

CENTRAL LABORATORY

 Av. Rod. Presidente Dutra, km 310 – Jardim das Rosas
 Itatiaia – RJ | CEP 27580-000

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HE-EG-LAB-LT-E-143-14-R3

Issue Date: 02/12/15

Page 1 de 11

Client:	PENETRON BRASIL LTDA		
Reference:	IGENERAL APPLICATIONS		
Center of Cost:	60.001	Proposal:	PC-N00-021-13-R2
Tests Performed: Concrete Chloride Diffusivity Coefficient			

The results of the test (s) and the considerations made in this report have limited significance to the samples and the conditions under which the tests were performed.

1 – Objective:

This report aims to present the results of tests on samples of concrete cast at Holanda Engineering's Central Laboratory located in Itatiaia City, Rio de Janeiro, Brazil aiming high durability applications particularly for marine concrete works.

This report presents results of concrete with water-cement factor of 0.45 to 0.0%, 0.8% and 1.0% Admix (additive integral waterproofing crystallization).

2 – Methodology:

- ✓ NBR 12654/92 – Concrete Technology Control of Components Materials – procedure;
- ✓ NBR 12655/06 – Portland Cement Concrete – Preparation, Control and Receiving – Procedure;
- ✓ NBR 12821/09 – Concrete Laboratory Preparation - Procedure;
- ✓ NBR 5738/08 - Concrete – Procedure for Making and Curing of Cylindrical freshly Concrete Specimens in Laboratory;
- ✓ NBR 5739/07 - Concrete – Compressive Strength of Cylindrical Concrete Specimens;
- ✓ NBR NM 67/98 - Concrete – Standard Method For Slump of Hydraulic Cement Concrete;
- ✓ NBR NM 47/02 - Concrete – Air Content of Freshly Mixed Concrete by the Pressure Method;
- ✓ NT Build 492-11.99 - Concrete, Mortar and Cement-Based Repair Materials: Chloride Migration Coefficient;
- ✓ Durability design of Concrete Structures in severe Environments – ODD E. GJØRV.
- ✓ AASHTO TP 95-11 - Standard Method of Test for Surface Resistivity Indication of Concrete's Ability to Resist Chloride Ion Penetration.

3 – Sample (s):

3.1 Identification of Materials:

Dosage studies were performed with samples received in 4/11/13 and identified as follows:

Type of Material	Client Identification/Description	Laboratory Number
Natural Sand	River Bed Sand Supplier Martins Lara & Lara LTDA	193/13
Coarse Aggregate M.S.A. ¾"	Coarse Aggregate M.S.A. ¾" Supplier Valle Sul Mining Co. - Quarry Pombal	194/13
Cement	CP III 40 RS CSN Cement Plant - Volta Redonda/RJ	192/13
Water Reducer Admixture	Maximent 110 Maxchem	-
Plasticizer Admixture	Maxifluid 900 Maxchem	-
Addition	Penetron Admix	-

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HE-EG-LAB-LT-E-143-14-R3

Issue Date: 02/12/15

Page 2 de 11

3.2 Concrete Mix Design:

3.2.1 Water Cement Ratio 0,45:

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Test Code:	3.01.001
Test Date:	28/10/13 to 28/10/14

	TRIAL MIX	EXP 639	EXP 640	EXP 641
	Date	28/10/13	28/10/13	28/10/13
	Hour	13:25	14:10	14:50
kg/m ³	Blast Slag Cement CPIII 40 RS 192/13	445	443	444
	Active Additions	0,0	0,0	0,0
	Mixing Water (H ₂ O)	200	200	200
	Fine Aggregate (Natural Sand) - 193/13	843	840	841
	Coarse Aggregate ¾" (19mm) - 194/13	872	869	870
Admixtures /Addition	1 - MAXIMENT MX 110	0,6%	0,6%	0,6%
	2 - MAXIFLUID 900	0,3%	0,3%	0,3%
	3 - PENETRON ADMIX	0,0%	0,8%	1,0%
	Water Cement Ratio (W/C)	0,45	0,45	0,45
	m	3,854	3,854	3,854
	k	0,60	0,60	0,60
	H	9,281	9,281	9,281
Temperatures °C	Ambient	28,8	24,6	26,6
	Cement	25,5	25,1	26,0
	Mixing Water	28,5	27,0	27,1
	Fresh Concrete	27,1	26,6	26,7
Fresh and Hardened Concrete Properties	Initial Slump (mm):	260,0	245,0	240,0
	Flow (mm):	560,0	500,0	530,0
	Entraining Air (%):	1,3	1,6	1,5
	Axial Compressive Strength (MPa)			
	28 days	44,5	44,4	46,6
	56 days	52,2	44,9	47,1
	90 days	55,3	48,6	49,4
180 days	63,5	62,3	57,5	

