TEST REPORTS

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PENETRON®
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TOTAL CONCRETE PROTECTION™

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INTRODUCTION

The following section contains a Summary of examination methods and results from tests conducted on PENETRON® system treated concrete. These tests, conducted by independent, accredited laboratories, demonstrate the remarkable efficacy of the PEN ETRON ® system to meet or exceed a wide range of physical and chemical performance criteria through standards and test methods defined by various governing industry agencies.

Copies of the full test report documents are available upon request. Please contact your PEN ETRON® representative.

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PENETRON® TEST REPORTS

BOND STRENGTH TESTING

3/8/1985	ALL ISLAND TESTING ASSOCIATION INC.		
	Shear And Bond Tests		
	Results:		
	SHEAR TESTS	**LOAD (LB.)**	
	AGE IN DAYS	**14**	**28**
	Reference	3113	4086
	Penetron Slurry	3343	4104
	Penetron Powder	2335	2868

	BOND TESTS	**LOAD (LB.)**	
	AGE IN DAYS	**14**	**28**
	Reference	*	7280
	Penetron Slurry	*	7295

*** In both Reference and Penetron Treated specimens, the reinforcement steel yielded with the steel still firmly bonded to the concrete.**

		LOAD (LB.)	
	AGE IN DAYS	**14**	**28**
	Penetron Slurry	340	540

10/25/1993	*REPORT NO. 93-4091*
	Shimel and Sor Testing Laboratories, Inc., Cedar Grove, NJ.
	Bond Strenght of Penetron Coated Concrete
	Results: The bonding strength of Penetron to concrete at 14 days at age was 220 psi. It is expected that at the age of 28 days the bonding strength will reach at least 250 psi

4/1/1997	REPORT: NR. 620497
	Rigas Technical University; Department of Constructions: Subfaculty “Building Materials”
	Determination of Waterproofing According to “Concrete, ways to determine waterproofing” approved by OCT12730. 5-84 (Cement-concrete surfaces).
	Results: Penetron is recommended for waterproofing of either the positive or negative side, which is used in unfavorable conditions. Penetron has tensile strength (23.7kg/sq.cm) without the joining area with a surface with destruction and/ or damage.

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3/9/2005	**REPORT NO: WJJ-04235/COMMISSION NO: WJJ-04267**
	Tongji Institute For Survey on Construction Quality
	Research Report on Properties of Penetron Cementitious Capillary/Crystalline Waterproofing Coating
	Bond Strenght of Penetron using two test methods
	Result: The results indicated both injection and brush-on bond strength were comfortably above 1.0MPa (requirement of GB18445-2001) and the brush –on bond strength exceeded it by 96%. This latter method is in accordance with general Penetron application; hence this figure is closer to what will be achieved in real life. Penetron has a good bond, and showed high injection and brush-on bond strength. The brush-on method is in line with practical applications on projects.

CHEMICAL RESISTANCE TESTING

10/19/1993	**REPORT NO. 93-3981**
	Shimel and Sor Testing Laboratories, Inc., Cedar Grove, NJ.
	Laboratory Testing of Penetron Waterproofing Materials for Chemical Resistance
	Result: The Penetron treated concrete was found to be resistant to acidic and alkaline conditions ranging between pH values of 3 to 11. The untreated concrete (control) had surface weathering when exposed to pH of 3, rain water chlorides and sulfate solutions.

CHLORIDE RESISTANCE TESTING

6/10/1983	**ISLAND TESTING EGP. ASSOCIATION INC.**
	Durability of Concrete and Penetron of de-icing chemicals into concrete were evaluated by freeze-thaw testing of treated and untreated concrete panels
	Result: For the conditions of this test, the surface treatment reduced the chloride concentration at the 1” depth by 50% at the 3” depth by 67% and at the 5” depth by 75% of that in the untreated panels.

12/21/1994	**REPORT NO. 94-6175**
	Shimel and Sor Testing Laboratories, Inc., Cedar Grove, NJ.
	Laboratory Testing of Penetron Waterproofing Materials
	Result: The water-soluble chloride content of Penetron was very low and about equal to that of the concrete. The test results indicate that the beneficial effects of Penetron are not related to chlorides.

COMPRESSIVE STRENGTH TESTING

3/4/1985	**ALL ISLAND TESTING ASSOCIATION INC.**
	To Determine if the Compressive Strength of Concrete is Affected by Treatment with Penetron
	Result: The use of Penetron resulted in a strength gain of approximately 5.52% over the untreated concrete.

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11/22/1993	REPORT NO. 93-4559
	Shimel and Sor Testing Laboratories, Inc., Cedar Grove, NJ.
	Laboratory Testing of the effects of Penetron Treatment on the Compressive Strength of Concrete.
	Result: The treating concrete surface with Penetron resulted in a slight increase in the compressive strength of the concrete.

12/21/1994	REPORT NO. 94-6175
	Shimel and Sor Testing Laboratories, Inc., Cedar Grove, NJ.
	Laboratory Testing of Penetron Waterproofing Materials
	Result: As per ASTM C39, the Penetron treated and the untreated (control) cylinders were slightly higher than the untreated cylinders. This increase corresponds to approximately 6% gain over the untreated concrete. Primary benefit of Penetron is waterproofing concrete surface rather than increasing the compressive strength.

7/15/1997	REPORT NO. : B 20297/BSB/1
	Setsco Services PTE LTD
	Determination of Compressive Strength of Concrete Applied with Penetron Cementitious Capillary Waterproofing System

Table 1: Compressive Strength

Sample Reference	Control			Treated with Penetron		
Cube Reference	1	2	3	1	2	3
Date of Cast	11/4/1997					
Date of Test	18/04/97					
Age at Test	7					
Compressive Strength (N/mm²)	24.0	24.0	24.0	24.5	24.0	24.5
Average Compressive Strength (N/ mm²)	24.0			24.5		

Table 2: Compressive Strength Test

Sample Reference	Control			Treated with Penetron			Treated with Penetron Slurry after 28 days of curing		
Cube Reference	1	2	3	1	2		1	2	3
Date of Cast	11/4/1997								
Date of Test	9/5/1997						10/5/1997		
Age at Test	28						29		
Compressive Strength (N/mm²)	30.5	30.5	31.0	36.5	35.5	35.0	35.5	36.0	36.0
Average Compressive Strength (N/mm²)	30.5			35.5			36		

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7/15/1997	REPORT NO.: B 20297/BSB/2A					
Setsco Services PTE LTD						
Comparative Test for Water Permeability on Plain Grade 30 Concrete Applied with Penetron Cementitious Capillary Waterproofing System (powder)						
Table 1: Compreesive Strenght						
Sample Reference	Concrete Substrate					
Cube Reference	1	2	3	4	5	6
Date of Cast	11/4/1997					
Age of Test	7			28		
Compressive Strenght (N/mm²)	24.0	24.0	24.0	30.5	30.5	31.0
Average Compressive Strenght (N/mm²)	24.0			30.5		

7/15/1997	REPORT NO.: B 20297/BSB/2B					
Setsco Services PTE LTD						
Comparative Test for Water Permeability on Plain Grade 30 Concrete Applied with Penetron Cementitious Capillary Waterproofing System (powder)						
Table 1: Compressive Strenght						
Cube References	1	2	3	4	5	6
Date of Cast	11/4/1997					
Age of Test	7			28		
Compressive Strenght (N/mm²)	24.0	24.0	24.0	30.5	30.5	31.0
Average Compressive Strenght (N/mm²)	24.0			30.5		

FREEZE-THAW RESISTANCE TESTING

6/10/1983	ISLAND TESTING EGP. ASSOCIATION INC.
	Durability of Concrete and Penetron of de-icing chemicals into concrete were evaluated by freeze-thaw testing of treated and untreated concrete panels
	Result: For the conditions of this test, the surface treatment reduced the chloride concentration at the 1" depth by 50% at the 3" depth by 67% and at the 5" depth by 75% o9f that in the untreated panels. Visual examination of the panels after completion of the cycles showed a markedly increase in surface erosion of the untreated panels over the treated panels.

9/11/2001	SWEDISH NATIONAL ROAD ADMINISTRATION: REGION STOCKHOLM
	BERGAB - Berggeologiska Undersökningar AB (Rock-geological Investigations/Analyses Ltd.)
	Project Tunnel Expressway Södra Länken, Contracts SL 01, 02, 03
	Results: Tests performed shows that a Penetron treatment is a functional method to proof for water leaking through sprayed concrete in tunnels. The method ought to be used to move leakages to sections where it can be handled--drained. Penetron treatment does not deteriorate the frost resistance of the sprayed concrete.

