Concrete Waterproofing by Crystallization™

Concrete Durability Enhancement by Crystallization™

CHLORIDE PENETRATION TESTS ON XYPEX ADMIX C-SERIES (C-1000NF) MODIFIED COMMERCIAL CONCRETES

Joint Research Project by
The Australian Centre for Construction Innovation, UNSW & Xypex Australia

By Gary Kao
B.Mat.E, M.sc
Research Engineer

0	14-09-2004	Issued for Information	GK	GJ/GB

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1. INTRODUCTION

In accordance with Xypex Australia's ongoing commitment to research and development, further research has been undertaken to evaluate the impact of the addition of Xypex Admix C-Series (C-1000NF) on commercially batched concretes with a prescription of 435 kg cementitious and a 0.40 water to cement ratio which reflects concrete utilized in areas where durability is a concern.

The concretes selected included supplementary cementitious materials (fly ash and slag) to represent concretes typically used in durable structures.

This abstract outlines the results of the investigation into the impact of the addition of Xypex Admix C-Series on chloride penetration and diffusion rates of the concretes researched. This research was carried out by The Australian Centre for Construction Innovation (ACCI/UNSW). The results reported in this abstract include results from two test methods, namely, **ASTM C1202 (CSIRO modified)** and **ACCI chloride diffusion test in 3% NaCl**.

2. MATERIALS AND TESTING METHODS

The three types of cement used were:

A. AS3972 Type-GB with 25% fly ash (AS3582.1 or ASTM C618 Class F)
B. AS3972 Type-GB slag blend with approximately 38% slag (AS3582.2)
C. AS3972 Type-GB slag blend with approximately 60% slag (AS3582.2).

AS 1478.1 Type–WR (neutral set) admixture was added as required to target a slump of 80mm. Xypex Admix C-Series was dosed at 0.8% or 1.2% in accordance with manufacturer's directions. Table 2-A shows test methods and objectives used in this research

Table 2-A Description of Chloride Resistance Test Methods

Test Method	Source	Objectives
Rapid Chloride Ion Test	ASTM C1202 / CSIRO Modified[1]	**E**lectrical indication of concrete's ability to resist chloride ion penetration
ACCI Chloride Diffusion Test	ACCI	**D**etermination of chloride penetration and chloride diffusion coefficients of concrete after immersed in 3% sodium chloride solution for 35 and 105 days.

3. TEST RESULTS AND DISCUSSIONS

3.1 Rapid Chloride Ion Test – ASTM C1202 / CSIRO Modified

The results of the rapid chloride ion test ASTM C1202 / CSIRO[1] Modified are summarized and shown in Table 3.1-A

Table 3.1-A Summary of Test Results

Mix Code	W/C Ratio	Cement Type and Content (Kg)	Xypex Admix C-1000NF (% of cement content)	CSIRO Modified ASTM C1202
2FA1	0.40	25% FA (435)	Nil	Control
2FA2	0.40	25% FA (435)	0.8%	**-76%**
2FA3	0.40	25% FA (435)	1.2%	**-90%**
2LS1	0.40	38% Slag (435)	Nil	Control
2LS2	0.40	38% Slag (435)	0.8%	**-71%**
2LS3	0.40	38% Slag (435)	1.2%	**-73%**
2HS1	0.40	60% Slag (435)	Nil	Control
2HS2	0.40	60% Slag (435)	0.8%	**-47%**
2HS3	0.40	60% Slag (435)	1.2%	**-62%**

3.2 ACCI Chloride Diffusion Test in 3% NaCl Solution

The test procedures and sample preparations were the same as those of the Nordtest (NT BUILD 443[2] - Accelerated Chloride Penetration Test). However, instead of using 16.5% NaCl solution in Nordtest, the ACCI modified Nordtest uses a 3% NaCl solution, which is similar to the chloride concentration in natural seawater. The duration of immersion of samples in 3% NaCl

solution was set at 35 days and 105 days. The results of the ACCI chloride diffusion testing are summarized and shown in Table 3.2-A and Fig 3.2-A (i), (ii), & (iii). All Xypex Admix C-Series treated concretes demonstrated marked reduction of chloride diffusion coefficients