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HE-EG-LAB-LT-E-143-14-R3

Issue Date: 02/12/15

Page 3 de 11

EXP 639



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HE-EG-LAB-LT-E-143-14-R3

Issue Date: 02/12/15

Page 4 de 11

EXP 640



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HE-EG-LAB-LT-E-143-14-R3

Issue Date: 02/12/15

Page 5 de 11

EXP 641



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HE-EG-LAB-LT-E-143-14-R3

Issue Date: 02/12/15

Page 6 de 11

4 – Test Results:

4.1 Chloride Diffusivity Coefficient (CD):

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Test Code:	1.10.007
Test Date:	20/11/13 a 17/11/14

The following are the results of the determination of chloride migration coefficient (DC) and the photographic records from the depth of penetration to the doses tested.

Table 1: Chloride Diffusivity coefficient Determination – Water-Cement Ratio 0,45.

CD (Average Value) (x 10 ⁻¹² m ² /s):	EXP 639 (0,0% Admix)	EXP 640 (0,8% Admix)	EXP 641 (1,0% Admix)
28 days	2,45	2,13	2,46
90 days	3,49	1,51	1,55
180 days	1,67	0,77	0,74

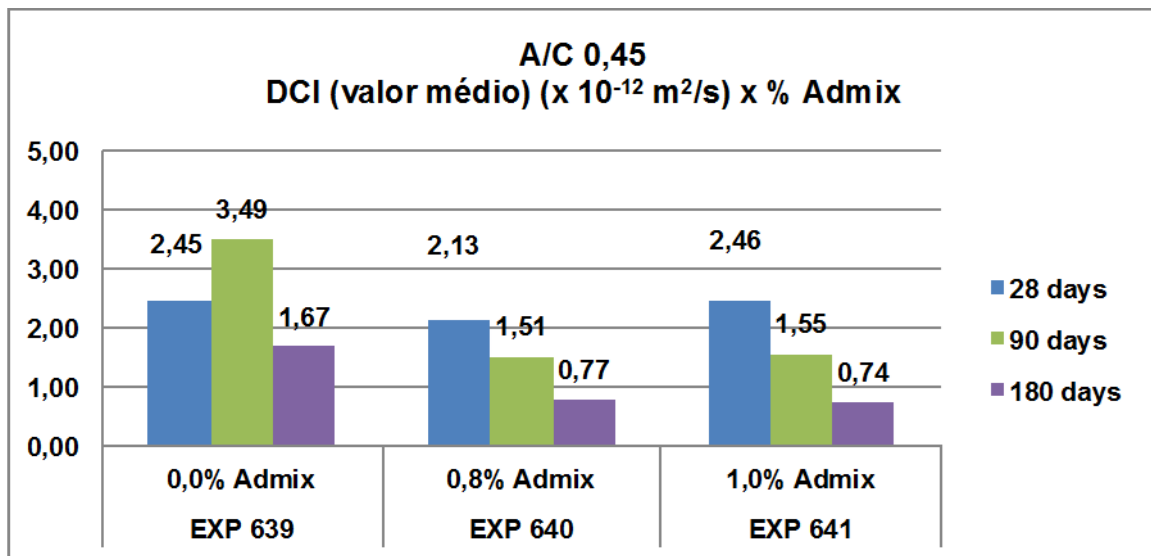


Chart 1: Chloride Diffusivity Coefficient to 28, 90 e 180 days - Water-Cement Ratio 0,45.

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HE-EG-LAB-LT-E-143-14-R3

Issue Date: 02/12/15

Page 7 de 11



Figure 1: Depths of chloride Penetration at 28, 90 and 180 days – EXP 639 (0,0% Admix).

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HE-EG-LAB-LT-E-143-14-R3

Issue Date: 02/12/15

Page 8 de 11



Figure 2: Depths of chloride Penetration to 28, 90 and 180 days – EXP 640 (0,8% Admix).

