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Application of Natural Products to make Integral Water Repellent Concrete

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Abstract

A number of natural organic materials, such as wax, oil or fat has been used to impregnate porous building materials for thousands of years. During the long history of construction with mineral binders natural products such as egg white and animal blood have been added to the fresh mix of mortar and concrete to produce integral water repellent materials. The aim of the project presented in this contribution is to investigate the influence of addition of oxblood to the fresh mix of concrete on capillary suction of the hardened product and on chloride penetration. Conventional concrete with a water-cement ratio of o.5 has been prepared with addition of different amounts of ox blood. First it will be shown that capillary suction can be reduced significantly. In this way frost resistance and durability in direct contact with water can be improved. As a second step chloride penetration into this integral water repellent concrete has been determined. It was found that chloride penetration is slowed down considerably as compared to penetration of chloride into neat concrete. It will be shown that use of ox blood as a water repellent agent for concrete is an economical and at the same time an ecological technology to extend service life of reinforced concrete structures in aggressive environment.

Keywords: integral water repellent concrete, animal blood, capillary absorption, chloride penetration

1 Introduction

Surface impregnation of concrete and other cement-based materials with liquid silane is by now a well established technology to avoid capillary absorption of water and salt solutions and to slow down the rate of chloride penetration significantly. In this way service life of reinforced concrete structures in marine environment or in frequent contact with de-icing salt solutions can be extended considerably [1, 2]. This beneficial effect is not yet taken into consideration adequately by most methods for service life prediction. An alternative method, i.e. integral water repellent treatment of concrete, has not been investigated to the same extend as surface impregnation up to now although in some practical applications it would be advantageous if not necessary.

Nowadays silane emulsion and other silane-based products are successfully applied for the production of integral water repellent mortars and concrete [3-5]. Metal soaps are also used for special applications [6, 7]. In the thousands of years old history of production and use of mineral binders in construction a great number of natural products have been applied to reduce capillary absorption, to minimize maintenance and to extend service life of structural elements. Wax oil and fat have been used to impregnate the surface of natural stones, mortars and concrete. Oil has also been added to the fresh mix in order to obtain integral water repellent mortar and concrete. In the Roman Empire huge aqueducts have been built to provide enough fresh water for the population in the big cities. Many of these impressive constructions could not have fulfilled their task without integral water repellent mortars, used as coating for the water channels. Red Indians of Middle America added the juice of a special cactus to fresh mortar to make it water repellent and more durable. Many more natural organic materials have been applied.

In historical records one finds also notes on the use of animal blood in water constructions. More recently a few papers reported promising properties of concrete and mortars with oxblood added [8]. A US Patent describes the use of oxblood as air entraining agent [9]. Increased frost resistance of concrete made with oxblood is also mentioned in the literature.

In this contribution oxblood has been added to the fresh mix of concrete. The aim of these test series was to find out if oxblood will reduce capillary absorption of water and salt containing solutions and if the rate of chloride penetration into concrete can be reduced. If this is the case, use of oxblood may lead to more durable constructions and to increased service life in an ecological way.

2 Experimental

A standard concrete with water-cement ratio of 0.5 has been prepared as a basis and reference material for this project. The detailed composition of the concrete is given in Table 1. To the basic mix 5 % and 10 % oxblood, related to the amount of mixing water, has been added.

Table 1: Composition of plain concrete given as kg/m^3

Components	Cement	Gravel	Sand	Water	W/C
Mass/volume	320	1267	653	160	0.5

From the neat reference concrete and the concrete with oxblood added cubes with an edge length of 100 mm have been cast in steel forms. After 24 hours curing under wet burlap the cubes were unformed and placed in a humid room (T=20 °C; RH>95 %) until the age of 28 days. At an age of 28 days the cubes were cut into two halves with a diamond saw. The half cubes were then dried in a ventilated oven at 50 °C until constant weight had been reached. Then the smaller side surfaces (50 x 100 mm) were sealed with wax. Now the blocks were ready for absorption tests. The surface which was in contact with the steel form during hardening has been put in contact with water and the weight gain was measured in regular intervals for 72 hours.

3 Results and discussion

3.1 Compressive strength

First the compressive strength of the reference concrete and of the concrete containing oxblood has been determined. Results are compiled in Table 2. Obviously strength is reduced by the addition of oxblood. There are at least three major reasons for this effect. Oxblood contains a substantial amount of water, which means that the effective water-cement ratio increases. The aerating function of oxblood further reduces strength and finally the presence of many organic compounds in the mixing water influences the rate of hydration of Portland cement.