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GAMMA RADIATION

6/19/1993	**CERTIFICATE NO. 9305-4136**
	Shimel and Sor Testing Laboratories, Inc., Cedar Groove, NJ.
	Exposure of Penetron Treated Concrete to Gamma Radiation
	Result: Visual comparison, photograpghs and the adhesion test performed on the Penetron coating both and before and after exposure to 5.76 x 104 of gamma radiation do not reveal any perceptible ill effects or damages. The defects as listed under USA Standard No. Rads N6.9-1967 "Protective Coatings (Paints) for the Nuclear Industry" were evaluated. No fine line cracking (ASTM D661-44), checking (ASTM D660-44), alligatoring, mud cracking (ASTM D661-44), blistering (ASTM D714-56), flaking (ASTM D772-47), discoloration, delamination and chalking (ASTM D659-44) were observed. The categories embrittlement, bubbling, blistering (ASTM D714-56), orange peeling, catalyst migration are not applicable because the Penetron material, according to the technical literature does not act strictly as a surface covering, but rather a treatment which is absorbed into the voids and capillaries of the concrete, later filling these areas with crystalline structures.

INFRARED SPECTRA ANALYSIS

12/21/1994	**REPORT NO. 94-6175**
	Shimel and Sor Testing Laboratories, Inc., Cedar Groove, NJ.
	Laboratory Testing of Penetron Waterproofing Materials
	Result: PENETRON treated concrete samples were tested by infrared spectroscopy Methods.The amount of Penetron components at the 1/2 depth from the trated surface was considerable.Untreated comcrete sample had considerably less calcium, slilca and their components and reaction than the treated concrete of the depths studied.

MICROSCOPIC EXAMINATION

12/21/1994	**REPORT NO. 94-6175**
	Shimel and Sor Testing Laboratories, Inc., Cedar Groove, NJ.
	Laboratory Testing of Penetron Waterproofing Materials
	Result: Microscopic examinations revealed that the Penetron components that diffused into the concrete surface resulted in a crystalline growth, white in color. These crystalline growths appeared to be hydration products of the Penetron components with cement's calcium-silicate gel in the matrix of the concrete.

PERMEABILITY TESTING

12/21/1994	**REPORT NO. 94-6175**
	Shimel and Sor Testing Laboratories, Inc., Cedar Groove, NJ.
	Laboratory Testing of Penetron Waterproofing Materials
	Result: The water permeability of Penetron treated concrete was considerably slower than that of untreated concrete. This indicates that Penetron treatment improves the waterproofing properties of the concrete considerably.

4/1/1997	**REPORT: NR. 620497**
	Rigas Technical University: Department of Construction: Subfaculty "Building Materials"
	Determination of Waterproofing According to "Concrete, ways to determine waterproofing" approved by OCT 12730. 5-84 (cement-concrete surfaces).
	Result: Penetron is recommended for waterproofing of either the positive or negative side, which are used in unfavorable conditions. Penetron stands hydrostatic water pressure 1Mpa (10kg/sq.cm). It is directed from Penetron-coating. In this case, waterproofing is W10. Penetron stands hydrostatic water pressure of 0.8MPa (8kg/sq.cm). It is directed from concrete surface (Penetron-coating is situated opposite). In this case, waterproofing is W8.

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7/15/1997	REPORT NO.: B 20297/BSB/2A					
	Setsco Services PTE LTD					
	Comparative Test for Water Permeability on Plain Grade 30 Concrete Applied with Penetron Cementitious Capillary Waterproofing Systems (powder)					
Permeability Test at 3.0 kgf/cm^2						
Sample Reference	**Control**			**Treated' with Penetron Cementitious Capillary Waterproofing System Powder**		
	C1	**C2**	**C3**	**T1**	**T2**	**T3**
Dimensional Measurement Avg.Diam. (mm)	101.1	100.0	100.0	99.9	100.3	100.8
Average height, L (mm)	51.6	51.7	51.7	51.9	51.8	51.8
Cross-sectional Area, A (m2)	8.03 X10-3	7.85 X 10-3	7.85 X 10-3	7.84 X 10-3	7.90 X 10-3	7.98 X 10-3
Permeability Hydraulic radient across samples i=30/L (m head of ater/m)	581	580	580	578	579	579
Constant Flow Rate, Q (cc/hr)	0.03216	0.03449	0.03630	0.01579	0.01474	0.01714
m3/sec	8.93X10^{-12}	9.58X10^{-12}	1.01X10^{-11}	4.39X10^{-12}	4.09X10^{-12}	4.76X10^{-12}
Coefficient of Permeability, k (m/sec)	1.91X10^{-12}	2.10X1 0^{-12}	2.22X1 0^{-12}	9.69X10^{-13}	8.94X10^{-13}	1.03X10^{-12}
Average Coefficient of Permeability, k (m/sec)	2.08X10^{-12}			9.64X10^{-13}		
Comparative Ratio	0.46					

7/15/1997	REPORT NO.: B 20297/BSB/2B					
	Setsco Services PTE LTD					
	Comparative Test for Water Permeability on Plain Grade 30 Concrete Against Concrete Applied with Penetron Cementitious Capillary Waterproofing System (slurry).					
Permeability Test at 3.0 kgf/cm^2						
Sample Reference	**Control**			**Treated' with Penetron Cementitious Capillary Waterproofing System Slurry**		
	C1	**C2**	**C3**	**T1**	**T2**	**T3**
Dimensional Measurement Average Diameter (mm)	101.1	100.0	100.0	101.2	101.2	100.9
Average height, L (mm)	**51.6**	**51.7**	**51.7**	**53.4**	**52.5**	**53.6**
Cross-sectional Area, A (m^2)	8.03 X10-3	7.85 X 10-3	7.85 X 10-3	8.04 X 10-3	8.03 X 10-3	8.00 X 10-3
Permeability Hydraulic gradient across samples I=30/L (m head of water/m)	**581**	**580**	**580**	**562**	**571**	**560**
Constant Flow Rate, Q (cc/hr)	0.0321625	0.0344875	0.0363020	0.02037	0.01938	0.01897
m^3/sec	8.93X10^{42}	9.58X10-12	1.01x10-11	5.66X10^{42}	5.38X10^{42}	5.26X10^{-12}
Coefficient of Permeability, k (m/sec)	1.91X1042	2.10X10-	2.22X10-	1.25X104	1.17X104	1.17X1042
Avg. Coefficient of Permeability, k (m/sec)	2.08X10^{-12}			1.20X10^{-12}		
Comparative Ratio	0.58					

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7/15/1997	REPORT NO.: B 20297/BSB/3A
	Setsco Services PTE LTD
	Water Permeability on Plain Grade 30 Concrete applied with Penetron Cementitious Capillary Waterproofing System

Permeability Test at 3.0 kgf/cm^2	
Sample Reference	Treated with Penetron Cementitious Capillary Waterproofing System Powder
Dimensional Measurement Average Diameter (mm)	99.5
Average height, L (mm)	52.0
Cross-sectional Area, A (m^2)	7.78X10^{-3}
Permeability Hydraulic gradient across samples I=30/L (m head of water/m)	577
Constant Flow Rate, Q (cc/hr)	0.01515
m^3/sec	4.21X10^{-12}
Coefficient of Permeability, k (m/sec)	9.38x10-12

REPORT NO.:	B20297/BSB/3B
	Setsco Services PTE LTD
	Water Permeability on Plain Grade 30 Concrete applied with Penetron Cementitious Capillary Waterproofing System (slurry).

Permeability Test at 3.0 kgf/cm^2	
Sample Reference	Treated with Penetron Cementitious Capillary Waterproofing System Slurry
Dimensional Measurement Average Diameter (mm)	99.9
Average height, L (mm)	52.8
Cross-sectional Area, A (m^2)	7.84x10^{-3}
Permeability Hydraulic gradient across samples I=30/L (m head of water/m)	568
Constant Flow Rate, Q (cc/hr)	0.02032
m^3/sec	5.64x10^{-12}
Coefficient of Permeability, k (m/sec)	1.27x10^{-12}

7/16/1998	REPORT NO. 98-12398
	Shimel and Sor Testing Laboratories, Inc., Cedar Groove, NJ.
	Laboratory Testing of Penetron Waterproofing Materials
	Result: Penetron coated concrete samples were tested in compliance with DIN 1048 with regard to their water impermeability. The hydrostatic pressure was increased by 1 bar every 48 hours. By the time a pressure of 16 bars was reached (156.79 meters) (232 psi), no penetration of moisture through the coating was to be stated. The test surface of the water permeable inner core did not show any damage, nor water permeabilities of the Penetron coating.