Table 3.2-A Chloride Ion Diffusion Coefficients for All Mixes

Mix Code	W/C Ratio	Cement Type and Content (Kg)	Xypex Admix C-1000NF (% of cement content)	Chloride Diffusion Coefficient ($10^{-12}m^2/s$)		Ratio to Control (105 days)
				35 days	105 days	
2FA1	0.40	25% FA (435)	Nil	15.0	8.0	-
2FA2	0.40	25% FA (435)	0.8%	8.5	6.8	**- 15%**
2FA3	0.40	25% FA (435)	1.2%	5.8	3.5	**- 56%**
2LS1	0.40	38% Slag (435)	Nil	4.0	3.5	**-**
2LS2	0.40	38% Slag (435)	0.8%	2.2	2.5	**- 29%**
2LS3	0.40	38% Slag (435)	1.2%	1.5	1.0	**- 71%**
2HS1	0.40	60% Slag (435)	Nil	3.0	1.7	**-**
2HS2	0.40	60% Slag (435)	0.8%	3.5	1.2	**- 29%**
2HS3	0.40	60% Slag (435)	1.2%	2.5	1.2	**- 29%**

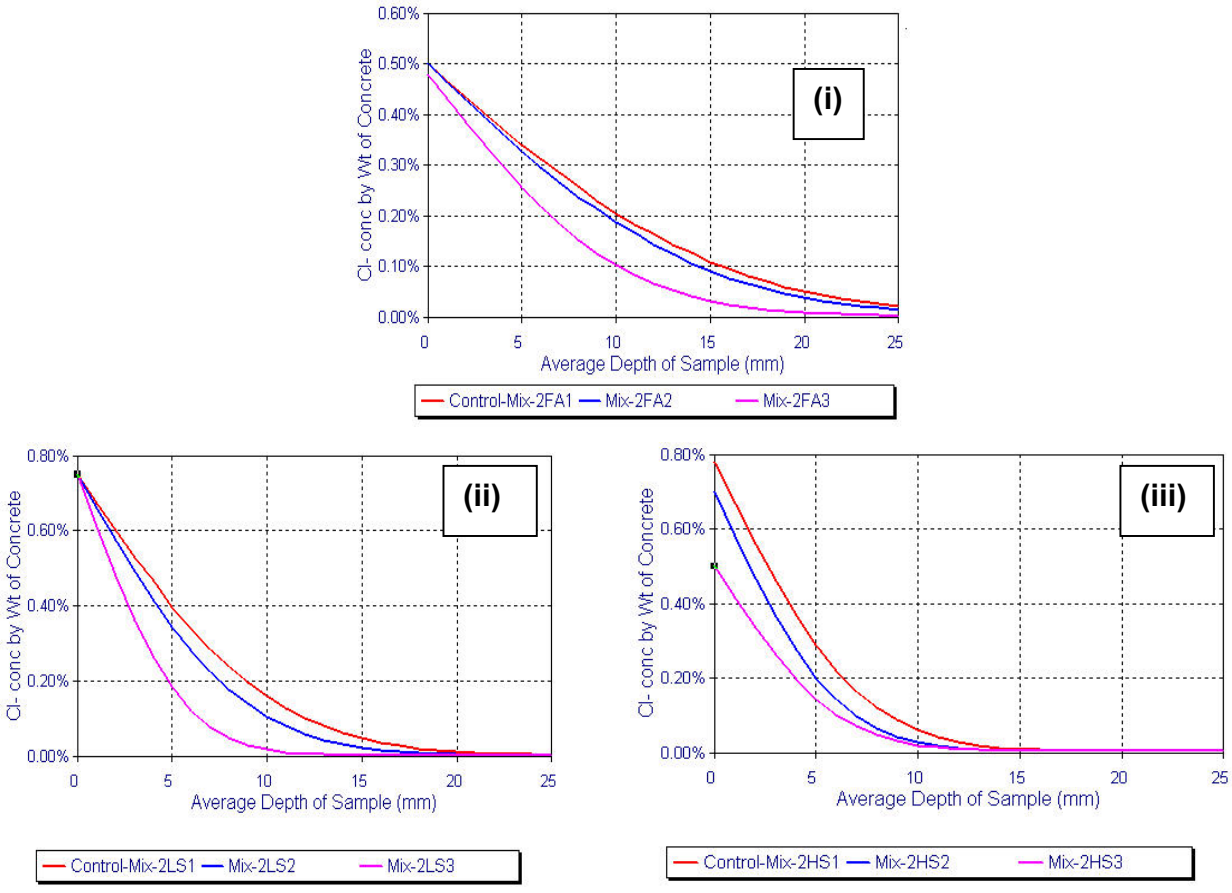

Fig 3.2-A Chloride Diffusion Profiles from ACCI Chloride Diffusion Test (i) 25% Fly Ash Concretes; (ii) 38% Slag Concretes; (iii) 60% Slag Concretes

3.3 ESTIMATION ON CORROSION INITIATION TIME** BASED ON CHLORIDE DIFFUSION

An example of using the software LIFE 365**[3,4,5] on prediction of corrosion initiation time is shown in Table 3.3-A and Fig 3.3-A for Type-GB (38% slag) concrete mixes evaluated. The parameters for the model include;

1) Concrete cover depth (set as 70mm).
2) Chloride diffusion coefficient of concretes (from Table 3.2-B).
3) Threshold chloride concentration at reinforcement level (0.03%wt of concrete).
4) Exposure environments (set as marine splash zone).

Table 3.3-A Estimated Time of Corrosion Initiation Due to Chloride Diffusion

Concrete Mix	2LS1	2LS2	2LS3
Xypex C1000NF by weight of Cement	0	0.8%	1.2%
Corrosion Initiation Time (year)	**42**	**59**	**147**
Ratio to Control	1.00	1.40	2.50

Disclaimer (**): Estimation of corrosion time initiation and references in this section are only intended for comparison between control concretes and Xypex Admix C-Series modified concretes in this research project. Performance data included in the figures are derived from both publications in concrete literature and research test results. Major criteria and boundary conditions were set prior to the estimations. It should be noted that the calculated corrosion initiation time values might be very different if a database of the long-term performance of Australian concretes were available for analysis. Readers are urged to read the publications and seek further details on this research project to understand the limitations on using this software.

