XYPEX AUSTRALIA

Subject:
Water Absorption & AVPV and Water Permeability on Xypex Admix Modified Commercial Concretes

AUSINDUSTRY START RESEARCH PROJECT

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1. INTRODUCTION:

A substantial research program was undertaken at the The Australian Centre for Construction Innovation of the University of New South Wales with financial support from AUSINDUSTRY under a START Graduate Research Grant. The primary aim of this research was to determine the benefits resulting from the use of Xypex Admix as an integral component of concrete required to demonstrate superior durability in aggressive environments. This program used commercial concretes which contained conventional water reducing admixture, different supplementary cementitious materials and Xypex Admix at various dose rates.

This brief abstract outlines test results obtained for **water absorption & AVPV** using AS1012.21 and **water permeability test** (ACCI). Assessment of these test results indicates that, whilst concrete performance was influenced by cement type, Xypex Admix can also significantly improve the durability of concrete in aggressive environments.

2. MATERIALS:

To minimise the difference in performance between “lab concrete” and “site concrete”, and to ensure relevance for construction applications, commercial concrete batches were used in this research. One of two types of cement was used in each of the concrete mixes, i.e. AS3972 Type-GP (SL) Portland cement only, or AS3972 Type-GB fly ash blend with 20% fine fly ash (Type F).

All concrete batches were supplied by a ready-mix plant based on 32 MPa grade commercial concrete mixes. AS1478.1 Type-WR (neutral set) admixture was added as required to achieve a target slump of 80mm. Xypex Admix was dosed at 0.8% or 1.2% in accordance with manufacturer’s directions. Table 2.1 summarises 7 concrete mixes using different cements and admixtures.

TABLE 2-1. CEMENT AND ADMIXTURES IN CONCRETE MIXES

Mixture Code	*Cement Type*	*Xypex Admix / Dose*	*Water Reducer*	*Superplasticiser*
GPC	Type-GP (SL)	Nil	Pozz 370	Nil
GPX1	Type-GP (SL)	C-1000NF / 0.8%	Pozz 370	Nil
GPX2	Type-GP (SL)	C-1000NF / 1.2%	Pozz 370	Nil
GPX3	Type-GP (SL)	C-2000NF / 0.8%	Pozz 370	Nil
FAC	Type-GB (20% Fly Ash)	Nil	Pozz 370	Nil
FAX1	Type-GB (20% Fly Ash)	C-1000NF / 0.8%	Pozz 370	Nil
FAX3	Type-GB (20% Fly Ash)	C-2000NF / 1.2%	Pozz 370	Nil

3. TEST RESULTS & DISCUSSIONS:

3.1 Water Absorption & AVPV Test (AS1012.21)

The water absorption and AVPV (Apparent Volume of Permeable Voids) of concretes were determined in accordance with the Australian Standard AS1012.21. The tests were conducted under four different curing conditions in order to understand the effects of air or limewater curing and the curing time on water absorption and AVPV of varying concretes. These curing conditions were:

1. 7 days limewater curing followed by air curing at 23 °C until age of 56 days
2. 7 days limewater curing followed by air curing at 23 °C until age of 180 days
3. 56 days continuous limewater curing
4. 180 days continuous limewater curing.

Table 3.1-1 summarises the water absorption test results for all concretes under the four curing conditions. In general, the Xypex Admix modified concretes had lower water absorption than the respective control concretes under all curing conditions. The most significant reduction in water absorption of 14% and 15% was found with the Xypex Admix modified fly ash concretes Mix-FAX1 and Mix-FAX3 compared with the control Mix-FAC at the concrete age of 180 days.

All concretes recorded lower water absorption values under continuous limewater curing to 56 or 180 days compared to that under 7 days limewater curing followed by air curing to 56 or 180 days. The reduction in water absorption under continuous limewater curing was more significant in the concretes using blended cement containing fly ash. The Xypex Admix modified concretes also benefited more under limewater curing than the control concretes.

Table 3.1-2 shows the effect of increased curing time on water absorption test results under either air curing or limewater curing conditions. The increase in curing time either in air or limewater resulted in decreased water absorption in all concretes. The increase in air curing from 56 days to 180 days resulted in reduction of water absorption by 1.2% to 9.1%. The most significant reduction in water absorption due to prolonged limewater curing was found with fly ash concretes Mix-FAX3 and Mix-FAX1. Both had 20% lower water absorption when limewater curing was extended from 56 to 180 days. It appeared that prolonged limewater curing accelerated the chemical reaction time of Xypex Admix in concrete and hence reduced the water absorption.

