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Influence of Concrete Quality, its Age and Moisture Content, on the Penetration Depth of Water Repellent Agents

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Abstract

Differences in boundary conditions strongly influence the effectiveness of a water repellent treatment. In the case of real buildings these boundary conditions always occur simultaneously and, in spite of extensive preliminary testing, cannot be distinguished individually. Through laboratory testing the influence of the individual parameters on the effectiveness of a water repellent treatment could be shown. The results obtained provide information on the influence of concrete quality, permissible moisture conditions and the minimum age of the concrete to be treated.

Keywords: effectiveness of a water repellent treatment, concrete quality, permissible moisture conditions, minimum age

1 Introduction

The performance of a water repellent treatment depends on various factors [1]. These factors can be divided into parameters of choice and specific local boundary conditions. The parameters of choice are:

- Selection of the product
- Application technique
- Pretreatment
- Subsequent treatment

The boundary conditions are

- Concrete quality
- Moisture conditions in the background
- Concrete age
- Climatic conditions at the time of application

Concrete quality and concrete age can only be influenced at the time of construction planning. For the enterprise that is to apply the water repellent treatment these factors are set.

In the context of extensive preliminary investigations the water uptake has been measured at different points on concrete walls of three different tunnels [2]. The aim of these preliminary investigations was the *in situ* determination of the possible penetration depth of a water repellent treatment. These investigations showed that each of the boundary conditions mentioned above influences the depth of penetration. Since for real buildings these factors act simultaneously, it was not possible to distinguish the influence of the individual factor.

In subsequent laboratory tests each of the boundary conditions, i.e. concrete quality, moisture conditions and concrete age, were analyzed seperately in order to determine their influence on the performance.

2 Experimental

2.1 Concrete quality

In a first experiment a pure liquid silane (100%) was sprayed wet-on-wet onto the sample in a single application in order to determine the penetration depth as function of the w/c ratio. The penetration depths are represented in Figure 1.

In a second experiment an in-depth water repellent treatment was carried out, where specimens were completely immersed into 100% liquid silane for 2-hours. The specimens used had reached their equilibrium humidities at two different conditions: 60% R.H. corresponding to the average summer humidity, and 90% R.H.

corresponding to autumn or winter average humidity in the Swiss midland. The results are shown in figure 2

The quality of the cement binder also strongly influences the quality of concrete. Therefore, a third experiment was carried out using mortar cubes with three different types of cement. These were: White cement (C_4AF-concentration < 1%), HS cement (C_3A-concentration < 2%); and, ordinary portland cement. The results are shown in figure 3.

The w/c ratio in all samples is w/c = 0.50, the cement content is Z = 500 kg/m^3. The applications were as follows:

- 2 times conventional impregnation (wet-on-wet, airless, 100% silane);
- in-depth water repellent treatment (15-min contact, 100% silane);
- water repellent treatment using a viscous paste (300 g/m2, 80% silane);
- water repellent treatment with a viscous product based on silane mixed with bentonite (1000 g/m^2, about 70% silane)

2.2 Moisture conditions

A fourth experiment used mortar wafers with a thickness of 15-mm (w/c = 0.35 to 0.55, cement content Z = 500 kg/m^3) have immediately after the production been put into different conditionings until weight constancy. The different relatiive humidities to which the specimens were exposed before treatment were: 100 %, 93 %, 85 %, 75 %, 54 %, 18 %, ~ 0 %.

After treatment, the mortar wafers were returned to the conditioning climates for the water repellent film to form. After 14 days their surfaces were plunged into water during 28 days, in order to test the effectiveness of the water repellent treatment. For each combination of w/c-ratio and conditioning climate 3 specimens were examined. The number of specimens, for which the water repellent treatment had failed, i.e. 0, 1, 2 or all, was determined. For this purpose, a water repellent treatment was considered as failing, if water uptake of the specimen exceeded the average of the well treated samples by more than 20%.

Figures 4 and 5 show the number of failures after 24-h and 28-d respectively, differentiated regarding their w/c ratios. Figure 6 shows the ratio of failures to the total number of samples differentiated with regards to their moisture content.