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6/18/1998	TESTING REVIEW NR. 64-98					
	Riga Technical University Building Faculty: The Building Materials Laboratory					
	Determination of Waterproofness under GOST 12730.5-84					
STOOD UNDER THE WATER PRESSURE, KGF/CM^2 (MPA), HOURS.						
No. Of Sample	Boring Place	6 (0.6)	8 (0.8)	10 (1.0)	12 (1.2)	14 (1.4)
1	“A” place of measurement	16	16	16	16	16
2	10th panel, 1.5m height,	16	16	16	-	-
3	1. Measure point	16	16	16	16	16
4	“C” place of measurement	16	16	-	-	-
5	14th panel, 1.5m height	16	16	16	-	-
6	7. Measure point	16	-	-	-	-

STOOD UNDER THE WATER PRESSURE, KGF/ CM2 (MPA), HOURS			
No. Of Samples	Boring Place	Samples bored in 1996 (before covering of Penetron)	Samples bored in 1998 (after covering of Penetron)
1	**“A” place of measurement**	4	14
2	**10th panel, 1.5 mm height**	6	10
3	**1. Measure Point**		14
	Average Ratio	5	12.7
4	**“C” place of Measurement**	8	8
5	**14th panel, 1.5 mm height**	6	10
6	**7. measure point**		6
	Average Ratio	7	8

3/9/2005	REPORT NO: WJJ04267/COMMISSION NO: JJ04267
	Tongji Institute for Survey on Construction Quality
	Research Report on Properties of Penetron Cementitious Capillary/Crystalline Waterproofing Coating
	Result: Test results showed the concrete specimens still had higher impermeability even though Penetron coating was removed from both positive and negative side at 28 days. Impermeability of specimens with Penetron coating removed from negative side had a 300% increase and impermeability of specimens with Penetron coating removed from positive side had a 466% increase in waterproofing protection when compared to the control concrete, which was much above the requirement of Chinese standard GB18445-2001 it was demonstrated that Penetron has excellent crystal growth and in-depth waterproofing ability. Penetron treated concrete still had high impermeability even though Penetron coating was removed, showing that Penetron has the ability to waterproof concrete through integral capillary crystallization.

8/5/2005	REPORT: 303.897-1
	OFI: Technologies & Innovation GmbH
	Water Penetron of Concrete Specimen Treated with “Penetron” following OENORM B 3303, 2002-09-01
	Results: According to the testing per OENORM B 3303, 2002-09-01, the reference showed an average water penetration depth of >100mm. For the vertical joint, the left side showed 32mm and the right showed 58mm. The horizontal joint showed 22mm of average water Penetron with the joint treated with Penetron lies in a distance of 25mm from the penetrated surface.

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12/13/1999	**REPORT NO. 317-99**
	Seal/Laboratory of Building Materials, Riga Technical University
	Concrete Hidroinsulating Material PENETRON
	Results: Test carried out according to the ISO 7031 revealed that exposure to the gamma-rays and their intensity does not influence the water resistance of the concrete. For Penetron coated samples, the depth water penetron in the concrete is lower than for uncoated samples.

1/24/1995	**REPORT NO. 95-387**
	Shimel and Sor Testing Laboratories, Inc., Cedar Grove, NJ.
	Laboratory Testing of Penetron Waterproofing Systems
	Results: Concrete core section tested was coated with a minimum of gold in order to provide surface, which could be studied by light microscopy and compared to SEM images. Penetron coated concrete surfaces develop improved concrete microstructure and waterproofing properties.

	LICENSE NO. 128/C.C. NO. 57499
	The Kingdom of Saudi Arabia
	Technical Report on Penetron
	Results: In accordance of German specifications No. 1048, no water penetration is noticed on the surfaces of the three samples tested under pressure.

TOXICITY TESTING

12/26/1984	**FDRL STUDY NO. 8375A/TEST ARTICLE ID: 84-0909**
	Food and Drug Research Laboratories, Inc.
	Acute Oral Toxicity of Penetron in Sprague-Dawley Rats
	Result: According to 16 CFR 1500, Penetron is not considered to be toxic and does not require cautionary labeling

6/5/1997	**REPORT NO: B20297/EL/4**
	Setsco Services PTE LTD
	Cytotoxicity Test on Penetron Cementitious Capillary Waterproofing Systems
	Results: The product shall be regarded as being suitable for contact with water intended for human consumption as it exhibits a “non-cytotoxic” response when in contact with Vero cells.

9/2/1999	**REPORT: 981660CH90088**
	Materialab Limited
	Report on Analysis of Coating Material: Non Toxicity Test (Migration of Toxic Elements)
	Results: The submitted test sample complied with the test requirement of BS 5665: Part 3 1995 for toxic element content.

1/00/2001	**REPORT: GB171219-1998**
	Department of Toxicology, Beijing Municipal Centers for Disease Prevention & Control
	Standard for Safety Evaluation of Equipment and Protective Materials in Drinking Water Syatem
	Results: The mouse oral toxicity test revealed results of LD_{50}>10000mg/kg body weight concluding that the test article is actual nontoxic. From the results of the testing, Penetron showed no evidence of clastogenic activity when administered orally in this vivo test procedure, thus the micronucleus test of the bone marrow cell is negative. The result of the Ames test is also negative both in the absence and presence of S9 mix.

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8/2004	REPORT: 2004KL0620
	Sirim QAS International Sdn. Bhd.
	BS 6920: Part 1: 2000 (Suitability of Non-Metallic Product for Use in Contact with Water Intended for Human Consumption with Regard to Their Effect on the Quality of the Water)
	Results: The sample tested complied with all the requirements of BS 6920: Part 1: 2000; Clause 5, 6 & 8

X-RAY ANALYSIS TESTING

1/24/1995	REPORT NO. 95-387
	Shimel and Sor Testing Laboratories, Inc., Cedar Grove, NJ.
	Laboratory Testing of Penetron Waterproofing Systems
	Results: Calcium accumulation in concrete below the Penetron coating to 25-50mm depths. Calcium appears to be in the form of $Ca(OH)_2$ and calcium-silicate gel. Crystalline growths are the diffusion products of the components of the Penetron coating on the concrete surface. Below 50mm depths, Ca(OH) is less while the silica content from cement becomes dominant. Penetron coated concrete surfaces develop improved concrete microstructure and waterproofing properties.

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TEST REPORTS
PENETRON ADMIX

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PENETRON® ADMIX TEST REPORTS

ABSORPTION TESTING

12/1/2002	ACCI REF. NO.: 58324
	University of New South Wales: The Australian Centre for Construction Innovation
	Properties of Type GP Cement Concrete Modified with Penetron Admix
	Testing Water Absorption and AVPV (AS 1012.21) and Water Sorptivity (RTA Test Method T362)
	Results: See Table 4.4-1 The concrete Mix-P containing Penetron Admix had both slightly lower water absorption and AVPV Values than the control concrete Mix-C. See TAB Water Sorptivity (RTA Tes Method T362) has been used by RTA (NSW) as an Assessment test for quality assurance in the TRA QA Specification B80 for Concrete Works for Bridges. The test results clearly Shown that the use of Penetron Admix in Concrete Mix-P resulted in a reduction of the water penetration depth to 60% of that of The control concrete Mix-C. Also, the water penetration depth s of both concretes are much less than the maximum permitted depth of 25mm for the exposure classification B1 and 35mm for the exposure classification. A required in the RTA (NS) QA Specification B80.

TABLE 4.4-1 WATER ABSORPTION AND AVPV (AS 012.21)

Test Item	Mix-P	Mix-C
Water Absorption	6.35%	6.48%
Apparent Volume of Permeable Voids	14.35	14.88%

TABLE 4.5-1 WATER SORPTIVITY PENETRATION DEPTH (RTA-T362)

TEST ITEM	Mix-P	Mix-C
Water Sorptivity Penetration Depth (RTA-T620	10.2	416.

12/1/2003	ACCI REF. NO.: J#61707
	The University of New South Wales: The Australian Centre for Construction Innovation
	Testing Properties of a commercial Concrete Mix Modified with Penetron Admix
	Results: The water absorption and the apparent volume of permeable voids (AVPV) in hardened concrete were tested according to AS 1012.21. According to the acceptance criteria of VICROADS based on AVPV for concrete in various exposure classifications,the acceptable AVPV value for exposure classification B1 and B2 is less or equal to 15% and 14% respectively. Penetron Admix modified concrete satisfied both criteria. Exposure classification B2 is described in AS3600 as such “permanently submerged in sea water” and the classification B1 includes several exposure environments less aggressive than B2.

