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23 JUL 2001

Inner City Bypass Project
Brisbane

4.5 Kilometres
Links Hale Street at Paddington
to
Kingford Smith Drive at Hamilton

Client:	**Brisbane City Council**
Superintendent:	**Sinclair Knight Merz**
Contractor:	**Leighton Contractors**
Design:	**Leighton's Design Team** **Contact: Mr. Iain Burgess**
Engineers:	**Maunsell McIntrye** **Contact: Mr. John Hart**
Concrete Supplier:	**CSR Construction Materials** **Contact: Mr. Todd McGurgan**
Xypex Australia:	**Marketing Executive** **Contact: Ms. Maria Bobeldyk**
Waterproofing Contractor:	**Xycrete** **Contact: Mr. Kevin Hill**

Contents:

Maunsell
McIntyre

Maunsell McIntyre Pty Ltd
Level 9, 161 Collins Street
Melbourne Vic 3000
Australia
Tel: +61 3 9653 1234
Fax: +61 3 9654 7117

Maunsell

FACSIMILE

To:	MMPL (ICB Site Office)			Sheet: 1 of	
Attention:	Peter Kouparitsas	Fax No:	07 - 3872 2765		
From:	Frank Collins	Copied to:	John Hart (ICB Site Office)		
Date:	27 July, 2000	Ref No:	Fgc055	Project No:	10206200.09
Subject:	**BICB – Xypex – Mix Trials and Slab Tests**				

Peter,

Further to my Draft DC 1690 sent by email Friday 21/7/00, & following discussion regarding the mix trials with Iain Burgess, LCPL are keen to conduct mix trials as well as producing trial cracked concrete slabs to test the effectiveness of Xypex for waterproofness. I have discussed this with John Connal and have the following suggestions:

1. The concrete mixes need to be essentially identical to the type of concrete mixes that CSR Readymix would use in this project for the concrete slabs in the Land Bridge and tunnel roof slabs. From the concrete mix trials we would be seeking clarification of the following information:

(i) Comparison concrete mixes with and without Xypex.

(ii) Measurement of the following fresh concrete properties (to Australian Standard AS1012): Initial slump and slump loss over 45 minutes, bleed, fresh density, air content, time to initial set, time to final set, compatibility with other chemical admixtures

(iii) Measurement of the following hardened concrete properties (to Australian Standard AS1012):

- Compressive strength at 1, 3, 7, and 28 days
- Drying shrinkage (to 56 days)
- Water absorption

2. Waterproofness of cracked slabs

Testing the waterproofness of cracked slabs, made on-site and of similar proportions to the Land Bridge deck slab, will be a better indicator of the waterproofing properties of Xypex compared with testing of laboratory-size samples. The slabs are designed to crack under the action of restrained shrinkage.

It is proposed to make six (6 No.) slabs at the ICB site. It is proposed that the slabs are representative of the Land Bridge deck slab and are of dimension <u>(at the cracked</u>

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ACN 004 846 824

section) of 160 x 1000 x 3000 millimetres. A typical slab is shown in the attached Figure 1. The proposed slab types are as follows:

(i) 3 No. slabs, with the configuration as shown in the attached figure, made with concrete containing no Xypex. The slabs are designed to generate cracking at mid-span under the action of restrained shrinkage. It is proposed that the cracked slabs are ponded with water on the top surface and the amount of water flow through the crack is monitored.

(ii) 3 No. slabs, with the configuration as shown in the attached figure, made with concrete containing Xypex. The slabs are designed to generate cracking at mid-span under the action of restrained shrinkage. It is proposed that the cracked slabs are ponded with water on the top surface and the amount of water flow through the crack is monitored.

The slab configuration and method of ponding are outlined below.

Internal restraint is provided by the 1 metre anchorage length (at each end) of Y20 bars longitudinally cast into the slab. The central 1 metre portion of the bars are sheathed with smooth PVC electrical conduit to minimise the concrete to steel bond. The cross-section at the centre of the slab is reduced by casting in a removable angle section to create a groove suitable to act as a crack initiator. The slabs should be made and cured to the same methods that LCPL would implement for the construction of deck slabs made with and without Xypex. The slabs should be de-moulded at 24 hours and placed (preferably) on roller supports (or on 2 layers of polythene plastic sheet on a smooth level surface). Following the period of curing, the slabs should be left exposed to drying conditions (& preferably sheltered from rain) to enable restrained shrinkage (& cracking) to occur. Cracks of different width can be generated by maintaining some of the slabs under drying conditions for longer duration of time.