Table 2: Compressive strength of neat reference concrete and of concrete containing 5 % and 10 % of oxblood

Oxblood added, %	0	5	10
Compr. Strength, N/mm^2	47.6	19.9	15.3
Compr. Strength, %	100	41.8	32.1

3.2 Capillary absorption

The capillary absorption of water by the reference concrete and by the integral water repellent concrete made with oxblood has been determined experimentally. The amount of water absorbed by capillarity has been plotted as function of square root of time as usual. Results obtained are shown in Fig. 1. Each value plotted in Fig. 1 is the average of four independent measurements. During the initial phase of capillary absorption the mass gain of the specimens can be approximated by a linear function. The inclination of the straight line through the origin is called coefficient of initial capillary absorption A_i. Values of A_i as obtained from the data shown in Fig.1 are presented in Table 3.

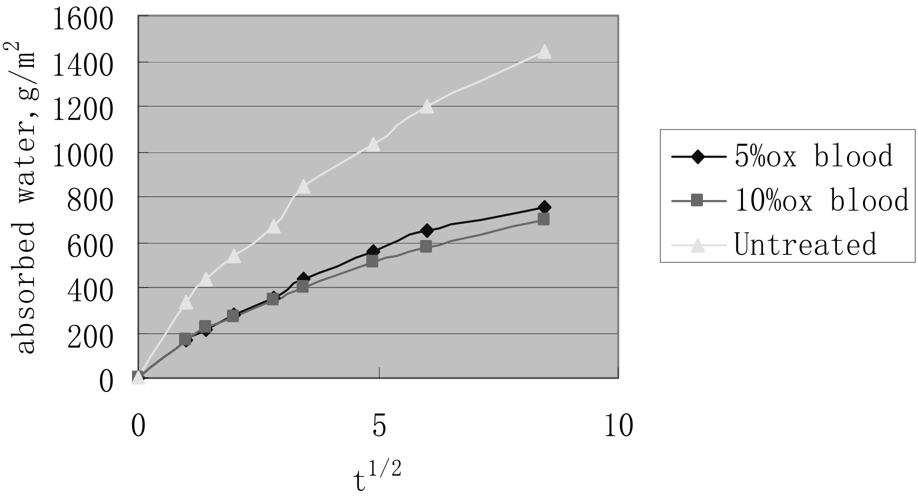

Figure 1: Capillary absorbed water by neat concrete and concrete containing 5 % and 10 % oxblood respectively as function of square root of time

On concrete treated with silane emulsion it has been observed that the water repellent agent was enriched in the surface near zone [4]. A similar effect has been observed on concrete made integral water repellent with metal soaps [6]. For this reason slices with a thickness of 5 mm, 10 mm and 40 mm have been cut from the surface though which the water was absorbed. It turned out that more water has been absorbed by both the neat and the integral water repellent concrete after the surface near zone with a thickness of 5 mm had been cut off. But no significant change could be observed after removal of layers with 15 mm and 40 mm. Results obtained after removal of the second layer are shown in Fig. 2 as an example.

The big difference between the cast surface and the cut surfaces can be explained partly by an enrichment of the water repellent agent i.e. oxblood, but as the neat concrete also absorbs significantly more water after removal of the surface near zone it is possible that the small amount of oil from the steel forms reduced generally capillary absorption of the surface near zone.

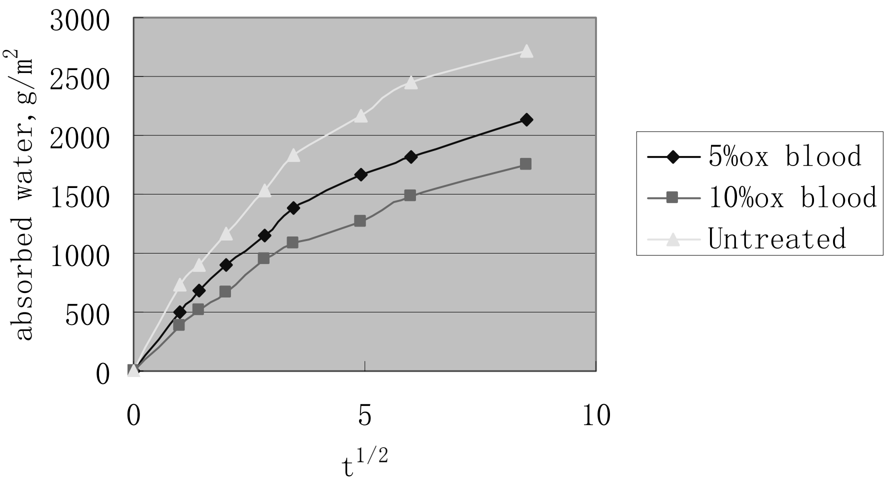

Figure 2: Capillary absorbed water through a cut surface 15 mm behind the cast surface