TABLE 3

Water Absorption	6.00%	
Apparent Volume of Permeable Voids	13.62%	

3/29/2006	REPORT NO.: 06-1918
	Sor Testing Laboratories, Inc., Cedar Grove, NJ
	Laboratory Testing of Penetron Admixture As Per NCHRP-244 Methods

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WATER ABSORPTION AFTER SOAKING IN 15% NACL SOLUTION FOR 21 DAYS	
Type of Treatment	**Weight, Gain % (")**
Control (Untreated)	2.89
Control- Untreated (Exposed to UV Light)	2.92
Penetron Treated	0.57
Penetron Treated (Exposed to UV Light)	0.60

* All test results are average of triplicate tests

RELATIONSHIP BETWEEN WATER ABSORPTION AND CHLORIDE ION CONTENT			
Type of treatment	**Chloride Ion content % (0-2 depth)**	**% Weight Gain21 Days in 15% NaCl Solution**	**Calculated percent chloride Ion in solution absorbedl**
Control (Untreated)	**0.263**	**2.89**	**9.1**
Control (Untreated) Exposed to UV light	**0.267**	**2.92**	**9.1**
Penetron Treated	**0.027**	**0.57**	**4.7**
Penetron Treated (Exposed to UV Light)	**0.029**	**0.6.**	**4.8**

REDUCTIONS OF WATER ABSORPTION AND CHLORIDES INTO CONCRETE		
Type of treatment	**Reduction of Water Absorption into Concrete, %**	**Reduction into Chloride Content in Concrete, % (*)**
Penetron Treated	80.2	89.7
Penetron Treated (Exposed to UV Light)	79.5	89.1

* 0-2 inch depth

	POLITECHNIKA KRAKOWSKA (TECHNICAL UNIVERSITY IN KRAKOW)
	Testing Report of Concrete Additive Penetron Admix
	Results: Absorption by weight, Penetron Admix treated Concrete I/I showed -nw of 4.7% as compared to control concrete I which showed -nw=6.7%. Penetron Admix treated Concrete II/I showed -nw of 4.5% and the control concrete II showed -nw of 6.6%.

AIR CONTENT TESTING

12/01/06	**ACCI REF. NO. 58324 - AIR CONTENT**
	The University of South Wales
	The Australian Centre for Construction Innovation - Properties of Type GP Cement Concrete Modified with Penetron Admix
	Results: The air content of fresh concrete in Mix-P was measured to be 1.7% which was lower than that of 3% in the control mix and which was measured according to AS 1012.4.2. A lower air content generally results in denser concrete and may influence compressive strength

BLEEDING TESTING

12/01/06	**ACCI REF.NO. 58324 - BLEEDING**
	The University of New South Wales: The Australian Centre for Construction Innovation
	Properties of Type GP Cement Concrete Modified with Penetron Admix
	Results: The bleeding of concrete in Mix-P was 3.2% which was also lower than that of 5.2% for the control mix

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CHEMICAL RESISTANCE TESTING

12/01/05	ACCI REF.NO. 58344 - LENGTH CHANGE IN SULPHATE SOLUTION (AS 2350.14)
	The University of New South Wales: The Australian Centre for Construction Innovation
	Properties of Type GP Cement Concrete Modified with Penetron Admix
	Results: Expansion of the samples of the concretes are shown in Table 4.8-1. Proposed assessment citeria of the AS 2350.14 test for Acceptable sulphate resistance is that the expansion should be no more than 900 microstains after 16 weeks immersion in the sulphate solution. Expansions of samples of the concrete Mix-P and Mix-C in this test were both less than 600 microstains or less than two thirds of the expansion limit of the proposed criteria. The expansion of the samples of Mix-P was slightly higher than that of control mix Mix-C.The deference in not very significant and the test result may have been influenced by the much higher slump (130mm) of Mix-P compared with that of Mix –C (80mm).

Table 4.8-1 EXPANSION IN MICROSTRAIN

Immersion Time (week)	0	2	4	6	8	10	12	14	16
Mix-P	0	106	165	224	271	334	419	489	591
Mix-C	0	69	139	176	218	295	345	386	463

8/31/2006	REPORT NO.: 2004A102007
	Shanghai Research Institute of Building Sciences
	Chemical Resistance of Penetron Admix Modified Mortar after soaked in various chemical solutions for 60 days.
	Results: Penetron Admix mortars were observed to have better resistance to chemicals than control mortars.

CHLORIDE RESISTANCE TESTING

12/01/02	ACCI REF.NO.58324 - CYCLIC CHLORIDE PENETRATION (ACCI METHOD)
	The University of New South Wales: The Australian Centre for Construction Innovation
	Properties of Type GP Cement Concrete Modified with Penetron Admix
	Results: After 14 days cyclic exposure in 15% salt solution and drying at 40^{o} C show the Chloride Penetration Depth (mm) to be 19.7 for Mix-P and 26.6 for Mix-C. The ACCI accelerated chloride penetration test demonstrated at 35% reduction in the accelerated chloride penetration depth with the use of Penetron Admix in concrete Mix-P compared to the control concrete Mix-C.

8/31/2004	REPORT NO.: 2004A102007
	Shanghai Research Institute of the Building Sciences
	Chloride Ion Penetration of Concrete: Hardened Concrete: Accelerated Chloride Penetron
	Chloride Ion Diffusion Coefficient of Concrete
	Results: Chloride ion diffusion coeffecinet can directly indicate penetration velocity of chloride ions through the concrete specimens.Penetron Admix could significally reduce the passage of chloride containing solutions and improve concrete compactness. Penetron Admix modified concrete had 30.8% reduction of 90 days when compared to control with similar slump.

10/10/2005	REPORT NO.: 05-4070A
	Sor Testing Laboratories, Inc., Cedar Grove, NJ
	Laboratory Tests of Penetron Admix in Concrete
	Results: As per AASHTO-T 277, Penetron Admix treated concrete showed very low chloride permeability with 750 charges passed/Coulombs. The control concrete showed high chloride permeability with 4130 charges passed/coulombs.

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3/29/2006	REPORT NO.: 06-1918
	Sor Testing Laboratories, Inc., Cedar Grove, NJ
	Laboratory Testing of Penetron Admixture As Per NCHRP-244 Methods
	Results: As per the requirements of the National Cooperative Highway Research Program Report 244, there was considerable reduction in the chloride content in the specimens treated with the Penetron. The reduction in chloride absorption by weight percent were:

Treatment	Reduction
Penetron Treated	89.7
Treated (Exposed to UV)	89.1

It was noted That the exposure to ultraviolet light had only a minor effect on the chloride absorption. In the control specimens, the depth of chloride penetration was very high at 0-1 inch depths and rather considerable at 1-2 inch depths. In the treated samples, chloride penetrations were measurable but not high at 0-1 inch depths. While at the 1-2 inch depths, the chloride penetrations were minimal. It is concluded from these test results that treating concrete with Penetron Admixture at the rate studied reduced considerably (at least 89%) the amounts of chloride penetrations to a concrete depth of 1 inch and practically eliminates the penetration of chlorides to depths beyond 1 inch.

CHLORIDE (CL-) ION CONTENT OF CONCRETE CUBES AFTER 21-DAYS SOAKING IN 15% NACL SOLUTION (‘) (“)

Type of Treatment	Chloride Ion Content % by Weight of Concrete	
	0-1 Inch Depth	1-2 Inch Depth
Control (Untreated)	0.244	0.021
Control (Untreated) Exposed to UV Light	0.246	0.021
Penetron Treated	0.023	0.004
Penetron Treated (Exposed to UV Light)	0.024	0.005

* The background chloride content of the concrete was 0.001%. All results were corrected by subtracting the background value from the chloride results.

** All test results are the average of triplicate tests

WATER ABSORPTION AFTER SOAKING IN 15% NACL SOLUTION FOR 21 DAYS

Type of Treatment	Weight, Gain % (*)
Control (Untreated)	2.89
Control - Untreated (Exposed to UV Light)	2.92
Penetron Treated	0.57
Penetron Treated (Exposed to UV Light)	0.60

* All test results are average of triplicate tests

RELATIONSHIP BETWEEN WATER ABSORPTION AND CHLORIDE ION CONTENT

Type of treatment	Chloride Ion content, % (0-2” depth)	% Weight Gain 21 days in 15% NaCl Solution	Calculated percent chloride ion in solution absorbed
Control (Untreated)	0.263	2.89	9.1
Control (Untreated) Exposed to UV light	0.267	2.92	9.1
Penetron treated	0.027	0.57	4.7
Treated (Exposed to UV Light)	0.029	0.60	4.8

REDUCTIONS OF WATER ABSORPTION AND CHLORIDES INTO CONCRETE

Type of treatment	Reduction of Water Absorption into Concrete, %	Reduction into Chloride Content in Concrete, % (*)
Penetron Treated	80.2	89.7
Penetron Treated (Exposed to UV	79.5	89.1

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* 0-2 inch depth

5/1/2006	**REPORT NO.: 06-3241**		
	Sor Testing Laboratories, Inc., Cedar Grove, NJ		
	Shrinkage, Modulus, Resistance to Chlorides & Creep Test of Penetron Admixture Treated Concrete		
Resistance to Chloride Penetron			
Age, days	Depths, inches	Chloride (Cl) Contents (‘)	
		mg/kg	lbs/cu yard
60	0.0625 to 0.50	37	0.14
	0.50 to 1.0	24	0.09
90	0.0625 to 0.50	42	0.16
	0.50 to 1.0	26	0.10

(*) The dry unit weight of the concrete was 3915 lbs./cu. yard.