Following cracking and prior to water ponding, the crack width should be measured at several locations at the top and side. A reservoir for ponding water should be set up on the top surface of the slab (e.g. – PVC pipe section sealed with silicone sealant) and a constant water head (e.g. – 50 millimetres) maintained for 7 days. The top of the reservoir should be cover to prevent evaporation. Water permeating through the crack from the down-stream concrete face should be collected in a tray and the quantity measured. The two types of concrete, with and without Xypex, can be ranked. If the concrete slab containing Xypex has not healed sufficiently and seepage continues the post-cracking treatment using Xypex concentrate should be implemented and assessed. Following completion of the test the cores should be drilled through the cracked section to assess the amount of healing that has occurred across the crack due to the action of Xypex.

FACSIMILE cont.

Subject: **BICB – Xypex – Mix Trials and Slab Tests** SHEET 3 OF

I welcome your comments on this test programme. I believe there is a risk involved with not using a conventional waterproofing membrane and the effectiveness of Xypex, and potential side-effects with it's use, should be thoroughly assessed before we can approve it's use.

Regards

Frank Collins

Three structures on the ICB were sealed using Xypex Admixture concrete, the Inner Northern Busway tunnel at Normanby, the RNA tunnel under the RNA showgrounds and the Landbridge at York's Hollow.

The RNA tunnel was built using the cut and cover method. It consists of cast insitu walls covered with precast planks with and in-situ deck slab. The Landbridge used conventional T-Roff girders with a cast in-situ deck slab. On both structures, a waterproof membrane was specified to reduce leakage and prevent water from dripping onto the carriageway of the ICB.

The design life of structures on the ICB is 100 years. During investigations of the various membrane types, the longevity of the membrane on the landbridge and the RNA tunnels was questioned. On both structures, heavy equipment would be needed to place the soils and to install drainage and irrigation systems once the soil had been placed.

Both structures were to be covered in soil with a depth varying from 0.3m to 1.0m. This left the membrane for both structures exposed to potential damage from excavators, tent stakes and garden forks both during and after construction.

The use of a topping slab was considered on the RNA tunnel but rejected due to the difficulty in placing and ensuring no damage to the membrane during placement, as well as the extra expense.

A topping slab on the Landbridge would reduce the depth of soil available for the plants and trees due to the structural requirements that limited the depth of soil allowed.

A number of alternatives to a waterproof membrane were investigated. Xypex was identified as potentially a superior solution, which will fulfil long-term water proofing requirements including the ability to accommodate structural cracks. Xypex concrete had been successfully used on the South Bank Parking Structure without a waterproof membrane. There a 1m depth of fill, which has been planted in a similar manner to the landbridge, was placed over the slab. The average slab thickness was approximately 200mm. The parkland has a permanent irrigation system and the soil is constantly wet. Inspections of the structure showed no noticeable leakage. A number of commercial residential buildings built with Xypex and without a waterproof membrane that had similar gardens to South Bank were also inspected and no leakage found.

A series of trials were set up to determine the effectiveness in the autogenous seal healing properties of Xypex.

The results of the water flow tests show that Xypex can effectively seal small cracks up to 0.7mm. Xypex appears to reduce the flow in cracks wider than 0.7mm. In time these crack may self heal, however a proper repair as per the Xypex specification should be used.

The results of the physical concrete tests indicate that concrete with Xypex added shows no adverse reactions. Slump, consistency and set times were all within the normal limits of conventional concrete.

Xypex concrete was used first on the Landbridge and then on the RNA tunnel. The advantage of the Xypex concrete was seen during backfilling operations when full size trucks were used to replace the approximately 15,000m^3 of soils imported and compacted on top of the tunnel roof slab to form the basis for the pavement in the RNA. Drainage, sewerage and services where then reinstated. Once completed, the area was topped with asphalt to form a parking lot.

Interim Report – Xypex Trials conducted August/September 2000.

