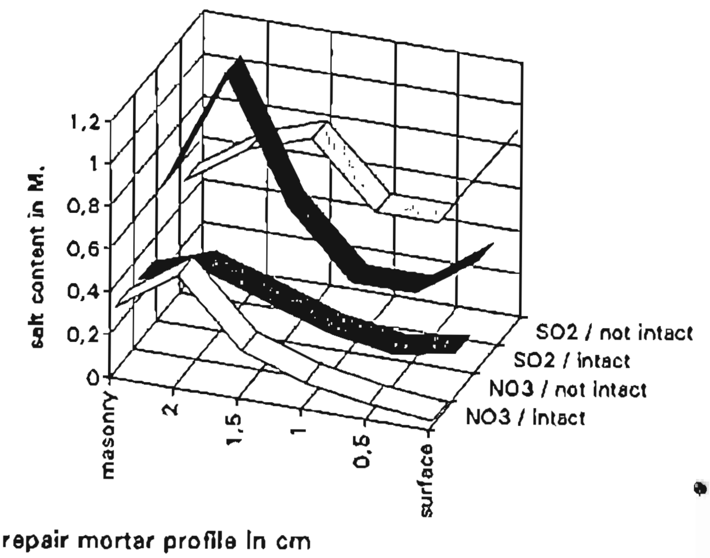
FIG, 4A
Moisture profile in repair mortars



This graphical presentation clearly shows the function of intact repair mortar: the damp is concentated on the inside of the mortar, and the surfaces are dry. Only when the repair mortar fails, for instance due to ageing, does the moisture at the surface increase. In this case, the moisture at the surface was increased by salt permeation.

Salts are transported by moisture (rising or circulating) in the masonry. It is not, therefore, surprising that the salt profile is parallel to the moisture profile. This is the salt profile for the repair mortar (approx. 2 cm thick).

FIG. 4B
Salt concentration profile in repair mortars



In parallel with these chemical analyses, scanning electron microscopy studies on the grain structure were performed by Dr. Goretzki at HAB, Weimar. These have already been published by DROLL & MEIER (1994) and GORETZKI et al (1993). No completely filled pores were ever found. The salts only grew into the air pores or into light aggregate particles - in this case perlite aggregates - at opened capillary pores. Presumably, the majority of the salts is fixed in the binder structure in the area of the capillary pores. See also publications by HILBERT et al (1992) and KAISER et al (1995).

As a further object, a wall in the Monastery in Waldsassen is presented. Here an extreme ingress of water and salts from the backfilling of the masonry has led to demages of the wall surface. During the renovation various mortars (two repair mortars, standard commercial trass/lime, lime/cement and lime mortars) were applicated and compared for around 10 years (optical inspections, sampling and chemical analysis of drill dust and drill cores).

Approximately the same phenomena were noted in the repair mortar as with the example presented earlier. The repair mortar surfaces are still in visually perfect condition. Other, adjacent surfaces with different mortars were in some cases seriously damaged after only six months. Now, all the non-repair mortars at the highly exposed zones are completely destroyed.

4 CONCLUSION

- When correctly applied, repair mortars function for decades. They create a dry, salt-free, undamaged surface, a mortar base for paint coatings open to water diffusion.

- The characteristic feature of repair mortars is reduced ingress of moisture and salts from the contact zone into the masonry. This is achieved by the two moisture-breaking formulation measures:
  -Incorporation of air pores to break the capillaries,
  -Water-repellent treatment of the mortar cross-section
  (matrix with air pores and capillary pores)
  and additional creation of salt retention areas.

- The water-repellent treatment of repair mortars is normally achieved by means of metallic soaps, as a rule stearates and oleates. Which metallic soaps are used depends on the mortar system with its binders, aggregates, fillers and other additives.

- The cross-sectional water repellence of repair mortars results from hydrophobic treatment of the air pore walls and capillary walls.

- The durability of repair mortars is dependent on the water-repellent treatment; water vapour diffusion is preserved, i.e. there is no build-up of moisture behind the repair mortar caused by a blocking of the structure by salts.

Repair mortars shift the salt crystallisation horizon from the masonry into the mortar itself.

- In a number of cases damage has occured when repair mortars have been used, but mostly at an early stage. In those cases, repair mortars were used in application for which they are not designed. The following rule should be followed in the use of repair mortars: Repair mortars combat the causes of damage in the form of water ingress from driving rain and water vapour from condensation, capillary condensation and hydroscopic moisture absorption.

Repair mortars do not solve rising damp and moisture migration in the masonry. The damage resulting from these causes can only be concealed. On overexposure, repair mortars can fail. Therefore, measures accompanying the repair mortar, such as the installation of a new damp course, functioning drains and water discharges etc., should where necessary be implemented as indicated by preliminary tests and the compilation of a suitable renovation plan.

5 LITERATURE

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