COMPRESSIVE STRENGTH TESTING

1/051998	**REPORT NO.: B22906/DJ/1**
	Setsco Services PTE LTD
	Determination of compressive strength water absorption, water permeability and scaning electronic Microscopic (SEM) Examination on concrete cubes treated with Penetron Admixture
	Result: According to BS 1881: Pt 166: 1993

TABLE 1 : COMPRESSIVE STRENTH									
Sample Referance	Concrete treated with PENETRON Admix								
Specimen Reference	1	2	3	4	5	6	7	8	9
Size OF Cube (mm)	150								
Date of cast	01/12/97								
Date of cast	08/12/97			15/12/97			29/12/97		
Age At Test (days)	7			14			28		
Compression straingth (N/mm2)	34.0	34.0	33.5	38.0	38.5	38.5	41	41.5	41.5
Average Compression straingth (N/mm2)	34.0			38.5			41.5		

0122/1998	**REPORT NO.: B22906/DJ/2**
	Setsco Services PTE LTD
	Determination of compressive strength on concrete cubes treated with Penetron Admixture
	Result: According to BS 1881: Pt 166: 1993

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TABLE 1 : COMPRESSIVE STRENTH			
Sample Referance	Concrete treated with PENETRON Admix		
Specimen Reference	1	2	3
Size OF Cube (mm)	150		
Date of cast	01/12/97		
Date of cast	26/01/98		
Age At Test (days)	56		
Compression straingth (N/mm2)	45.0	43.0	44.0
Average Compression straingth (N/mm2)	44.0		

05/31/2001	**REPORT NO.: A3747/WCW**
	Setsco Services PTE LTD
	Report on Performance Assessment of Penetron Waterproofing Admixture
	Results: The compressive strength of concrete cubes made and tested at 28 days average 47.50 N/mm^2. The 7 days strength average at 44.0 N/mm^2. In some case, there were little gain in strength from 7 to 28 days and in other, the gain was as much as 14%. The average 7 and 28 days compreesive strength of the control concrete was 41.5 and 46.0 N/mm^2 respectively. The figures show that the admnixture did not have any adverse effect on the strength of the concrete.

09/01/02	**ACCI REF. NO.: 58036**
	The Australian Centre for Construction Innovation; University of New South Wales
	An Investigation of Plastic and Other Early Age Properties of a Concrete Containing Penetron Admix
	Results: The compressive strength of the Mix-PX at age 3 days was 1.37 times that of the control mix Mix-CT. At the age of 7 days, the compressive strength of Mix-PX was 1.30 times that of the control. The addition of Penetron Admix into concrete increased the early concrete strength significantly.

TABLE 2: TEST RESULT OF CONCRETE AT 3 AND 7 DAYS		
Test Item	**Mix- PX (Control)**	**Mix-CT (Admix)**
Compressive Strength at 3 Days	23.0 MPa	16.7 MPa
Compressive Strength at 7 Days	31.4 MPa	24.2 MPa
SSD Density at 7 Days	2372 kg/m^3	2341 kg/m^3

12/01/02	**ACCIREF. NO. 58324**
	Compressive Strenght at 3,7,28 and 91 days (AS 1012.9) Results: Cylinder specimens were cast from both Mix_P and Mix-C concrete batches. The specimens were initiually cured in moulds and covered with wet hessian in temperature-contreolled room at 23°C. They were removed from the moulds approximately 24 hours after casting and then cured in a limewater tank at 23°C. The compressive strength was tested in cylinder specimens according to the AS 1012.9. The Compressive strength of the Mix-P was 1.22 to 1.37 times that of the control Mix-C at ages between 3 days to 91 days despite the slump of Mix-P (130mm) being much higher than that of Mix-C (80mm). It was apparent that the use of the Penetron Admix in concrete significantly increased the concrete strength. The increase in compressive strength by the Penetron Admix was proportionately greater at the early ages of 3 and 7 days. An important benefit of the rapid early strength gain is to permit stiping of formwork earlier and to speed up the construction process. In the comparison of the compreesive strength of two concretes, it was repoeerted in Section 4.1 that the air content in the fresh concrete Mix-P would be expected to contribute to its higher compreesive strength at all the ages from 3 to 91 days.

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11/11/03	REPORT NO.: 2003CB1133
	Sirim Qas International Sdn, Bhd., Malaysia
	MS 26: Part 2: 1991: Method of Testing Concrete Part 2: Method of Testing Hardened Concrete: Section Three: Method for determination of Compressive Strength of Concrete Slabs
	Results: After 7 days, the sample with Admixture showed an average compressive strength of 25 MN/m^2 opposed to the control, which showed a compressive strength of 24.5 MN/m^2. After 28 days, the sample with Admixture showed an average compressive strength of 36 MN/m^2 and the control showed a compressive strength of 34.5 MN/m^2.

12/01/03	ACCIREF.NO.: J#61707
	The University of New South Wales: The Australian Centre for Construction Innovation
	Testing Properties of a Commercial Concrete Mix Modified with Penetron Admix
	Results: Compressive Strenght at 3, 28 and 91 days (AS 1012.9)

Table 1. Compressive Strenght of Concrete at 3, 28, and 91 Days			
Concrete Age (day)	3	28	91
Compressive Strenght (MPa)	22.2	39.6	43.5

08/31/04	REPORT NO: 2004A102007
	Shanghai Research Institute of Building Sciences
	Research Report on Performance Improvement of Concrete and Mortar treated with Penetron and Penetron Admix Compressive strength, flexural strength and tensile strength of concrete specimens according to China Standard.
	Results: Penetron Admix enhanced the workability and plastic properties of concrete by reducing the water demand. The addition of Penetron Admix increased compressive, flexural and tensile strengths, and significantly reduced chloride permeability when compared to control concrete with similar slump.

*Copies of the full test report documents are available upon request. Please contact your PENETRON® representative.

	POLITECHNIKA KRAKOWSKA (TECHINICAL UNIVERSITY IN KRAKOW)
	Testing Report of Concrete Additive Penetron Admix
	Results: After 28 days, the sample treated with Penetron Admix I/I showed a result of 46MPa opposed to the control (Untreated) concrete I, which showed 42 MPa. Penetron Aadmix II/I showed a result of 45MPa As compared to control II of 43 MPa.

10/10/2005	REPORT NO. 05-4070A
	Sor Testing Laboratories, Inc., Cedar Grove, NJ
	Laboratory Tests of Penetron Admix in Concrete
	Results: As per ASTM-C39, Penetron Admix treated concrete showed improvements over the control (untreated) concrete with a higher compressive strength.

5/1/2006	REPORT NO.: 06-3241
	Sor Testing Laboratories, Inc., Cedar Grove, NJ
	Shrinkage, Modulus, Resistance to Chlorides & Creep Test of Penetron Admixture Treated Concrete
	Result: The concrete mix tested meets the high performance concrete requirements of the NJ DOT specification requirements for the parameters tested.

Compressive Strength (ASTM C-39)		
Cylinder No.	**Age, days**	**psi**
A	28	5290
B	28	5230
C	56	5880
D	56	5910

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CRACK HEALING TESTING

12/12/1/2006	ACCIREF.NO.58324-AUTOGENOUS CRACK HEA;LING CAPACITY (ACCI METHOD)
	The Australian Centre for Construction Innovation; University of New South
	Properties of Type GP Cement Concrete Modified with Penetron Admix
	Results: It was shown that both concretes had recorded reduced leakage tare through the crack in concrete samples. This is the so_called "autogenous crack healing" capacity of cement concrete due to further hydration of the unhydrated cement particles exposed in the crack zone. However, Penetron Admix concrete Mix-P had shown significantly higher crack-healing capacity than the control concrete Mix-C. After 70 days exposure to moist atmosphere, the water leakage through the cracks in the concrete Mix-P reduced by 73% while that in the control concrete Mix-C reduced by 35%. The greater crack-healing capacity of the concrete Mix-P appears to be primarily attributable to the crystallization mechanism of the Penetron Admix.

CREEP TESTING

5/1/2006	**REPORT NO.: 06-3241**
	Sor Testing Laboratories, Inc., Cedar Grove, NJ
	Shrinkage, Modulus, Resistance to Chlorides & Creep Test of Penetron Admixture Treated Concrete
	Results: The concrete mix tested meets the high performance concrete requirements of the NJ DOT specification requirements for the parameters tested.

Creep Test (ASTM C-512)

Cylinder No.	**Creep: inch/inch/psi**	
	2 moths	20 years (*)
1	1.05×10^{-6}	0.31×10^{-6}
2	1.08×10^{-8}	0.32×10^{-6}

(*) Estimated from ACI Journal Proceedings 66 (12, December 68)

DRYING SHRINKAGE TESTING

12/01/02	**ACCI REF. NO.: 58324**
	The Australian Centre for Construction Innovation; University of New South Wales
	Properties of Type GP Cement Concrete Modified with Penetron Admix
	Results: The results of standard drying shrinkages of the two concretes are shown in the following Table 4.3-1. The drying shrinkage values of the two concretes were very similar at each age despite the slump of Mix-P (130mm) being much higher than that of Mix-C (80mm). After the drying period of 56 days, the drying shrinkages of Mix-P and Mix-C were both relatively low at 455 and 443 micostrains respectively. These shrinkage valuea are much lower than the maximum shrinkage of 700 microstrains under exposure classification B1 and B2, and 600 microstrains under exposure classification C specified in the RTA (NSW) QA Specification B80 for "Concrete Works for Bridges".