1. Reason for the Trials

The design life of structures on the ICB is 100 years. During investigations of the various membrane types, the longevity of the membrane on the landbridge and the tunnels was questioned.

A number of alternatives to a waterproof membrane were investigated. Xypex has been identified as potentially a superior solution which will fulfil long term water proofing requirements including the ability to accommodate structural cracks. Xypex concrete had been successfully used on the South Bank Parking Structure without a waterproof membrane. There a 1m depth of fill, which has been planted in a similar manner to the landbridge, was placed over the slab. The average slab thickness was approximately 200mm. The parkland has a permanent irrigation system and the soil is constantly wet. Inspections of the structure showed no noticeable leakage. A number of commercial residential buildings built with Xypex and without a waterproof membrane that had similar gardens to South Bank were also inspected and no leakage found.

MMPL proposed a series of trials to prove the Xypex system for this particular project for use in the Landbridge, RNA tunnel and the Normanby Tunnels.

2. MMPL Trial Specifications

Concrete test requirements were as follows:

(i) Measurement of the following fresh concrete properties (to Australian Standard AS1012): Initial slump and slump loss over 45 minutes, bleed, fresh density, air content, time to initial set, time to final set, compatibility with other chemical admixtures
(ii) Measurement of the following hardened concrete properties (to Australian Standard AS1012):
   - Compressive strength at 1, 3, 7, and 28 days
   - Drying shrinkage (to 56 days)
   - Water absorption

Testing the waterproofness of cracked slabs, made on-site and nilar proportions to the Land Bridge deck slab, was proposed as a better indicator of the waterproofing properties of Xypex than testing of laboratory-size samples.

MMPL proposed that 3 slabs be made at the ICB site. The slabs were to be representative of the Land Bridge and RNA tunnel deck slabs and have a dimension (at the cracked section) of 160 x 1000 x 3000 millimetres. A typical slab is shown in the attached drawings. The slabs were designed to crack at mid-span under the action of restrained shrinkage.

A 0.5 metre anchorage length (at each end) of Y20 bars longitudinally cast into the slab provided internal restraint. The central 2-metre portion of the bars were sheathed with smooth PVC electrical conduit to minimise the concrete to steel bond. An angle section was cast in to created a groove suitable to act as a crack initiator and reduce the cross section of the slab to 160mm.

Once cracks developed, a reservoir consisting of a 500mm high, 300mm-diameter cylinder was to be sealed onto the top of the cracks, and the rate of flow through the cracks monitored.

Following completion of the test the cores will be drilled through the cracked section to assess the amount of healing that has occurred across the crack due to the action of Xypex.

3. Sample Preparation

The slabs were made and cured to the same methods that would be implemented for the construction of deck slabs. Following the period of curing, the slabs were left exposed to drying conditions (sheltered from rain) to enable restrained shrinkage (& cracking) to occur.

After two weeks no cracks had formed. The slabs were then placed on timbers directly under the crack inducers, in order to induce a crack, this was unsuccessful. An attempt to crack the slabs with a sledgehammer was unsuccessful. Slab 1 was rocked over a timber to produce an impact, and a hairline crack was approximately 0.1 – 0.25mm formed. The crack increased in size over the following week to 0.7mm

At the end of three weeks, an excavator was used to break slabs 2 and 3 producing large cracks of the order of 0.6 – 0.9mm. These cracks also increased in size to 0.9mm to 1.2mm. Cracks were measured on the left hand face, the right hand face, and adjacent to the edge of the cylinders.

Slab No.	LHS	RHS	Centre 1	Centre 2
Slab 1	0.85	0.4 + 0.35 (two cracks)	0.6	0.7
Slab 2	0.7	1.1	0.9	0.8
Slab 3	1.1	0.9	1.2	1.3

Cracks greater than 0.7mm are larger than what Xypex claim they can effectively seal through autogenous self-healing alone without further Xypex repair procedures. They were flexural cracks, which taper down, at the bottom of the slab as opposed to shrinkage cracks, which would be of similar size throughout the slab. The flow path of the water through the flexural cracks produced differs from the shrinkage cracks in that the flow was more horizontal than vertical. The length of the flow path is similar and the head of up to 500mm is of a similar nature to what can be expected in the field. Photos 5 to 9 show the approximate crack sizes and shape.