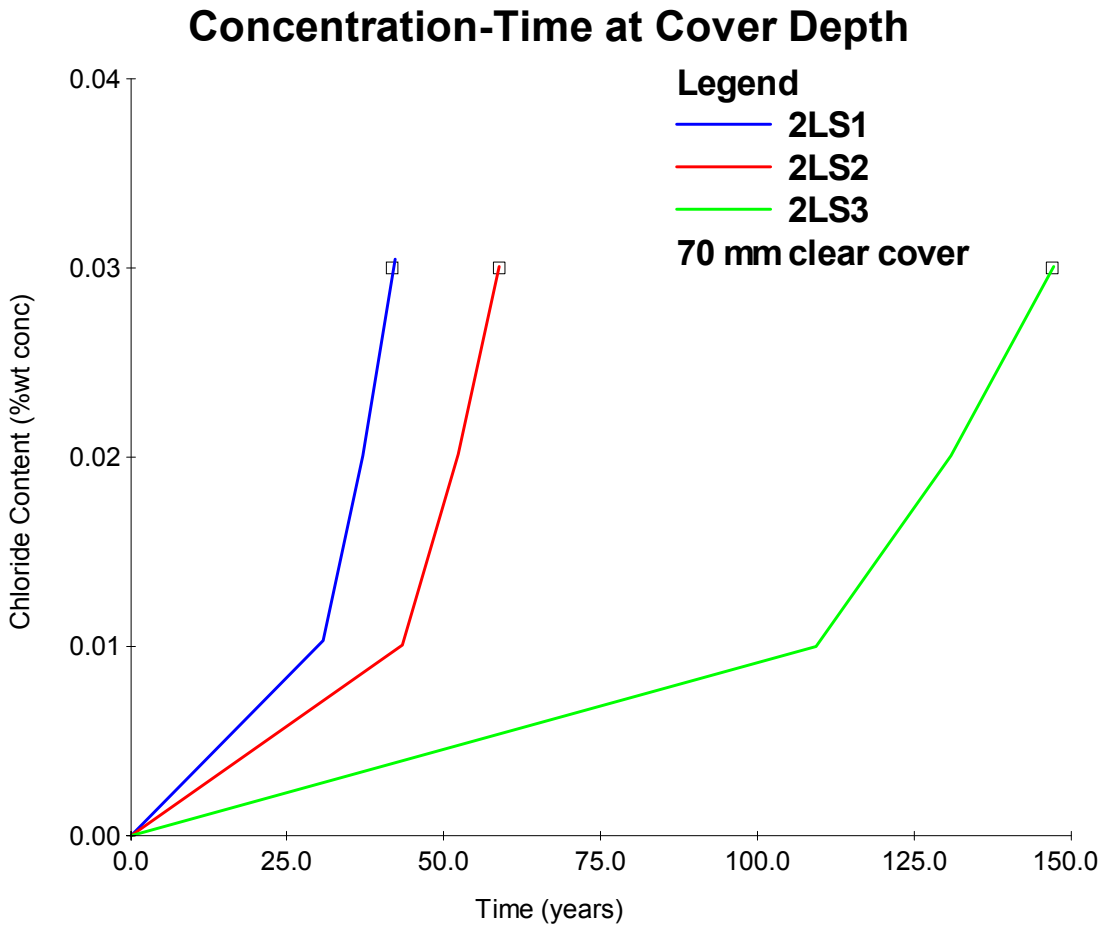

Fig 3.3-A **Estimated Corrosion Initiation Time to Reach Chloride Threshold at Cover Depth for Type-GB (38% Slag) Concretes**

4. CONCLUSIONS

This report outlines test results obtained for chloride resistance using test methods ASTM C1202 (modified) and ACCI chloride diffusion test. Xypex Admix C-Series with two dosage rates, 0.8% and 1.2%, was used with three types of cement in commercial concretes with nominal strength of 40MPa. Overall from the test results, concretes with the addition of Xypex Admix C-Series have demonstrated excellent performance.

5. REFERENCES

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4. Michael D.A., Thomas, Phil B. Bamforth, “Modeling Chloride Diffusion in Concrete Effect of Fly Ash and Slag”, Cement and Concrete Research, 29, 1999, pp487-495.
5. Boddy, A., Bentz. E., “An Overview and Sensitivity Study of a Multimechanistic Chloride Transport Model”, Cement and Concrete Research, 29, 1999, pp827-837.

ANNEX A

PLASTIC AND HARDENED STATE PROPERTIES OF XYPEX ADMIX C-SERIES (C-1000NF) MODIFIED COMMERCIAL CONCRETES

Joint Research Project by
The Australian Centre for Construction Innovation, UNSW & Xypex Australia

By Gary Kao
B.Mat.E, M.Sc
Research Engineer

0	28-08-2004	Issued for Information	GK	GJ/GB

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1. INTRODUCTION

In accordance with Xypex Australia's ongoing commitment to research and development, further research has been undertaken to evaluate the impact of the addition of Xypex Admix C-Series (C-1000NF) on commercially batched concretes with a prescription of 435 Kg's cementitious and a 0.40 water to cement ratio which reflects concrete utilized in area where durability is a concern.

The concretes selected included supplementary cementitious materials (fly ash and slag) to represent concretes typically used in durable structures.

This abstract outlines the results of the plastic and hardened state properties of the concretes researched. This research was carried out by The Australian Centre for Construction Innovation (ACCI/UNSW). The properties reported in this abstract include **slump**, **setting time**, **compressive strength**, and **drying shrinkage**.

