Water Repellent Treatment of Building Materials
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Paraffin Wax - An Ecological Water Repellent Agent

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Abstract

In the paper further developments in the area of injection methods by paraffin wax to improve the effectiveness, the safety and the reliability will be presented.

The works about the penetration techniques lead to a surface treatment by paraffin flooding. Paraffin flooding produces an absolutely waterproof surface inside and outside of buildings. The liquid paraffin is used for heating and penetration into the wall. The pump transports the liquid and hot paraffin to the top of the wall or to an area. The paraffin floods the surface, heats the wall and penetrates into the pores. The longer the flooding takes place, the more paraffin penetrates.

Results of experiments with brick and lime-sandstone to find the connection between the receptivity of the paraffin and the working temperature are shown. The aim is to find the appropriate paraffin wax for building up subsequent moisture barriers inside wall cross sections. The establishment of a moisture barrier takes place by means of a combined process of heating up the wall section and penetrating the paraffin through bore holes.

Keywords: paraffin wax, paraffin flooding, paraffin render, internal sealing, moisture barrier

1 Introduction

Building up subsequent moisture barriers belongs to the most difficult tasks in the area of building reconstruction. The barrier has to be placed in foundation walls, which are decisive for the buildings stability. Because this problem can't be solved with simple structural methods, there exist several strategies with different modes of operation and results. Besides mechanical and electrical methods, above all injection methods are used. The damaging moisture transport in porous building materials takes place in pores and capillaries, in micrometer size. That is the reason for injecting a pore-sealing or water repellent material. If the pores and capillaries are sealed or treated with a water repellent agent, no moisture can be transported and the treated area operates as a moisture barrier. To realise these moisture barriers, the injection medium has to be brought into the walls in a way which assures that the whole wall cross-section is affected. This is done by boring holes with distances of 10 cm up to 12 cm into the wall. The depth of the bore holes should be compatible with the wall's strength. The injection medium is poured into the holes with or without pressure. Methods not using pressure the capillary forces distribute the injection medium inside the building material. This process is accelerated by external pressure using pressure injection.

The injection methods mainly differ through the used injection medium. Silicates, water glass mixes, silicones, silanes and stearates serve as water repellent substances. By means of several effects, for example vaporisation of solvents, reaction with carbon dioxide or moisture at low alkalinity, the silicon resin molecules form a chain and the water repelling silicon resin covers the pore walls. If the pores are filled with water or if there is not enough moisture, if not enough solvent diffuses to the outside or not enough carbon dioxide diffuses to the inside of the massive and wet wall, the water repellent effects of the mentioned methods will decrease or not appear.

As pore-sealing substances cement suspensions, resins and paraffin are used in common. Cement suspensions and resins are generally penetrated into the wall under pressure. This is necessary because after producing or mixing these substances the hardening process starts after a so called pot-time and the mediums have to fill the pore space before. Furthermore, these materials can not be transported sufficiently through the capillaries because of their high viscosity. Therefore pressure is required.

Using paraffin as a pore-sealing substance, many of the above mentioned problems can be solved. Liquid paraffin is able to penetrate by means of capillary forces or pressure support. Therefore the treated wall has to be warmed up to a temperature above the melting-point of paraffin before or while the treatment takes place. Due to this heating process the moisture vaporises and the moisture-damaged masonry becomes dry. Thus the pore space will be free from moisture and filled and sealed with the heated paraffin.

2 About the Developments of Using Paraffin Waxes for Protection and Rehabilitation of Buildings

Paraffin Wax using is an old and well known possibility to protect and rehabilitate moisture damaged buildings. In this paper rehabilitation measures based on paraffin are presented.

The papers [1-3] specified the principal function of a subsequent moisture barrier in walls. If the material warm enough before or while the treatment takes place, the liquid paraffin fills the pores completely. Many buildings show the success of a thermal inducted filling of the pores with paraffin.