2.3 Concrete age

In literature a minimum age of 28 days [3], [4] sometimes even of 3 months [5] or more is required before a water repellent treatment is applied. This demand is justified as follows. The pores of young concrete are nearly completely filled with liquid, so that the water repellent treatment cannot penetrate. The hydration reaction is still intensively taking place during the first days and even weeks after production. If a water repellent treatment is applied too early, hydration products formed thereafter can cover the silicone resin film, which could lead to a loss of the hydrophobic effect.

As shown in the preceding experiments, when conditioning at high relative humidities a strong saturation of the pores obstructs the penetration of the water repellent treatment. This obstruction occurs regardless of whether the pores are saturated due to high air humidities, recent production or weathering.

In order to confirm loss of hydrophobic effect due to the ongoing formation of hydration products, thin mortar wafers (with a 15-mm thickness) were manufactured. These reach their equilibrium humidity within a few days. The wafers were impregnated at different times. The first samples were impregnated only two days after production, while the last ones were impregnated half a year later. After treatment the samples were stored for 28-days in water in order to check the effectiveness and to compare the results with those of reference samples. The results are represented in figure 7.

3 Results .

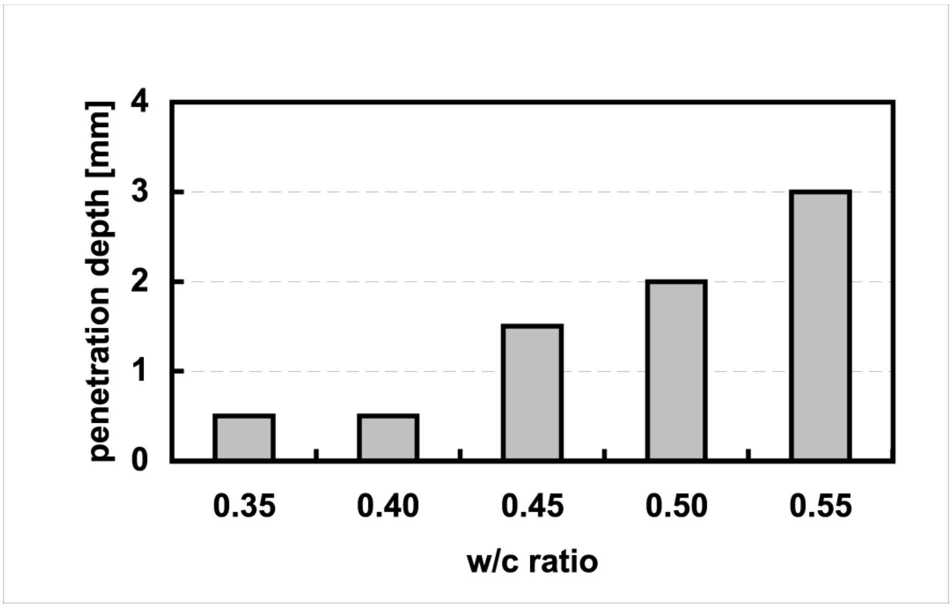

Figure 1: 1st Experiment: penetration depth x as a function of w/c ratio (conventional water repellent treatment)