Table 3.1-1 Summary of Water Absorption Test Results

Mix No	7d Lime + 49d Air	7d Lime + 173d Air	56 days Limewater	180 days Limewater
	Water Absorption (Ratio to control)	Water Absorption (Ratio to control)	Water Absorption (Ratio to control)	Water Absorption (Ratio to control)
Type-GP (SL)				
GPC	1.00	1.00	1.00	1.00
GPX1	0.99	0.98	0.96	1.00
GPX2	0.98	0.96	0.89	0.95
GPX3	0.99	0.93	0.94	0.99
Type-GB (20% Fly Ash, Type-F)				
FAC	1.00	1.00	1.00	1.00
FAX1	0.98	0.87	0.98	0.86
FAX3	0.95	0.86	0.96	0.85

Table 3.1-2 Effect of Curing Times on Water Absorption Test Results

Mix No	Water Absorption		Effect of Increased Curing Time (%)	Water Absorption		Effect of Increased Curing Time (%)
	(1)	(2)		(3)	(4)	
	7d Lime + 49d Air	7d Lime + 173d Air		56 days Limewater	180 days Limewater	
Type-GP (SL)						
GPC	-1.2%			-8.8%		
GPX1	-2.6%			-5.3%		
GPX2	-3.1%			-2.4%		
GPX3	-7.4%			-3.7%j		
Type-GB (20% Fly Ash, Type-F)						
FAC	7.9%			-9.7%		
FAX1	-4.5%			-20.6%		
FAX3	-2.5%			-20.4%		

Table 3.1-3 summarises the test results on AVPV (Apparent Volume of Permeable Voids). In general, the AVPV results showed similar trends to the water absorption results. The Xypex Admix modified concretes had lower AVPV values than the control mixes under all curing conditions. Significant reductions in AVPV were found with concrete Mix-FAX3 with 15% lower AVPV than the control Mix-FAC after 56 days limewater curing and with 12% lower AVPV after 180 days limewater curing.

Table 3.1-3 Summary of AVPV Test Results

Mix No	7d Lime + 49d Air		7d Lime + 173d Air		56 days Limewater		180 days Limewater	
	AVPV (%)	Ratio to control	AVPV (%)	Ratio to control	AVPV (%)	Ratio to control	AVPV (%)	Ratio to control
Type-GP (SL)								
GPC	14.17	1.00	13.70	1.00	13.17	1.00	13.35	1.00
GPX1	13.96	0.99	13.54	0.99	12.54	0.95	12.74	0.95
GPX2	13.47	0.95	13.18	0.96	11.99	0.91	11.59	0.87
GPX3	13.32	0.94	12.71	0.93	12.17	0.92	11.82	0.89
Type-GB (20% Fly Ash, Type F)								
FAC	13.06	1.00	12.95	1.00	12.71	1.00	10.75	1.00
FAX1	12.65	0.97	12.05	0.93	12.20	0.96	9.87	0.92
FAX3	12.80	0.98	12.08	0.93	10.84	0.85	9.47	0.88

The Xypex Admix modified fly ash concretes and Type-GP concretes have benefited from prolonged limewater curing and show more significant reductions in AVPV than the control mixes. Ongoing chemical reactions between Xypex Admix and cement by-products could be promoted by such curing conditions, which have resulted in reduced volumes of permeable voids. This test data is consistent with the previous international test results on Xypex admix modified concretes.

Xypex Admix is an inorganic admixture and the active ingredients react with water and a broad range of hydration by-products which include various metal oxides and salts (including potassium, unhydrated and partially hydrated cement particulate) as well as, but not only with calcium hydroxide regardless of the cement type or blend. The reaction products of Xypex Admix are in mineral crystal form and grow in the residual vacancies (pores and cracks) in concrete. With the crystalline structure then being subjected to an oven drying cycle the moisture held in the crystalline structure will evaporate under these forced conditions. When the oven dried Xypex admix modified sample is immersed in water the crystalline structure at the surface will then have the capacity to take up and bind moisture into the crystalline structure again and the absorption rate will be affected. This will be in addition to surface adhered water and the total absorbed water will end up being closed to the reference concrete.

This mechanism was correlated with current research test results, in which water absorption for all mixes was found to be similar or lower than control mixes. However, all Xypex Admix modified mixes showed lower AVPV values compared to control mixes. This is suggested to be due to the mechanism of pore filling generated by the crystallisation from reactions

between the Xypex Admix chemical, water and other by-products, and thus a reduction in overall volume of permeable voids. This phenomenon is supported in the following tests on water permeability.

VicRoads (VIC) has a specification for their concrete work based on AVPV value at 28 days. For grade 32MPa concrete, it requires the AVPV value not to be greater than 14%. In Table 3.1-3, all the concrete cured in limewater for 56 and 180 days had lower AVPV values than 14%. Concrete samples cured 7 days in limewater followed by air curing to 56 and 180 days, control concretes had AVPV close to 14%. However, the Xypex modified concretes had AVPV values considerably lower than 14%.

3.2 Water Permeability Test (ACCI Method)

Both Xypex Admix modified and control concretes made with Type-GP and Type-GB cements (containing 20% fly ash) were tested for water permeability by the ACCI method under water pressure up to 10 bars (100 metres water head). The concrete samples were cured in limewater for 90 days before testing for water permeability.