Historical measurements with paraffin wax are known from the beginning of our century [4,5]. The paraffin wax was applied only on the surface of the stone. A moisture transfer or diffusion was impossible within small areas, a state which should be avoided for building elements. This paper only presented possibilities of a complete filling of the material or the surface area with paraffin. Current research is focusing on a surface treatment by paraffin flooding. The mechanisms for the surface damage are excluded.

It is known that in the USA in the 1970's paraffin wax was used for internal sealed concrete [6]. Bridge decks have been treated with a montan wax blend. In all cases the internal sealing with the blend was claimed to be completely effective. The same analysis took place in the 1980's in the FRG about special methods to improve the frost/de-icing salt resistance of non-air-entrained concrete [7]. The addition of paraffin/montan wax and a subsequent heat treatment of the hardened concrete produced a high resistance against frost/de-icing salt attacks.

Intensive investigations for the application of paraffin wax as a building protection agent also took place in the former GDR [8,9]. Waterproofed, frost resistant and durable prefabricated units with different strengths are produced from concrete. Crack formation, shrinkage and water absorption are clearly reduced.

There are two different ways to produce a waterproof building material. With the first method, paraffin or montan wax beads are part of the crude concrete with 3 and more percent by weight and the treatment is carried out by an later heating. In the restoration or retrofitting of moisture damaged constructions, the liquid paraffin must be poured into the pores. With the second method in cases by injection, by special render with an addition of paraffin for wall surfaces or by paraffin flooding over wall surfaces.

Paraffin chemistry can't be described in the paper in a serious way, because there are too many interesting facts; basics can be found in [10]. The History of using waxes in any kind is comprehensively illustrated in [11].

For applications of paraffin, the fact that paraffin is compatible with the building material and the environment, plays a major role.

3 Technical Possibilities for Thermally Stimulated Penetration of Paraffin in Building Constructions by Injection Methods

Paraffin injection is carried out in the following way: heating sticks are introduced into the bore holes and after a sufficient drying and warming up of the masonry, the paraffin is filled in. Simple technologies work with cans and storage containers. The capillary forces then secure the distribution. It is also possible to accelerate the distribution of paraffin under pressure by using pressure aggregates. The sufficient warming of the masonry is important for these methods lest the paraffin stiffens during the penetration process.

By the help of this intensive heating process relatively big quantities of paraffin can penetrate into the construction. The penetrating volume is comparable with the volume of the pore space. This fact confirms and indicates the high degree of pore filling.

Important for the technical application is the velocity of penetration of paraffin in buildings materials. The velocity is determined by the capillary forces and the friction resistance of the capillary system. The paraffin pene-

