PENETRON
TOTAL CONCRETE PROTECTION

PENETRON slurry – the effective repair solution for carbonated concrete structures

Carbonation of concrete is the result of a chemical reaction between carbon dioxide in the air and calcium hydroxide as well as hydrated calcium silicate in the concrete to form calcium carbonates. Starting from the CO_2 exposed surface carbonation penetrates concrete through microcracks, pores and capillaries. Over time carbonation reduces the pH in the concrete from about 13 to around 8-9. A reduction in the pH annuls the natural passivation of steel reinforcement and – in the presence of moisture and oxygen – leads to corrosion, which promotes spalling of the concrete surface and the loss of mechanical strength.

Repairing carbonated concrete typically involves the removal of all loose concrete areas and exposure of the corroded steel reinforcement followed by a thorough cleaning of the rebar to remove any corrosion and other deposits. The steel reinforcement is then treated with a primer, either alkali-based or an epoxy resin or a sacrificial zinc-rich paint. After that the area is patched with a polymer-modified cementitious material.

To limit further carbonation a protective barrier coating that prevents the ingress of water can subsequently be applied after the relevant surface preparation. However, such coatings normally require reapplication after a few years. This is not just ineffective, but also costly.

Instead, PENETRON, a cementitious crystalline coating can be used to significantly simplify the repair process of carbonated concrete and protect the structure as well as restore durability.

PENETRON conforms to EN 1504-7 and is the world's first crystalline coating for the corrosion protection of embedded steel in concrete structures under repair. It can therefore fully replace the primer in conventional rebar repairs. Since it is highly alkaline it actively supports the passivation of the steel reinforcement and won't require re-alkalizing or the application of film-forming elastomer products. In addition, it increases the bonding with rebuilding mortars, provides self-healing properties and seals the concrete against the ingress of water even under high, hydrostatic pressure.

Recent tests have shown that PENETRON-coated concrete has a much higher resistance against carbonation.

The test compared the carbonation coefficient of two different concrete mixes.

A control mix designed according to SN EN 206-1, C30/37 (w/c ratio 0.45, CEM-I 42.5 – 370kg/m^3) for concrete exposed to corrosion induced by carbonation in cyclic wet and dry environments (XC4), as well as exposure classes XD3 (corrosion induced by chlorides other than from sea water; cyclic wet and dry), XD2b (swimming pools, structural members in contact with industrial waste water containing chlorides; > 0.5 g/1 CI) and XF4.

The second mix was an inferior, more porous mix designed according to SN EN 206-1, C20/25 (w/c ratio 0.6, CEM I 42.5 – 300kg/m^3) for concrete exposed to corrosion induced by carbonation in wet, rarely dry environments (XC2) and dry or permanently wet conditions (XC1). The Penetron coating was then applied to this concrete according to application instructions.

After curing, at an age of 96 days both samples were conditioned in a carbonation chamber for 63 days at a temperature of 20 ± 2°C, relative humidity of 57± 3% and a CO_2 concentration of 4.0 ± 0.1%.

The carbonation coefficient K_N (in mm/√year) was then determined over time (by measuring the carbonation depth in mm at 0, 7, 28 and 63 days) with the help of Swiss standard SIA 262/1.

The results show that the lower-quality concrete with Penetron has a 69% lower carbonation coefficient K_N (K_N = 0.59 mm/√year) than the deemed-to-satisfy, higher-quality concrete mix designed according to EN 206-1 (K_N = 1.88 mm/√year) for the cyclically wet and dry environments (XC4) in which carbonation is more likely to occur than in wet, rarely dry environments (XC2).

Time [days]	d_{KE} [mm]				d_{KM} [mm]
	Side A	Side B	Side C	Side D	
0	0.1	0.2	0.1	0.4	0.2
7	2.2	1.4	2.1	1.3	1.7
28	3.5	3.6	3.3	3.6	3.5
63	5.6	6.0	5.9	6.1	5.9
Constant *A*				[mm]	0.012
Coefficient K_S				[mm/√day]	0.724
Correction factor *c*				[-]	1.36
Carbonation coefficient K_N				**[mm/√year]**	**1.88**

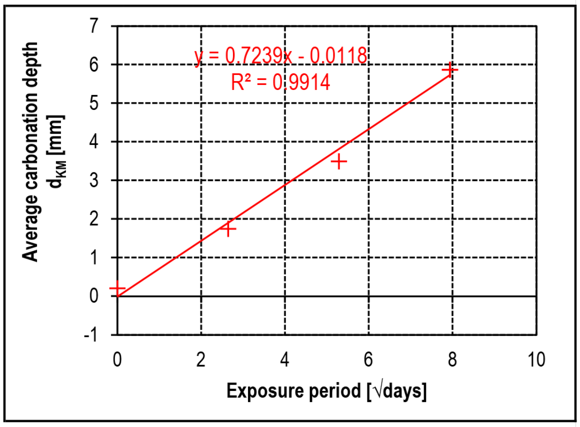

Figure 1 Carbonation results and carbonation coefficient K of the control sample

Time [days]	d_{KE} [mm]				d_{KM} [mm]
	Side A	Side B	Side C	Side D	
0	1.6	0.5	1.1	0.1	0.8
7	0.3	1.5	1.3	1.9	1.2
28	1.8	2.3	2.3	1.2	1.9
63	2.5	2.6	2.5	2.7	2.6
Constant *A*				[mm]	0.741
Coefficient K_S				[mm/√day]	0.226
Correction factor *c*				[-]	1.36
Carbonation coefficient K_N				**[mm/√year]**	**0.59**

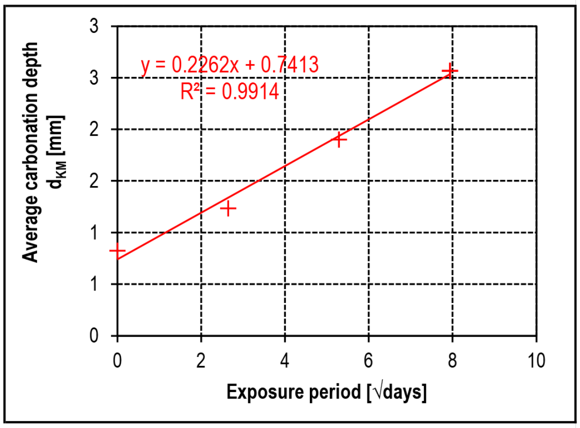

Figure 2 Carbonation results and carbonation coefficient of the Penetron-treated sample

This makes Penetron an effective, long-lasting one-product solution for the repair of carbonated concrete structures and rehabilitation of corroded reinforcement steel. Not only does Penetron significantly slow down the speed of carbonation – even in more porous concrete structures – it also reduces the potential of incompatibility problems of other multi-product repair solutions as well as the need for reapplication and significantly reduces cost of repairs.