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HE-EG-LAB-LT-E-143-14-R3

Issue Date: 02/12/15

Page 9 de 11

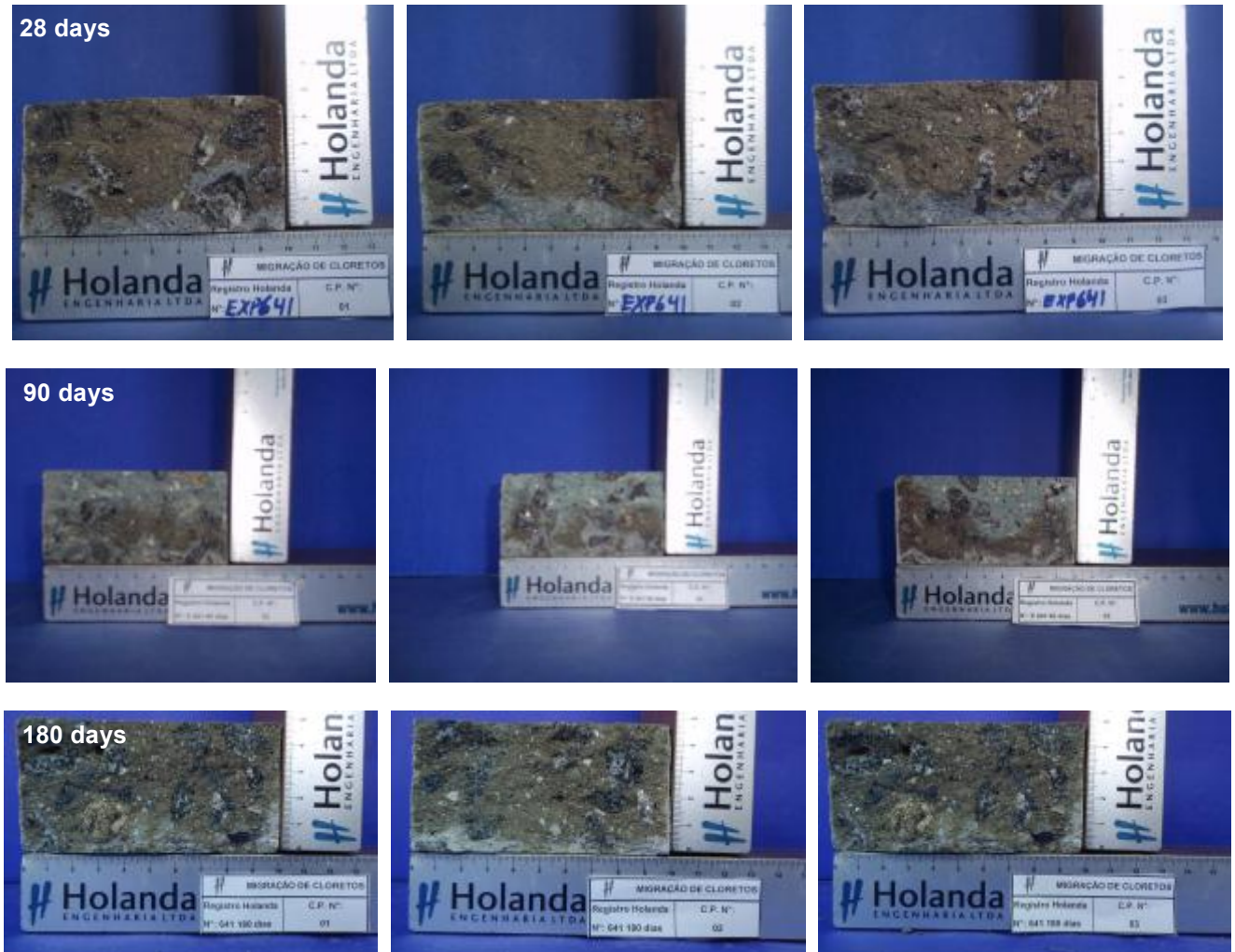


Figure 3: Depths of chloride Penetration to 28, 90 and 180 days – EXP 641 (1,0% Admix).

The table presented below, summarizes the range of values of chloride migration coefficients in reference of resistance to penetration by chlorides:

Chloride Diffusivity Coefficient ($DC_{28} \times 10^{-12} \text{ m}^2/\text{s}$):	Resistance to Penetration by Chlorides
>15	Low
10 – 15	Moderate
5 – 10	High
2.5 – 5	Very High
<2.5	Extremely High

Reference: TABLE 6.2 - Durability design of Concrete Structures in severe Environments – ODD E. GJØRV.