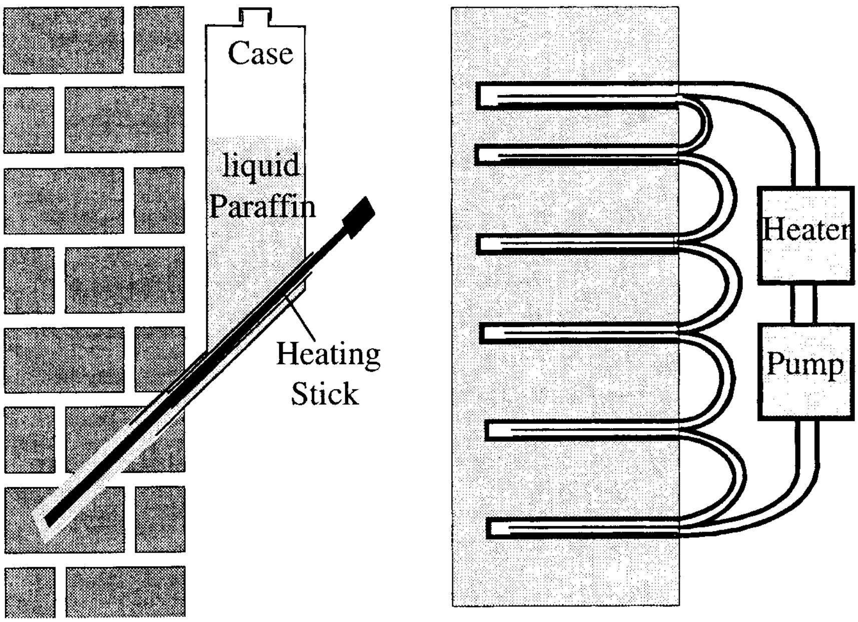

Figure 1: Left side is to be seen the Injection with a Paraffin case, on the right side constant Paraffin penetration with a pump

tration coefficients which are measured for bricks and limestone in chapter 3 describes the interaction of this two forces. If we use the results of this measurement we can calculate the penetration of paraffin around a bore hole to estimate the treatment time and especially the heating period.

The flux of melting paraffin which penetrates in the inner surface of a bore hole is described by eq. (1)

$$g_{paraffin} = \frac{w_{paraffin} \cdot 2 \cdot \pi \cdot r_{borehole} \cdot l_{borehole}}{2 \cdot \sqrt{t}} \qquad (1)$$

where:

$g_{paraffin}$	nass flux of paraffin per time
$w_{paraffin}$	paraffin absorption coefficient
$r_{borehole}$	radius
$l_{borehole}$	length
t	time.

Equation (1) describes the one dimensional distribution in probes of building materials. Nevertheless the penetration takes place in a system of capillaries and pores in all directions, so that the equation can be used for this case, too. In a time period Δt the paraffin penetrates in form of the mass flux $g_{paraffin}$ from the inner surface of the bore hole in radial direction in the construction. The depth of the front of penetration grows in this time period by the local distance Δz.

$$\Delta z = \frac{w \cdot r_{borehole} \cdot \Delta t}{2 \cdot \rho_{praffin} \cdot \Phi_{paraffin} \cdot (r_{borehole} + z)} \tag{2}$$

where,

ι	depth of penetration
Δz	depth distance of penetration in a time period Δt
$\Phi_{paraffin}$	paraffin storage capacity

By using an appropriate software the penetration depth can be estimated step by step by eq. (2). The figure (2) shows a result of this calculation. The graphs in figure (2) describe several cases. They reflect the influence of the diameter of the bore hole, the temperature of the melting point and working temperature of penetration.

The figure (2) shows clearly that the diameter of the bore hole determines the amount of paraffin which penetrates into the construction. If a small diameter is used the velocity of the penetration front is small and a long treatment time is necessary. If a big diameter for the bore hole is chosen the velocity is higher and the treatment time is shorter. Very important is the influence of the temperature of the melting point and the working temperature. The viscosity of the melted paraffin is low if a kind of paraffin with a low melting point, for example 50 °C, and a high working temperature, for example 150 °C, is used. In this case the velocity of the penetration front is high.

In the opposite case, if a paraffin with a high melting point from 95°C and a low working temperature of 110°C is used, the velocity of the penetration front is low and a long time period is necessary for a injection process to build up a water proof layer in the construction. If the distance between the bore holes is 12 cm for instance and the radius of the bore hole 2 cm, the depth of the penetration must be 5 cm to move the fronts of penetration together. The figure (2) indicates that a meeting of penetration fronts between the bore holes in the optimum case is possible after 2 hours. This is impossi-