Table 3.2-1. Water Permeability Coefficients

Mix No	GPC	GPX1	GPX2	GPX3	FAC	FAX1	FAX3
Water Permeability Coefficient (m/s)	$1.76X10^{-12}$	$0.98X10^{-12}$	Nil	$0.25X10^{-12}$	Nil	Nil	Nil

Table 3.2-1 presents the water permeability test results in terms of the permeability coefficient. During the water permeability tests, the concrete samples of Xypex Admix modified Type-GP concrete Mix-GPX2 showed no signs of water penetration under a 100-metres head water pressure. However, water penetration was observed through the 50mm thick samples of the Type-GP control Mix-GPC under a 60-metres head water pressure. Much lower water penetration rates were measured with the samples of Xypex modified Type GP concrete Mix-GPX1 and Mix-GPX3. The calculated water permeability coefficients for Mix-GPX1 and Mix-GPX3 were significantly lower than the control Mix-GPC, even though the absorption values shown in the Table 3.1-1 were similar to control.

No water transmission was measured for the three Type-GB cement (with 20% fly ash) concretes, which included both Xypex modified concretes, Mix-FAX1, Mix-FAX3 and the control Mix-FAC. Because the water permeability was negligible for fly ash concretes another method was used to examine water penetration depth by using the methylene blue technique as found in the RTA sorptivity test. Mix-FAC had an average of water penetration depth of

8mm whereas Mix-FAX1 showed no water penetration when tested using this method.

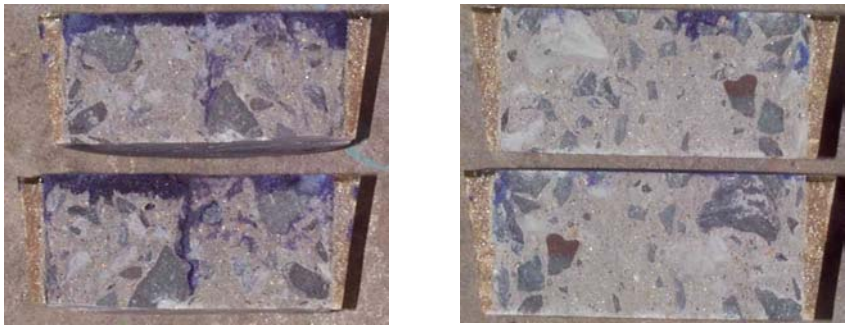

Fig 3.2-1 Water Penetration Depths in Water Permeability Tests
Mix-FAC (left) & Mix-FAX1 (right)

These water permeability results have correlated with tests completed by the US Army Corp. of Engineers, USA CRD C48-73 “Permeability of Concrete”, where Xypex treated concrete has also shown no leakage or penetration of water. Taywood Engineering proposed criteria for assessment of concrete quality based on water permeability coefficients, which were adopted by the British Concrete Society Committee on Insitu Permeability of Concrete. It was proposed that concretes with water permeability coefficients in the range of $1x10^{-10}$ to $1x10^{-12}$ m/sec have acceptable quality, while concretes with permeability coefficient greater than $1x10^{-10}$ m/s have poor quality. Concretes with permeability coefficients less than $1x10^{-12}$ m/s are regarded as very good concretes for use in severe environments. According to these criteria all Xypex Admix modified concretes are ranked as good quality concretes suitable for severe environments

4 CONCLUSION:

This abstract outlines test results obtained for water absorption & AVPV using test method AS1012.21 and water permeability test (ACCI). Xypex Admix with two dosage rates, 0.8% and 1.2%, were used with two types of cement in commercial concretes with nominal strength of 32 MPa. Four different curing conditions were used in water absorption tests to understand the effects of air or limewater curing and the curing time on water absorption and AVPV of different concretes.

Overall from the test results, concretes with the addition of Xypex Admix have demonstrated the following improvements:

1) Similar to lower water absorption and AVPV in Type-GP mixes under all curing conditions;
2) Significant lower water absorption and AVPV in Type-GB (20% fly ash) mixes under all curing conditions, especially with prolonged limewater curing;
3) Significant lower water permeability in Type-GP mixes at dosage rate of 0.8%, even

though water absorption values were similar to control;

4) No visible water leakage under water pressure up to 10 bars in Type-GP mixes at dosage rate of 1.2%;
5) No water penetration was measured in Type-GB (20% fly ash) mixes whereas control specimen has shown 8.0mm of water penetration under water pressure up to 10 bars;

Absorption testing alone is not intended for use as an indicator or measure of durability. However, when combining the results of the three tests used in this document, it gives the reader an indication of how Xypex Admix improves the concrete matrix and therefore it is suitable for use in concrete for water tight construction.

Overall from the research program, concretes modified with Xypex Admix were found to have properties similar or improved compared to concretes without Xypex Admix. Whilst strengths and drying shrinkages were typically improved, the most substantial improvements in properties were for durability related tests such as water and chloride penetration, and sulphate resistance. The introduction of Xypex Admix to concrete improved these later properties with all types of cements. These results confirm the suitability of Xypex Admix for use in concretes designed for service in aggressive environments.