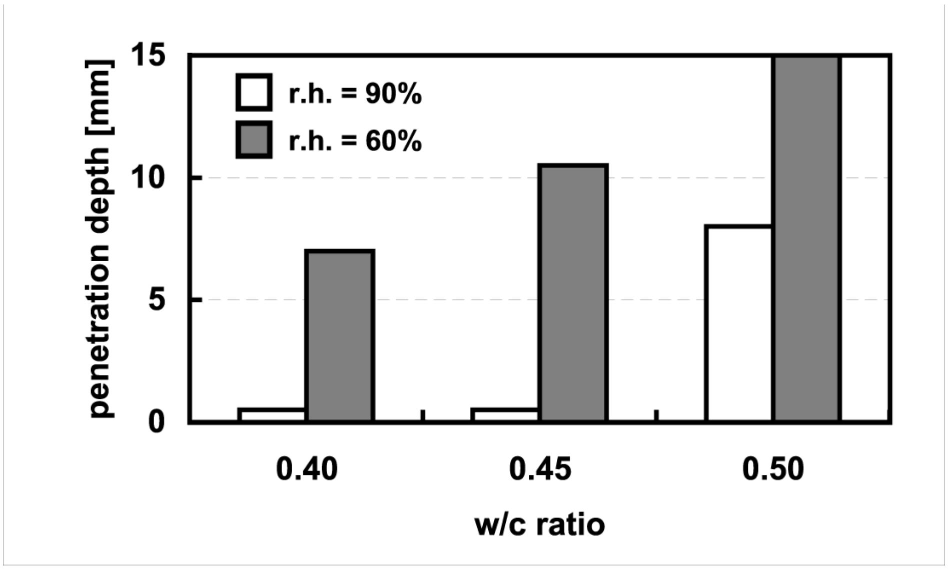

Figure 2: 2nd experience: penetration depth x as a function of w/c ratio and the humidity (in depth water repellent treatment)

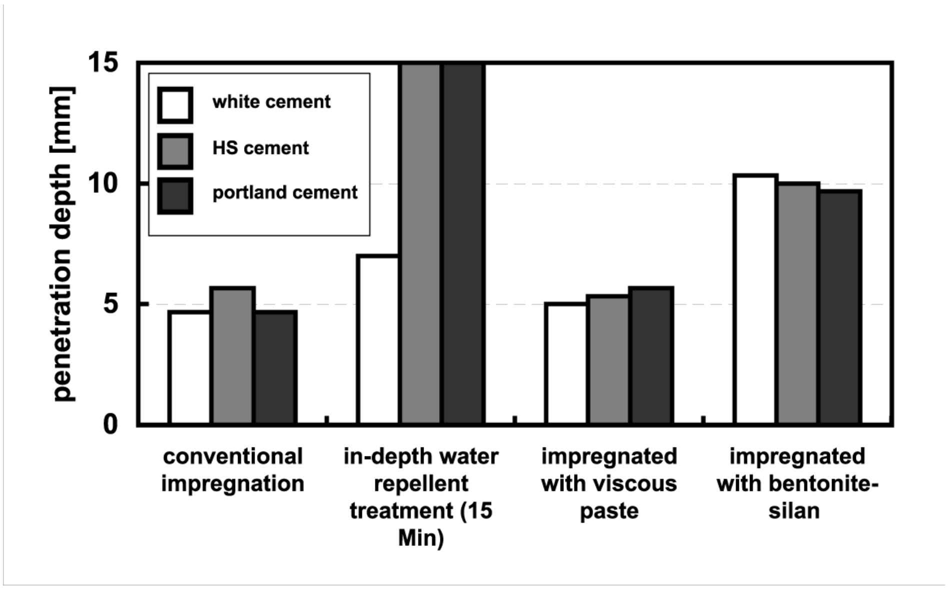

Figure 3: 3rd Experiment: penetration depth x as a function of the cement type and the application technique

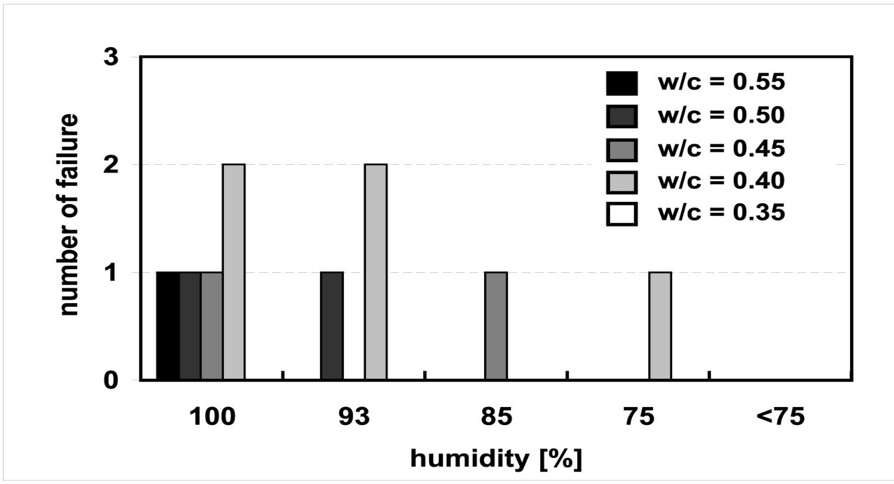

Figure 4: 4th Experiment: number of failures after water contact during 24h as a function of the w/c ratio and conditioning humidity