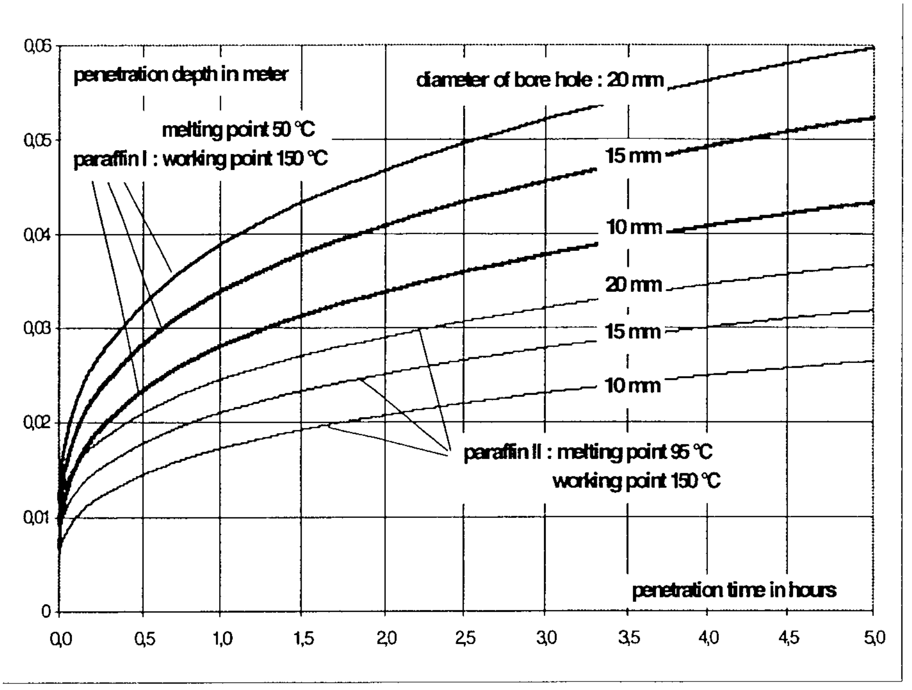

Figure 2: Penetration depth versus time for 2 different paraffin's, depending on the diameter of the bore hole

ble if a non-appropriate paraffin and a low working temperature were chosen.

4 Capillary Transport Characteristics

The penetration of paraffin into the pores without pressure and only by capillary forces is a complex process. The following aspects have to be taken into consideration:

- The paraffin characteristics, meanly the congealing/melting point and the viscosity, directly depending on the temperature. The influence is shown in the following Figure 3. A higher absorption coefficient is to achieve with a lower congealing point. The first two type numbers reflect the congealing point. A lower viscosity (type 7000 higher con-

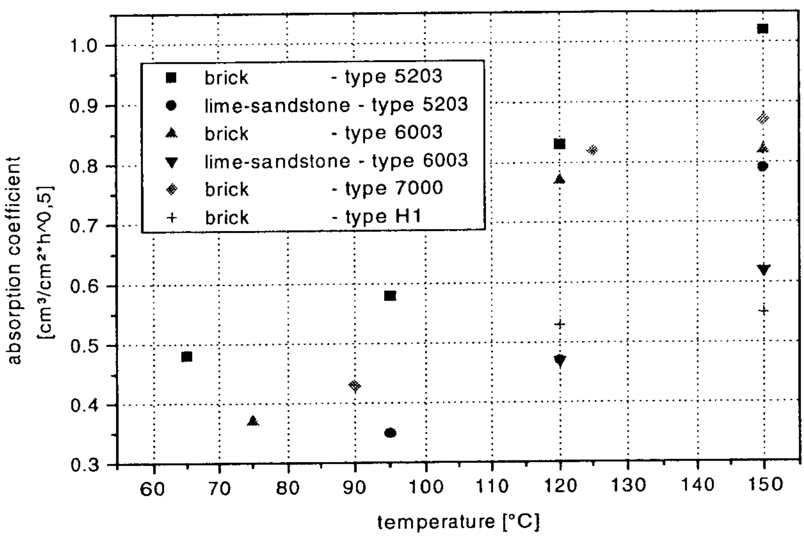

Figure 3: Arrangement of the water absorption coefficients at different temperatures for brick and lime-sandstone

gealing point / lower viscosity then 6003) can compensate a higher congealing point.:

- The working temperature of the paraffin and the material temperature determine the penetration. In principle a higher working temperature is linked with a higher absorption coefficient.
- The specific material characteristics are also shown by Fig. 3. The absorption coefficients for bricks are higher than for lime-sandstone. It's interesting, that the coefficient difference between 120 °C and 150 °C is higher for lime-sandstone than for brick. The reason is unknown at the moment.
- The influence of wall characteristics (cavity's, cracks etc.) are not tested in the laboratory. This has to be taken into account for practical applications. Different penetration methods for the paraffin are available.