TABLE 4.3-1 DRYING SHRINKAGE OF CONCRETE (AS 1012.13)

Drying Shrinkage (microstrain)

Drying Age A (day)	0	4	7	14	21	28	56	91
Mix-P	0	100	145	229	292	337	455	524
Mix-C	0	81	119	205	276	323	443	505

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12/01/03	ACCI REF. NO.: J#61707
	The University of New South Wales: The Australian Centre for Construction Innovation
	Testing Properties of a Commercial Concrete Mix Modified with Penetron Admix
	Results: Drying shrinkage of the concrete was measured with three prism samples according to AS 1012.13. The monitoring of changes in the specimen length due to drying shrinkage was extended from the normal period of 56 days to 91 days.

TABLE 2. DRYING SHRINKAGE OF CONCRETE (AS 1012.13)								
Drying Age (day)	0	4	7	14	21	28	56	91
Drying Shrinkage (microstrain)	0	121	169	269	355	404	530	598

5/1/2006	REPORT NO.: 06-3241
	Sor Testing Laboratories, Inc., Cedar Grove, NJ
	Shrinkage, Modulus, Resistance to Chlorides & Creep Test of Penetron Admixture Treated Concrete
	Result: The concrete mix tested meets the high performance concrete requirements of the NJ DOT Specification requirements for the parameters tested.

DRYING SHRINKAGE		
Condition	**Age, days**	**% Shrinkage (*)**
In Water	7	0.011
	28	0.013
In Air	7	0.018
	28	0.020

(*) Average of duplicate specimens

ELASTICITY TESTING

5/1/2006	REPORT NO.: 06-3241
	Sor Testing Laboratories, Inc., Cedar Grove, NJ
	Shrinkage, Modulus, Resistance to Chlorides & Creep Test of Penetron Admixture Treated Concrete
	Result: The concrete mix tested meets the high performance concrete requirements of the NJ DOT specimen requirements for the parameters tested.

MODULUS OF ELASTICITY (ASTM C-469)		
Cylinder No.	**Age, days**	**psi**
A	28	4.65×10^6
B	28	4.61×10^6
C	56	5.42×10^6
D	56	5.47×10^6

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FREEZE-THAW RESISTANCE

2/3/2004	REPORT NO.: 73/04
	Tallinn Technical University Testing Center: Building Materials' Testing Laboratory of the Institute Contruction Production, Estonia
	Determination of Frost Resistance of Concrete Cubes
	Results: The pressure resistance of the concrete cubes was determined following the requirements of COST 10180-90 and frost resistance according to the requirements of COST 10060-87 II method. The cube treated with Penetron Admix did not change in mass during the determination of their frost resistance. The other cubes experienced an average of loss of 0.1% in mass. The average pressure resistance of the cubes comparing with the figures of the control cubes had fallen to 3.7%.

10/10/2005	REPORT NO. 05-4070A
	Sor Testing Laboratories, Inc., Cedar Grove, NJ
	Laboratory Tests of Penetron Admix in Concrete
	Results: As per NY DOT Method of 502-3P, the concrete specimens were subjected to a 3% sodium chloride solution in 25 cycles of freeze thaw. The Penetron Admix treated specimen showed good durability under severe freeze thaw conditions with an average of 0.74% weight loss opposed to the control specimen with a 4.97% weight loss.

5/1/2006	REPORT NO.: 06-3241
	Sor Testing Laboratories, Inc., Cedar Grove, NJ
	Shrinkage, Modulus, Resistance to Chlorides & Creep Test of Penetron Admixture Treated Concrete
	Results: The concrete mix tested meets the high performance concrete requirements of the NJ DOT specification requirements for the parameters tested.

FREEZE-THAW DURABILITY (ASTM C-666)

Specimen No.	% Weight Loss	Relative Durability, % (*)
A	0.06	97.4
B	0.09	98.0
C	0.08	97.8
Average:	0.08	97.7

(*) ASTM C-494 requires a minimum durability factor of 80%

*Copies of the full test report documents are available upon request. Please contact your PENETRON® representative.

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PERMEABILITY TESTING

01/05/1998	**REPORT NO.: B22906/DJ/1**
	Setsco Services PTE LTD
	Determination of compressive strength, water absorption, water permeability and scanning electronic Microscopic (SEM) Examination on concrete cubes treated with Penetron Admixture
	Results: DIN 1048: Pt 5: 1991

TABLE 2: WATER PERMEABILITY TEST

Sample reference	**Concrete treated with Penetron Admix**					
Specimen reference	**1**	**2**	**3**	**4**	**5**	**6**
Date of Cast	**01/12/97**					
Date of water pressure applied	**08/12/97**			**30/12/97**		
Age at Test (days)	**7**			**29**		
Water pressure applied (N/ mm^2)	**0.5**					
Duration of test (hours)	**72**					
Depth of penetration (mm)	**18.**	**22.4**	**18.8**	**11.0**	**11.0**	**9.7**
Average depth of penetration (mm)	**20.0**			**10.6**		

05/31/2001	**REPORT NO.: A3747/WCW**
	Setsco Services PTE LTD
	Report on Performance Assessment of Penetron Waterproofing Admixture
	Results: Penetron Admixture has evidently reduced the porosity and permeability even of a water tight control and laboratory prepared concrete without reducing the water cement ratio. The improvement is expected to be more pronounced in concrete of lower quality and concrete cast in-situ. The coefficient of water permeability of the treated concrete is in the range of 10^{-13} m/s. Based on the guidelines given in DIN 1045, the treated concrete complies with the requirements for water resistant/waterproof concrete.

11/28/2002	**UNIT OF GEO-TECHNICAL STUDIES, FACULTY OF CIVIL ENGINEERING, UNIVERSITY OF ALEPPO, SYRIA**
	Technical Report About The Activity of Penetron Admix Industrial Material in The Impermeability of Beton Castings
	Results: The beton samples, to which the Penetron Admix Synthetic material is added, showed good results in high pressure (6-8 bars) permeability. The highest impermeability was observed on 10-14 day after treatment.

6/29/ 12/1/2002	**REPORT NO: ACCIREF. NO. 58324**
	The Australian Centre for Construction Innovation, Properties of Type GP Cement Concrete Modified with Penetron Admix
	Water Permeability Test (ACCI Method)
	Results: According to a review of permeability test methods published by British Concrete Society, concrets with permeability coefficients below 1 x 10^{-12} arev considered to be a very good while concrete with permeability coefficients between 1 x 10^{-12} m/sec are considered to be acceptable.

TABLE 4.9-1 COEFFICIENT WATER PERMEABILITY (ACCI-METHOD)

Test Item	**Mix-P (Treated Sample)**	**Mix-C(Control Sample)**	**Water Permeability Coefficient Reduction**
Coefficient of Water permeability (m/sec)	**1.76 x 10^{-12}**	**7.24 x 10-^{12}**	**Water Permeability Test (ACCI Method)**

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6/29/2005	REPORT NO.: 38/2005
	University of Bologna: Department of Earth, Geological and Environmental Sciences
	Water absorption at atmospheric pressure and under pressure conducted on a total of 42 cylindrical concrete samples.
	Results: Water absorption under atmospheric pressure shows that after 28 days of immersion, the sample treated with Penetron Admix showed a mean of 1.82 for W_{MS} and 1.98 for W_{MT}. The control showed results of 3.60 W_{MS} and 3.94 W_{MT}. The results for the water absorption under pressure expressed in mm of penetration at pressure of 700kPa and 2000 kPa indicate that the sample with Penetron Admix shows a mean of 4.8 kPa=700mm and 7.6 kPa=2000mm. The control shows a result of 15.3 kPa=700mm and 22.7 kPa=2000mm.

10/10/2005	REPORT NO. 05-4070A
	Sor Testing Laboratories, Inc., Cedar Grove, NJ
	Laboratory Tests of Penetron Admix in Concrete
	Results: As per ASTM-D 5084, the Penetron Admix treated concrete showed improvements of an average permeability of 2.45×10^{-10} cm/sec over the control (untreated) concrete of 3.66×10^{-8} cm/sec.