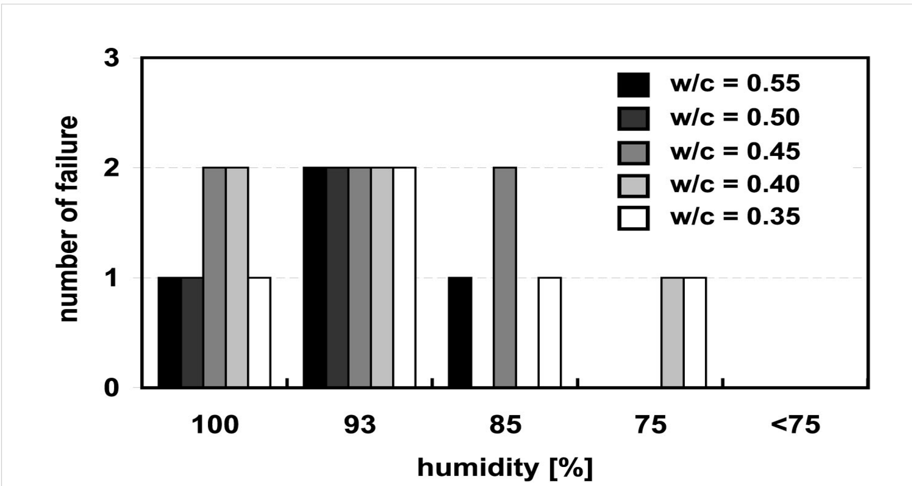

Figure 5: 4th Experiment: number of failures after water contact during 28d as a function of the w/c ratio and conditioning humidity

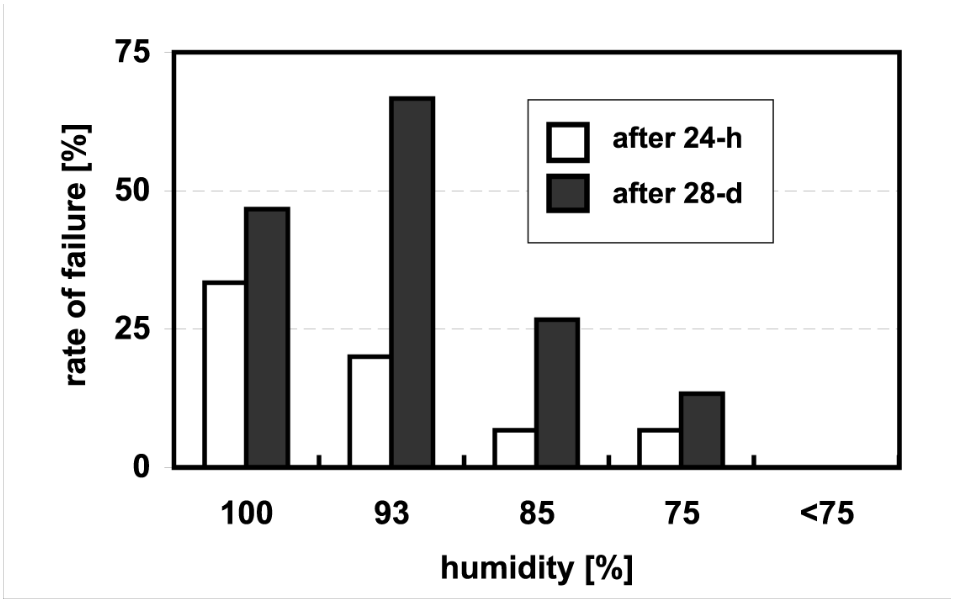

Figure 6: 4th Experiment: percentual ratio of failures after water contact during 24h and 28d as a function of the w/c ratio and the conditioning humidity