5 Production of Water Proof Render by Paraffin Treatment

For many tasks and aims a water proof render is necessary, e.g. for underground building constructions, drink water tanks, waste water tasks and channels and so on. A normal render system is not sufficient in this case. Several kinds of water proof render systems exist, which are developed for this case with several advantages and disadvantages.

The use of paraffin as a material to produce a water proof layer at the surface of constructions has the advantage, that paraffin is able to close the volume of all pores in building materials.

To produce a water proof range in a building construction several possibilities are available. At first sight warming up processes by a hot air flow or by flames seem to be useful. If the temperature is high enough in the area, to be penetrated, the paraffin can be brought to the surface by spraying, flooding or brushing. An analyses of this technique shows a row of difficulties. The heating process is a slow process and needs time. Therefore the heater system must be an adapt device and working by hand is not possible. The same is valid for the penetration process. For a sufficient depth of penetration and a complete filling of pores a determined amount of paraffin is necessary. The penetration velocity is low and the treatment time must be relatively long.

A second method was investigated in our laboratory. A paraffin granulate render system was used. The granulate was mixed to a normal render and the render was placed at the wall. When the render is hardened sufficiently, the distributed paraffin granulate is melted by the help of a heating process. Several heating systems have been tested. Figure (4-A) shows a system which works with a hot air flow along the surface, and in figure (4-B) a electrical heater system inside the render is shown. Furthermore, warming up processes by flames and by radiation have been tested. Table 1 gives an overview about the methods, the depth of penetration and the required power of the heating systems.

Table 1 shows several very different results. These are the effects of the technical realisation of the different systems, e.g. the transfer of the power from the heater to the render and the energy loss. By use of radiation, flames or hot air flow sufficiently large areas can be warmed up, but a high power for the heater is necessary, because the heat is produced at the surface of the construction and several energy losses exist. A heating plane inside the ren-

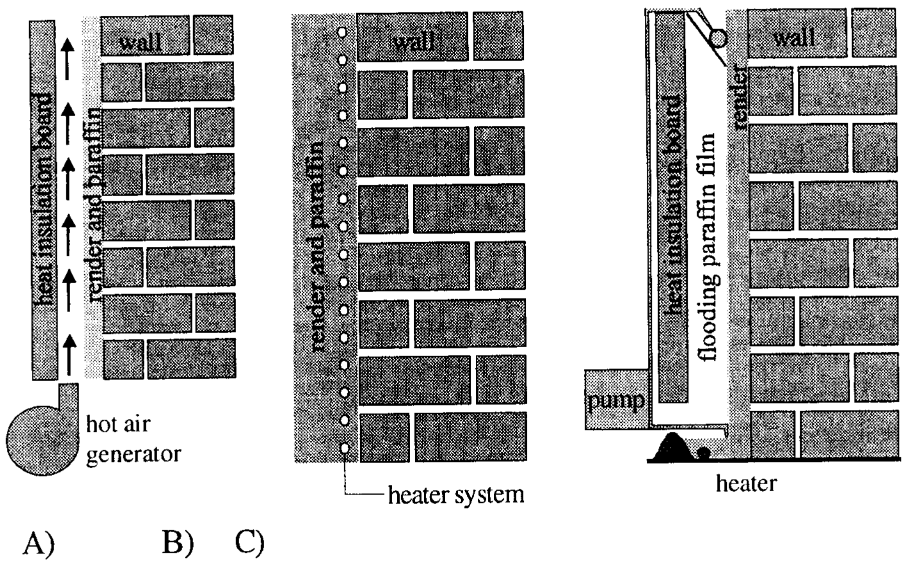

Figure 4: Generation of watertight render by paraffin treatment by using hot air (A), electric heater (B) or flooding paraffin film (C)

der like a grid is very economical because only a small energy demand exists. The heat is produced inside the render and the losses are small. The disadvantage is the handling of an electrical heater system in the process of fixing the render at the surface.