Table 3: The initial coefficient of capillary absorption A_i [g/m^2 h$^{0.5}$] of neat concrete and of concrete containing 5 % and 10 % of oxblood respectively; $A_{i,0}$ is measured through the cast surface and $A_{i,15}$ through a cut surface 15 mm behind the cast surface

Oxblood added %	$A_{i,0}$ Cast surface	$A_{i,15}$ Cut surface
0	345	715
5	195	505
10	190	410

3.3 Chloride penetration

The surface of the half cubes, which was in contact with the steel form, has been put in contact with a 5 % aqueous NaCl solution for 28 days. Then thin layers of concrete have been milled off successively and the chloride content of the powder, which has been collected, has been determined by means of ion chromatography. Results are shown in Fig. 3. It can be seen clearly that addition of oxblood does not totally prevent penetration of chloride into concrete if the surface is in contact with salt water. Nevertheless a significant reduction of chloride penetration is observed with 5 % oxblood being added and even stronger reduction with 10 % oxblood being added. This protective effect will be even more pronounced if the water-cement ratio is corrected for the water content of blood.

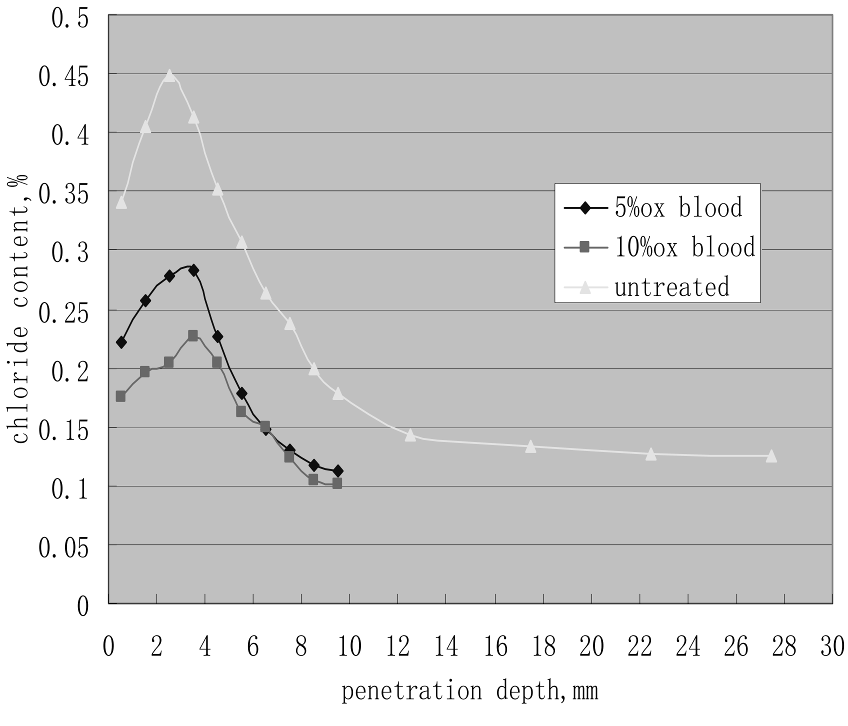

Figure 3: Chloride profiles as determined in neat concrete and in concrete containing 5 % and 15 % oxblood respectively after contact with 5 % NaCl solution for 28 days

From the results shown in Fig. 3 it is obvious, service life of reinforced concrete structures built with conventional concrete in marine environment will be comparatively low, as practical experience shows everywhere.

After contact with salt water for 28 days only, the penetration depth of chloride reaches already about 10 mm. Under these conditions it will not take longer than 20 years before the critical chloride content is reached at the position of steel reinforcement. Reduction of water-cement ratio may extend this period by a few years only. Another problem is crack formation, which is unavoidable in real reinforced concrete structures. It has been shown that chloride penetrates quickly in cracks in neat concrete. But chloride penetration into cracks can be practically avoided by water repellent treatment [10].

Addition of oxblood will increase the service life of reinforced concrete structures considerably. The influence of this type of integral water repellent concrete on service life has yet to be quantified, however. In any case this is an economical method to improve durability and to extend service life of reinforced concrete structures in aggressive environment. It is also a contribution to more ecological construction.

4 Conclusions

From the results obtained and described above the following conclusions can be drawn:

- Addition of oxblood reduces strength of concrete. This strength decrease can be at least partly compensated by reduction of water-cement ratio.
- Capillary absorption of water can be reduced by addition of oxblood. This will increase frost resistance of concrete and durability in permanent contact with water.
- Chloride penetration into concrete can be significantly reduced by addition of oxblood to the fresh mix of concrete. This protective measure will increase service life of reinforced concrete structures in marine environment.
- Addition of oxblood to concrete is an economical and at the same time an ecological measure to improve durability and service life of reinforced concrete structures in aggressive environment.

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