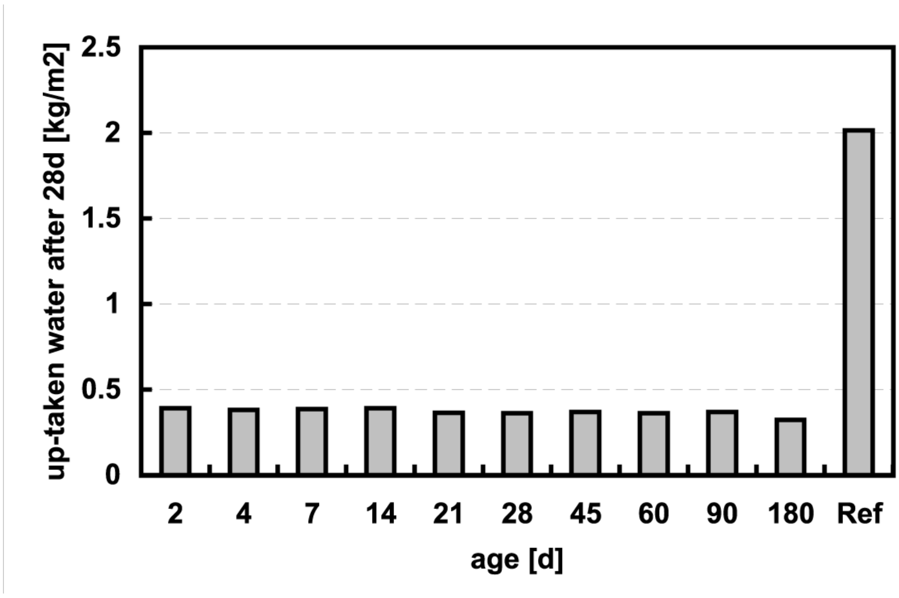

Figure 7: 5th Experiment: Water up-take after water-contact of 28d as a function of the age of the wafers when treated.

4 Conclusions

The first two experiments show that the w/c ratio can have a important influence on the penetration depth. Concrete with low w/c ratio (<= 0.40) can hardly be impregnated through conventional application (wet-on-wet, single application). The lower the w/c ratio, the more important is the influence of humidity. Pore radii of concrete with low w/c ratios are smaller than those of concrete with high w/c ratios. Due to capillary condensation these capillaries tend to be saturated even at lower humidities.

The cement type does not have a strong influence on the effective penetration depth. Only for an in-depth water repellent treatment with a contact time of 2h applied to mortar with white cement binder the penetration depth is significantly smaller than for mortar prepared with other types of cement.

The results in Figures 4 to 6 show that careful attention must be paid to moisture conditions of the underground concrete. Storage in water during 28 days after the application of a water repellent treatment leads in all cases, i.e. for all concrete qualities and w/c ratios, to an poor performance of the water repellent treatment. In particular relative humidities of 85% and above lead to an unreliable performance. Only for environments with relative humidities of 54% and lower, did the water repellent treatments prove always successful.

Thus if a building is in the equilibrium with a relatively high environmental humidity, special attention must be given to the selection of the application method and the performance check. Sometimes it is necessary to dry the underground surface before the application of a water repellent treatment.

The results of the fifth experiment allow to conclude that, in case the pores are already sufficient free of water, young concrete can be just as successfully impregnated as older concrete. Eventually a water repellent treatment initiates a drying process in the surface zone, which reduces or even stops the hydration in this area. As hydration is prevented, the concrete remains very porous. Firmness does not increase, so that the resistance against carbonation and the formation of cracks due to thermal or hygral deformation remain quite low.

Thus a water repellent treatment can be successfully applied to a young concrete, if the saturation of the pores is low enough. However in accordance with the considerations noted above it is preferable to postpone the application of a water repellent treatment as long as possible, in order minimize its impact on the hydration process.

5 References

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