An especially effectual method is the treatment of surfaces of building constructions with flooding of hot paraffin. If a sufficiently large amount of paraffin is sprayed at the surface, so that the paraffin film runs down along the surface, the hot paraffin warms up the material and penetrates into the material in the same time. The paraffin which runs off the surface can run in a circulation from a heater container to the surface and back to the heat container.

Figure (4-C) shows a device to realise this method. This system achieve best results of warming up the construction and penetration. Furthermore, power demand is lower and the control of the progress of the treatment is easier then with other methods.

Tabelle 1: *Tab. 1:* Application of methods working with Paraffin Granulate Render and depth of penetration by flooding a Paraffin film

Method	area with a temperature higher then 60 °C after 1,5	area with a temperature higher then 60 °C after 3 h	Power of the heater system
Hot Air Flow	4 cm	7 cm	9000 W / m^2
Flame	4 cm	7 cm	5000 W / m^2
Radiation	5 cm	8 cm	3000 W / m^2
Heating plane	1 cm	4 cm	1000 W / m^2
Flooding Paraffin	8 cm	14 cm	500 W / m^2

6 The Using of Emulsions from Paraffin Wax

Wax emulsions will be further tested for coatings in the future. A tight and sealing wax emulsion film can be developed without thermal induction, because the emulsion is liquid at a normal climate. Different viscosity's are possible. A heating system is only needed for the penetration of the wax into the upper surface and/or for the destroying of the emulsifying agent. Different systems are known for the using of wax emulsions from the anti-graffiti protection [12].

Wax emulsions inherent several advantages for practical applications:

- simple handling
  Wax emulsion can be applied by spraying, brushing and flooding. By flooding the emulsion over the surface much more agent can penetrate into the surface than by brushing or spraying. The technical equipment consist only of a few instruments and can be used again for other applications.
- higher safety
  If using a heat treatment the penetrated paraffin from the emulsion is visible and this is a very short process. More then one application is possible. The application amount depends on the porosity of

the material.

- application on any porous medium
  An emulsion with a droplet size smaller than the diameter of capillaries must used. A possibility for destroying the emulsifying agent is necessary. This can be a special brushing, different rays (micro waves, UV) or a low heat treatment. Is the droplet smaller (< 1 μm) than the capillary active pores (up to 10 μm), the emulsifying agent and the droplet fill the pores. The agent is in the pores and capillaries. If the droplets have the same size as the pores (ca. 10 μm), a good adhesion and no filling of pores take place. With the last possibility, the diameter of the droplet is higher (> 10 μm) than the pores, only the emulsifying agent fills the pores. A poor adhesion takes place and the droplet remains loose on top of the surface. The filling of the pores with paraffin takes place by a heat treatment.
- working over the head
  By using paraffin wax emulsions with a high viscosity at normal temperature or a paraffin creme working on the down side of bridges, under roofs or under other difficult conditions is no problem.

When emulsions (or paraffin waxes) evaporate, a paraffin film lays down on the surface of the capillaries. The water vapour can diffuse through the pores.

For waterproof surfaces one has to use other possibilities, like paraffin flooding. The mean characteristics of the emulsion the same as for pure paraffin: compatible with the building material and the environment.

7 Concluding Remarks

For different problems various techniques of a paraffin treatment are necessary. With the using of an appropriate paraffin, every damaging process caused by moisture is repairable. In the same way every building material can be protected with paraffin. The application is durable and ecological, and a demolished building produces no dangerous remains.

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