3/29/2006	REPORT NO.: 06-1918
	Sor Testing Laboratories, Inc., Cedar Grove, NJ
	Laboratory Testing of Penetron Admixtures As Per NCHRP-244 Methods
	Results: As per requirements of the National Cooperative Highway Research Program Report 244, the moisture loss of the untreated specimens at the age of 28 days was 2.10% by weight of the concrete. This amount of loss is normal for concrete exposed to 50% relative humidity at normal air temperatures. At the age of 7 days, the water loss was only 0.05%. This is expected since during the first 7 days, the cubes were in 100% relative humidity. The water losses of the treated specimens during the 14 days in the controlled room at 50% relative humidity were between 0.017 and 0.018 grams per cm^2 area. It should be noted that the average reduction in the moisture loss, as compared to the control was 81.1%. Exposure to ultraviolet light did not have any significant effect on the performance of the treated samples.

	POLITECHNIKA KRAKOWSKA (TECHINICAL UNIVERSITY IN KRAKOW)
	Testing Report of Concrete Additive Penetron Admix
	Results: Concrete with Penetron Admix I/I showed W28 (1.0MPa) and the control concrete I showed W8 (0.8MPa). Concrete with Penetron Admix II/I showed W30 (3.0MPa) to the control concrete II of W9 (1.4MPa)

SCALING RESISTANCE TESTING

10/10/2005	REPORT NO. 05-4070A
	Sor Testing Laboratories, Inc., Cedar Grove, NJ
	Laboratory Tests of Penetron Admix in Concrete
	Results: Specimens used were 12x12x3" with a salt solution of calcium chloride. After 50 cycles of freeze thaw, specimens were reted according to ASTM-C672. Penetron Admix concreted very slight scaling opposed to the control (untreated) concrete, with showed moderate to severe scaling.

3/29/2006	REPORT NO.: 06-1918
	Sor Testing Laboratories, Inc., Cedar Grove, NJ
	Laboratory Testing of Penetron Admixture As Per NCHRP-244 Methods
	Results: The scaling resistance test results indicated that the Penetron treated concrete had only trace amount of scaling, while the control samples had moderate to severe scaling when exposed to chloride salts under freeze-thaw conditions.

TEST RESULTS OF ASTM C-672

Sample ID	After 100 Cycles of Freeze-Thaw (*)
Control (Untreated)	Moderate to Severe Scaling
Penetron Treated	Trace Scaling

* Three specimens per treatment

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SEM X-RAY ANALYSIS

05/31/2001	REPORT NO.: A3747/WCW
	Setsco Services PTE LTD
	Report on Performance Assessment of Penetron Waterproofing Admixture
	Results: The SEM-EDX analysis conducted on the treated concrete showed the presence of dendritic crystals, which are found in pores such as capillary tracts, shrinkage cracks and bleed water tracts that allow crystallization of the additional cementitious material. This clearly shows the crystallization effect of Penetron Admixture, which reduces and seals the pores in the concrete. This will effectively enhance the durability of the concrete by preventing ingress of water and chemicals that destroy the matrix of the cement hydrate.

10/25/2002	REPORT NO.: A6127/CHF
	Setsco Services PTE LTD
	Microscopic Analysis on the Concrete Cores From Retaining Wall at Changi Airport Terminal 3
	Results: A lot of coarse-grained elongated crystals were seen lining the crack. All these crystals showed low birefringence under crossed polarized microscope. The coarse grained elongated crystal contained mainly Ca, O, and Si. The fine grained neele-like crystal was predominantly made up of Ca, Si, O, S, which was probably ettringite.

12/1/2002	ACCI REF. NO.: J060673 & J061037
	University of New South Wales: The Australian Centre for Construction Innovation
	Microscopic Examination of Crystalline Products in Penetron Admix Modified Concrete Samples After a Crack Healing Test Result
	Results: The observation from a comprehensive SEM examination of the Penetron Admix modified Type GP concrete samples demonstrate significant evidence of a crystallization mechanism by which the Penetron Admix reacts with cement hydrates to form characteristic crystalline networks and effectively seal cracks in the modified concrete.

TABLE 1. CRACK HEALING CAPACITY (ACCI-METHOD)

Crack Healing Time (from Concrete Age 21 Days)	Relative Leakage Rate through Cracks in Penetron Modified Concrete (Mix-P)
0 Days	100%
21 Days	88%
70 Days	27%
151 Days	12%

SETTING TIME TESTING

12/01/06	ACCI REF.NO.58324 - INITIAL SETTING TIME AND FINAL SETTING TIME
	The University of New South Wales: The Australian Centre for Construction Innovation
	Properties of Type GP Cement Concrete Modified with Penetron Admix
	Results: Initial setting time for the Mix-P was 20 minutes shorter than that of the control mix, while the final setting time of Mix-P was 45 minutes shorter. The short setting time in conjuction with less bleed is generally beneficial to concrete construction because of a reduced time period between concrete casting and surface finishing on site. This was determined according to the procedures of AS 1012.18.

SLUMP TESTING

12/1/2003	ACCI REF. NO.: J#61707
	The University of New South Wales: The Australian Centre for Construction Innovation
	Testing Properties of a commercial Concrete Mix Modified with Penetron Admix
	Results: The slump test of fresh concrete was carried out at the time of arrival of the concrete truck at the ACCI Laboratory. The slump of the concrete batch was measured to be 80mm.

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*Copies of the full test report documents are available upon request. Please contact your PENETRON® representative.

12/01/02	ACCI REF. NO. 58324
	The University of New South Wales: The Australian Centre for Construction Innovation
	Properties of Type GP Cement Concrete Modified with Penetron Admix
	Results: While the target slump was 80 mm for both concrete batches, the slump of Mix-P (130mm) was found to be much higher than that of the control Mix-C (80mm) when tested at the ACCI (Slump test undertaken with fresh concrete according to AS 1012.3.1 with the designed target slump of 80mm for both concrete mixes) A possible explanation is that the addition of the Penetron Admix into Mix-P had significantly increased the indicated workability of the concrete.

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REVIEW OF PENETRON ADMIX TEST REPORTS BY SETSCO SERVICES IN SINGAPORE

1. Introduction

This review is intended for the use of Reverton Engineering (S) Pte Ltd and is based on the documents provided by Reverton Engineering (S) Pte Ltd as listed in Section 2. The specific objectives are:

1.1 Performance of Penetron in comparison to control mix without Penetron.
1.2 Detection of crystals in microstructure of hardened concrete containing Penetron.

2. Documents

2.1 ICS Penetron – Integral Capillary Permanent Waterproofing System
2.2 Report on Performance Assessment of Penetron Waterproofing Admixture (Ref:A3747/WCW) prepared for Reverton Engineering (S) Pte Ltd by Wong Chung Wan, Karen Tay Yen Ping and Chen Hong Fang of SETSCO Services Pte Ltd dated 31/05/2001.
2.3 Test Report (Ref:A6127/CHF) prepared by SETSCO Services Pte Ltd dated 25/10/02 titled Microscopic Analysis on the Concrete Cores from Retaining Wall at Changi Airport Terminal 3.
2.4 Test Report (Ref: A6348/JAS/1) prepared by SETSCO Services Pte Ltd dated 21/01/2003, entitled Determination of Water Penetration on 150mm Concrete Cubes Submitted by Reverton Engineering (S) Pte Ltd on 16/01/2003.
2.5 Test Report (Ref: A6348/JAS/2) prepared by SETSCO Services Pte Ltd dated 31/01/2003, entitled Determination of Water Penetration on 150mm Concrete Cubes Submitted by Reverton Engineering (S) Pte Ltd on 16/01/2003.
2.6 Test Report (Ref: A6349/JAS/1) prepared by SETSCO Services Pte Ltd dated 31/01/2003, entitled Determination of Water Penetration on 150mm Concrete Cubes Submitted by Reverton Engineering (S) Pte Ltd on 16/01/2003.
2.7 Test Report (Ref: A6349/JAS/2) prepared by SETSCO Services Pte Ltd dated 30/01/2003, entitled Determination of Water Penetration on 150mm Concrete Cubes Submitted by Reverton Engineering (S) Pte Ltd on 16/01/2003.
2.8 Test Report (Ref: A6352/JAS/1) prepared by SETSCO Services Pte Ltd dated 17/02/2003, entitled Determination of Water Penetration on 150mm Concrete Cubes Submitted by Reverton Engineering (S) Pte Ltd on 10/02/2003.
2.9 Test Report (Ref: A6352/JAS/2) prepared by SETSCO Services Pte Ltd dated 17/02/2003 entitled Determination of Water Penetration on 150mm Concrete Cubes Submitted by Reverton Engineering (S) Pte Ltd on 10/02/2003.
2.10 Test Report (Ref: A6352/JAS/3) prepared by SETSCO Services Pte Ltd dated 26/02/2003, entitled Determination of Water Penetration on 150mm Concrete Cubes Submitted by Reverton Engineering (S) Pte Ltd on 10/02/2003.
2.11 Test Report (Ref: A6352/JAS/4) prepared by SETSCO Services Pte Ltd dated 26/02/2003, entitled Determination of Water Penetration on 150mm Concrete Cubes Submitted by Reverton Engineering (S) Pte Ltd on 10/02/2003.
2.12 Review of results of Tests on Concrete with Penetron Admixture (Ref: G1174/WCW) prepared for Reverton Engineering (S) Pte Ltd by Wong Chung Wan of SETSCO Service Pte Ltd dated 04/04/03.
2.13 Test Report (Ref: A6612/JAS/1) prepared by SETSCO Services Pte Ltd dated 07/04/2003, entitled Determination of Water Penetration on 150mm Concrete Cubes Submitted by Reverton Engineering (S) Pte Ltd on 02/04/2003.
2.14 Test Report (Ref: A6612/JAS/2) prepared by SETSCO Services Pte Ltd dated 23/04/2003, entitled Determination of Water Penetration on 150mm Concrete Cubes Submitted by Reverton Engineering (S) Pte Ltd on 02/04/2003
2.15 Test Report (Ref: A6577/JAS) prepared by SETSCO Services Pte Ltd dated 27/04/2003, entitled Determination of Water Penetration on 150mm Concrete Cubes Submitted by Reverton Engineering (S) Pte Ltd on 27/03/2003
2.16 Test Report (Ref: A6665/JAS/1) prepared by SETSCO Services Pte Ltd dated 28/04/2003, entitled Determination of Water Penetration on 150mm Concrete Cubes Submitted by Reverton Engineering (S) Pte Ltd on 23/04/2003.
2.17 Test Report (Ref: A6665/JAS/2) prepared by SETSCO Services Pte Ltd dated 09/05/2003, entitled Determination of Water Penetration on 150mm Concrete Cubes Submitted by Reverton Engineering (S) Pte Ltd on 23/04/2003.
2.18 Copies of two pages containing tabulated results of Water Penetration tests – DIN 1048:Part 5:1991, Water Permeability Tests – Housing and Development Board Test Method for Coefficient Permeability and Stiffening Time for treated and control concrete test samples.
2.19 Copies of four sheets of compressive strength test results by SETSCO Services Pte Ltd dated 25/01/03, 27/01/03, 15/02/03, and 17/02/03 respectively.