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HE-EG-LAB-LT-E-143-14-R3

Issue Date: 02/12/15

Page 10 de 11

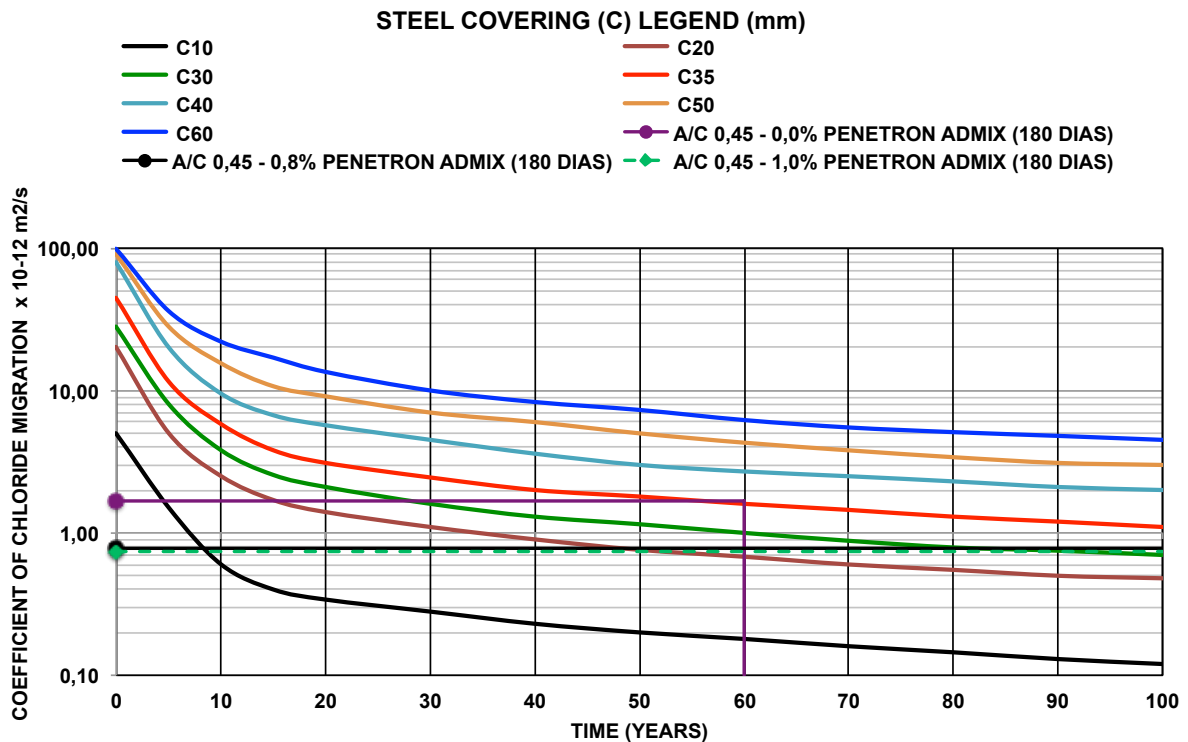
5 – Analysis of the Results

The results of tests obtained by the method of determination of chloride migration coefficient (I_{nn}) classify all the concrete mixes of this program as high durability concrete. The results of tests at the age of 90 days as well as at the age of 180 days classify concretes with very high features to "Extremely High" according to table 6.2 reference-Durability design of Concrete Structures in severe Environments (ODD e. GJØRV) regarding the penetration resistance of chlorides. The results indicate an improvement for this property due to the addition of Penetron, in levels of 0.8% and 1.0%.

The following figure, was developed based on studies presented by German researchers and enlarged by Holanda, F.G. consultant: the abacus relates the coefficient of migration of chlorides with the design concrete steel covering, aimed to estimating the useful life of the concrete structure to which begins some mechanism of corrosion of structural steel.

Based on test values obtained, it is observed that for a 35mm of steel covering for concrete, without the use life of Penetron corresponds to 60 years while using Penetron Admix the ratio of 0.8% relative to weight of cement is sufficient to extend the life of concrete in over 40 years.

This conclusion is very important for use by designers and owners in special projects that require concrete of high chloride durability or in situations previously established by contract or bid documents.



The results at the age of 28 days showed atypical behavior, and for this reason further testing may be carried out for verification of the behavior in younger ages and to other levels of W/C ratio.

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HE-EG-LAB-LT-E-143-14-R3

Issue Date: 02/12/15

Page 11 de 11

Specific requirements should be analyzed according to relevant technical documentation of the Project concerned.

Itatiaia – RJ, 12 de February de 2015.


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