2. MATERIALS

The three types of cement used were:

A. AS3972 Type-GB with 25% fly ash (AS3582.1 or ASTM C618 Class F);
B. AS3972 Type-GB slag blend with approximately 38% slag (AS3582.2);
C. AS3972 Type-GB slag blend with approximately 60% slag (AS3582.2).

AS1478.1 Type-WR (neutral set) admixture was added as required to target a slump of 80mm. Xypex Admix C-Series which complies to AS1478.1 Special Purpose Admixture Type-SN, dosed at 0.8% or 1.2% in accordance with manufacturer's directions.

3. TEST RESULTS AND DISCUSSIONS

Test results are summarized and shown in Table 3-A.

Table 3-A Summary of Test Results

Mix Code	W/C Ratio	Cement Type and Content (kg)	Xypex Admix C-1000NF (% of Cement Content)	Slump (mm)	Setting Time	Compressive Strength			Drying Shrinkage
						3 days	28 days	91 days	
2FA1	0.40	25% FA (435)	Nil	95	Control	21.9	36.2	46.7	719
2FA2	0.40	25% FA (435)	0.8%	105	+ 2.2~2.5 hrs	22.1	44.1	53.8	577
2FA3	0.40	25% FA (435)	1.2%	100	+ 1.4~2.3 hrs	28.0	47.5	58.0	562
2LS1	0.40	38% Slag (435)	Nil	95	Control	28.1	49.9	64.8	814
2LS2	0.40	38% Slag (435)	0.8%	100	+ 2.2~2.7 hrs	28.6	52.7	65.7	689
2LS3	0.40	38% Slag (435)	1.2%	90	+ 4.0~4.1 hrs	28.6	52.9	66.3	711
2HS1	0.40	60% Slag (435)	Nil	100	Control	14.2	38.1	49.3	803
2HS2	0.40	60% Slag (435)	0.8%	125	+ 0.8~1.6 hrs	12.4	36.5	47.8	772
2HS3	0.40	60% Slag (435)	1.2%	95	+ 1.0~1.3 hrs	15.7	42.0	53.4	772

3.1 Slump (AS1012.3):

Compared to the control slumps were within the normally acceptable range with the exception being Mix-2HS2.

3.2 Setting Time (AS1012.18):

Xypex Admix C-Series modified concrete exhibited extensions in setting time when compared to the control. The results of Mix-2LS3 are inconsistent with the other results.

3.3 Compressive Strength (AS1012.9):

Overall, Xypex Admix C-Series concretes exhibited higher compressive strengths when compared to the controls with the exception of Mix-2HS2. All mixes at 91 days demonstrated continued strength gains.

- **Xypex Admix C-Series modified Type-GB (25% fly ash) concrete:**

  At age of 28 days, mixes recorded up to 31% higher strengths than the control;

- **Xypex Admix C-Series modified Type-GB 38% slag concrete:**

  At age of 28 days, compressive strengths showed an increase of 6% over the control;

- **Xypex Admix C-Series modified Type-GB 60% slag concrete:**

  At age of 28 days, compressive strengths were higher than the control by up to 10%;

3.4 Drying Shrinkage (AS1012.13):

Drying shrinkage results of all Xypex C-Series treated mixes exhibited improved performance. In particular, results for the Fly Ash mixes showed significant reduction in shrinkage.

- **Xypex Admix C-Series modified Type-GB (25% fly ash) concrete:**

  At 56 days, mixes recorded lower shrinkage of up to 22% compared to control.

- **Xypex Admix C-Series modified Type-GB 38% slag concrete:**

  At 56 days, mixes recorded lower shrinkage of up to 15% compared to control.

- **Xypex Admix C-Series modified Type-GB 60% slag concrete:**

  At 56 days, mixes recorded lower shrinkage of up to 4% compared to control.

4. CONCLUSIONS:

Test results confirm that Xypex Admix C-Series was compatible with both fly ash and slag blended cement concretes which also contained a typical neutral set water reducing admixture. Overall, Xypex Admix C-Series has demonstrated improvements with no adverse effects on

general properties of concrete in both its plastic and hardened state. Results indicate improvement in both shrinkage and compressive strength may be achieved with Xypex Admix C-Series.