PENETRON®
TOTAL CONCRETE PROTECTION

Crystalline Growth
Bridging gaps between permeability and durability

Introduction

The construction industry has over 40 years of experience in the integral crystalline waterproofing field. Simply adding Penetron Admix, a crystalline waterproofing admixture, to concrete allows the construction industry to build economical and durable structures in a shorter timeframe, lasting up to 60 years longer.

When concrete is treated with the Penetron Admix, the concrete itself has the ability to self-heal and seal all hairline cracks, pores and capillaries within the concrete matrix when exposed to water. This results in a waterproof concrete element with the ability to withstand high hydrostatic pressure and chemical attack with a pH range of 3 to 11.

The challenge posed is that the method used to waterproof and protect concrete needs to be seen for an individual to believe that it is present.

Experiments & Results

The main objective of this report is to provide visual proof of the crystal growth inside the concrete matrix, which results in a decreased concrete permeability and overall increase in durability.

Visual Verification

Cracked Penetron Admix containing concrete samples were cured in water for six months and examined under a microscope to verify the crystal growth. The images below were taken of the same sample and cracked area, but at different magnifications (x100, x500 and x1000). It is very clear that needle-like crystals formed within the crack, bridging and self-healing the crack. The crystals did not only grow in the cracked area, the crystalline growth is present within the entire concrete matrix, as well.

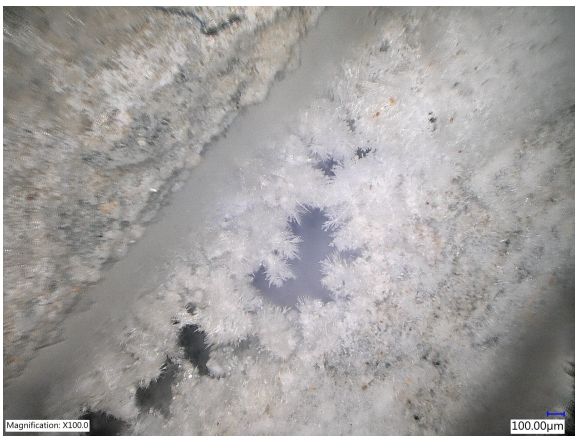

Figure 1

Figure 2

Figure 1 & 2: Crystal growth in cracked concrete (Left: Magnification x100, Right: Magnification x500)

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Figure 3: Crystal growth in cracked concrete (Magnification x1000)

Permeability Tests

Through a variety of test methods, the efficacy of Penetron Admix, a permeability reducing admixture, is confirmed.

The DIN 1048:5 Water Permeability Test assesses the permeability of concrete samples by exposing the samples to a driving pressure of 72.5 psi (0.5 N/mm2) for a period of 72 hours. On completion, the samples are removed from the permeability apparatus and split down the center, and the water penetration depth is measured and marked. The results are summarized in the table below.

Table 1: DIN 1048: 5 Water Permeability Test Results

Sample	Maximum water penetration depth in inches (mm)	Average water penetration depth in inches (mm)
1P (Penetron Admix treated)	No water penetration	No water penetration
2P (Control)	1.026" (26 mm)	0.695" (18 mm)

A second permeability test was performed in accordance with ASTM Standard D5084. The test consists of the measurement of hydraulic conductivity of saturated porous materials with a flexible wall permeameter, using both Method A (the constant head test method) and Method D (the constant rate of flow test method).

The untreated/control sample displayed a hydraulic conductivity of 2.1x10-9 cm/sec, compared to the Penetron Admix treated sample with a hydraulic conductivity of 3.1x10-11 cm/sec, measured at similar ages of 40 to 45 days. This shows the Penetron Admix treated sample had a measured hydraulic conductivity of 68 times less than the untreated sample.

A third permeability test was performed in accordance with the U.S. Army Corp of Engineers test method CRD-C 48-92 Standard Test Method for Water Permeability of Concrete. The control and Penetron Admix treated samples were tested by applying a water pressure of 200 psi until the flow became essentially constant. The average flow rate for the last five days of testing is used to calculate the average water permeability. The results are summarized in the table below.

Table 2: CRD-C 48-92 Water Permeability Test Results

	Control Sample	Penetron Admix Treated Sample
Average flow rate for last 5 days of testing (cm^3/hr)	0.052	0.009
Averagewater permeability (ft^3/sec)/(ft^2(ft head/ft))	2.86×10^{-12}	4.82×10^{-13}

Conclusion

The purpose of this report was to examine the crystal growth inside the concrete matrix as a result of Penetron Admix, verify how Penetron Admix decreases the permeability of concrete, and determine whether the durability of the concrete will be affected.

The main conclusions of the report hold as follows:

- When Penetron Admix containing concrete is exposed to water, the chemical reaction is activated, resulting in the formation of insoluble crystals in all hairline cracks, pores and capillaries throughout the entire concrete matrix.
- The needle-like crystal growth is clearly visible during microscopic examination, showing how the crack is bridged and sealed.
- The crystalline growth within the concrete matrix results in a decrease in concrete permeability, making the concrete itself waterproof/impermeable.
- The DIN 1048:5 Water Permeability Test showed there was no water penetration while exposing the Penetron Admix treated sample to a driving pressure of 72.5 psi (0.5 N/mm^2) for a period of 72 hours, compared to the control sample showing an average water penetration depth of 0.695" (18 mm).
- The ASTM Standard D5084 Water Permeability Test showed the Penetron Admix treated sample had a measured hydraulic conductivity of 68 times less than the control sample.
- The CRD-C 48-92 Standard Test Method for Water Permeability of Concrete showed the Penetron Admix treated sample was 6 times less permeable compared to the control sample.

According to ACI 201.2R-01, the "Durability of hydraulic-cement concrete is defined as its ability to resist weathering action, chemical attack, abrasion, or any other process of deterioration. Durable concrete will retain its original form, quality, and serviceability when exposed to its environment."

Because water plays a vital role in the chemical and most physical processes that take place in concrete, including the required and damaging ones, lowering the permeability of concrete will result in a decrease in deterioration and increase in the durability of concrete.

Penetron understands the relationship between crystalline growth, decreased permeability and concrete durability.

References

1. Report of Results for ASTM C39 and DIN 1048:5 (EN 12390-8): Water Permeability, Professional Service Industries Inc.
2. Report of Results for ASTM Standard D5084: Permeability Tests on Treated and Untreated Concrete, Ardaman & Associated Inc, 12 February 2015.
3. Report of Results for CRD-C 48-92: Water Permeability, Penetron Permeability Testing, TEC Services, 26 September 2016.
4. ACI 201.2R-01