Test reports are listed in chronological order. All the listed documents in this Section are not reproduced in this Review but they should be read together with the comments in this Review.

*Copies of the full test report documents are available upon request. Please contact your PENETRON® representative.

3. Review On Documents

The documents listed in Section 2 above are reviewed either individually or in groups as indicated under each sub-heading.

3.1 Document 2.1

This document is a brief summary on the waterproofing admixture "Penetron" describing the mechanism of formation of crystalline barriers. Basically, the admixture contains active silicates that can react with the calcium hydroxide liberated by the hydration of the Portland cement in concrete mixes. These additional products are formed in the capillaries of the cement paste structure and in voids or cracks present in the concrete.

3.2 Document 2.2

This Report is a review of test results based on concrete prepared with ordinary Portland Cement at a water-to-cement ratio of 0.46. The water content is 185 kg/m3 , cement content of 398 kg/m3 and the dosage of Penetron used in the treated mix is 0.8 kg per 100 kg of cement (3.18 kg for a cement content of 398 kg/m3).

The compressive strength of the mixes with and without the addition of Penetron had similar compressive strength at 28 days. The water penetration data (DIN 1045) at 7, 21 and 28 days showed a significant reduction (40 to 60%) in penetration depth. "Crystallization of additional cementitious materials" was observed "in pores such as capillaries, cracks and bleed water tracts" under 3000 to 4000 magnifications. Coefficient of permeability values of 5 and 7 x 10^{-13} m/s were reported at ages of 28 and 7 days respectively for the mix with Penetron but no test was conducted on the control plain mix.

3.3 Document 2.3

This Report is on cores taken from locations with observed surface cracks for microscopic examination. The concrete in the structure is likely to be similar to the mix with Penetron in Document 2.2 (same project was indicated in both Documents). The main finding is that "coarse-grained elongated crystals and fine grained needle-like crystals" are observed in cracks. The first is identified as calcium silicates and the second, "probably ettringite".

3.4 Documents 2.4 to 2.11, Document 2.13 to 2.19

The results for each type of test are tabulated separately for comparison.

3.4.1 Mix Design

Mix Reference	Cement (kg/m³)	Water (kg/m³)	Sand (kg/m³)	Course Agg. (kg/m³)	Daratard Mira 99 (ml/100kg cement)	Penetron (kg/100kg cement)
Control	380	160	780	1000	800	
0.8 Mix	380	160	780	1000	800	0.8
1.0 Mix	380	160	780	1000	800	1.0

The nominal water-to-cement ratio is 0.42 for both mixes.

3.4.2. Slump and Stiffening Times

Mix Reference	Control	0.8 Mix	1.0 Mix
Slump – mm	120	110	100
Initial – min	345	375	480
Final – mm	450	510	630

The mixes have similar slump but Penetron dosage increases stiffening times. However, it should be noted that the report indicated that the test is in accordance with SS 320:1987 for which the two stiffening times are specified as to penetration resistance of 0.5 MPa and 3.5 MPa respectively and are not referred to as "Initial" and "Final". On the other hand ASTM C 403 defines penetration resistance of 3.5 MPa and 27.6 MPa as "Initial" and "Final" setting times respectively. The test results are likely to be those in accordance with ASTM C 403 penetration resistance levels.

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3.4.3. Compressive Strength

Only the Control and 0.8 Mix result are provided. The mean and range for each mix and test age are based on 3 batches of 3 cubes each (i.e. 9 cubes)

Mix Reference	Compressive Strength (Pa)			
	7 days – Mean	7 days – Range	28 days – Mean	28 days - Range
Control	39.5	5.5	50.5	3.5
0.8 Mix	38.0	3.5	55.5	2.0

The addition of Penetron tends to lower early age strength but leads to a slightly higher 28 days strength. A slower rate of early strength development often produces a better later age strength. However, the differences are to likely to have a major effect on the other properties reported in the following sections.

3.4.4 Water Penetration to DIN 1048:part5:1991

The mean and range for each mix and test age are based on 3 samples.

Mix Reference	Depth of Water Penetration (mm)			
	7days-Mean	7 days - Range	28 days - Mean	28 days - Range
Control	28.7	3.2	21.7	3.3
0.8 Mix (Plant 1)	17.6	2.8	9.5	2.6
0.8 Mix (Plant 2)	12.3	5.1	14.1	5.2

The mean penetration for Plant 2 at the age of 28 days is higher than that at the age of 7 days. This is not as expected. For both ages, the range of results is higher than the others. In spite of this, the results indicate that the addition of Penetron has reduced the penetration depth to significant extent at both ages. The results at 7 days are already lower than that of the control mix at 28 days.

3.4.5 Water Permeability

The mean and range for each mix and test age are based on 3 samples.

Mix Reference	Water Permeability Coefficient (m/s)			
	7 days – Mean	7 days – Range	28 days – Mean	28 days - Range
Control	16.5×10^{-13}	1.3×10^{-13}	18.6×10^{-13}	4.0×10^{-13}
0.8 Mix (Plant 1)	7.84×10^{-13}	1.71×10^{-13}	6.05×10^{-13}	1.35×10^{-13}
0.8 Mix (Plant 2)	6.95×10^{-13}	0.31×10^{-13}	5.98×10^{-13}	1.28×10^{-13}

The addition of Penetron has reduced the permeability coefficient significantly. The results at 7 days are already lower than that of the control mix at 28 days.

3.5 Document 2.12

The mix proportions indicated in this document show sand content of 780 kg/m3 and course aggregate content of 800 kg/m3 and the others similar to those of the (0.8 mix) in document 2.15 (as shown in Section 3.4.1 above). It is likely that the coarse aggregate in this document should also be 1000 kg/m3 (such that the density is in the expected range of 2300 to 2400 kg/m3).

The scanning electron microscope image at 9,000 magnification shows only very small amount of needle-like crystals. Their identification of their composition is not yet available. The cement used in this case is a high slag cement compared to ordinary Portland cement (Document 2.3) for which the reaction products of Penetron were observed. Several factors may be advanced for the difference.

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(a) The use of a high slag cement results in a denser paste structure and the slag is also in competition with the Penetron admixture for the available calcium hydroxide.
(b)
(c) The current mix has a water-to-cement ratio of 0.42 compared to the other at 0.46. The water content of the current mix is 160 kg/m3 compared to the other at 185 kg/m3. The volume of paste as well as the initial water voids of the current mix is lower.
(d)
(e) The crystals were observed, "in pores such as capillaries, cracks and bleed water tracts". The extent of these types of defects is expected to be present in the current sample to be much less.

4. CONCLUDING REMARKS

The test results in the documents listed under section 2 have been reviewed. They clearly indicate the improvement in the permeability coefficient and reduction in penetration depth under the specific test methods used.

The dense structure of the high slag cement paste structure and the much lower extent of defects in the concrete has resulted in a very much less presence of reaction products from Penetron admixture added.

It is recommended that the paste structure of the control mix be examined to provide another source for

comparison. Prepared by Dr. Tam Chat