At this stage the cylinders were sealed onto the slabs using silicone and tested for leakage.

3. Results

On filling the cylinders with water, it was noted that the water was not flowing along the crack, but was simply flowing out the crack under the silicone. We increased the width of the silicone seal around the cylinders over the crack to 75mm, to force the water to flow through the crack.

The cylinders were filled with water and monitoring began on all three slabs. The cylinders were monitored approximately hourly for the first day, thereafter at least twice per day. The cylinders were re-filled when there was approximately less than 20mm of water left in the bottom. On a number of occasions, the cylinders ran completely empty, particularly overnight on the first two days. Thereafter, the flow had decreased enough that filling was only necessary either in the morning or late afternoon.

Figures 1 –3 show the results of the trials up to 13/09/2000. At that stage, we believed that although the flow rate had decreased, we would not effectively seal the cracks in slabs 2 and 3. The crack size was monitored during the trial, there was an increase in the size of the cracks in the early morning when compared to those measured in the afternoon, indicating that the cracks were affected by the thermal movement of the slabs.

Slab No.	Morning (7:30AM)	Afternoon (3:00 PM)
1	0.85mm	0.7mm
2	1.1mm	1.0mm
3	1.2mm	1.1mm

The tests were stopped on Slabs 2 and 3 and the cylinders were removed and the Xypex repair procedure followed. The tests continued on Slab 1 until the 20/09/2000. Figure 4 shows the results including the last week of testing. The flow rate in slab 1 decreased to a negligible amount.

The Xypex specification for the admixture calls for a thorough inspection of the surface for shrinkage cracks within 48 hours of the initial set. Any cracks found are to be treated with a Xypex concentrate solution. In line with this specification, the cracks on slabs 2 and 3 were ground back, and a Xypex concentrate slurry applied to the crack in accordance with the Xypex Specification. Photos 10 to 12 show the repair operation. The cracks were then cured for 4 days. To date there are no visible cracks on the repair. The repairs will be tested along similar lines to the initial tests

Attached are the concrete test results. The slump, slump loss and initial set time are all within practical limits.

The strength tests show consistent higher concrete strengths when compared to a typical 40Mpa concrete mix.

The results of the drying shrinkage test initially indicated that a high shrinkage strain expected, however, the current results indicate a drying shrinkage of the order of 800 microstrain at 56 days is likely. This is approximately 150 microstrain higher than the average reported by CSR over the last six months for the standard N40 mix. This is contrary to the Xypex literature and shrinkage test results for Xypex concrete used on other contracts around Brisbane. Further shrinkage tests on standard N40 mix and an N40 with Xypex have been performed. The test results are still outstanding.

4. Conclusions

The results of the physical concrete tests indicate that concrete with Xypex added shows no adverse reactions. Slump, consistency and set times were all within the normal limits of conventional concrete.

The results of the water flow tests show that Xypex can effectively seal small cracks up to 0.7mm. Xypex appears to reduce the flow in cracks wider than 0.7mm. In time these crack may self heal, however a proper repair as per the Xypex specification should be used.

The Xypex specification calls for a thorough inspection of the slab within 48 hour after pouring the concrete. All cracks are to be treated with a Xypex concentrate repair. This process should eliminate the large cracks that were tested in the trial.

The Xypex specification calls for the degree of crack control to be "moderate to strong" when implementing Clause 9.4.3.4 of AS3600 and requires a minimum of 1% (0.25% per layer in each direction) which is expected to limit the crack width to less than 0.4mm. With these requirements met, it can reasonably be expected that any cracks from shrinkage and creep that occur after the deck has been covered will be less than 0.7mm and thus would autogenously self heal.

5. Recommendations

Xypex concrete is recommended to replace waterproof membranes in the INB Tunnel, the Landbridge and the RNA Tunnel subject to the following conditions:

(i) The Xypex dosage rate in the concrete is as per manufactures specification
(ii) The Xypex specification is strictly adhered to in regards to batching, placing, compaction and curing.
(iii) The crack control steel as per AS3600 Clause 9.4.3.4 is included in the design.
(iv) A thorough inspection of the deck is carried out within 48 hrs and all cracks repaired in accordance with the Xypex specification.

6. Attachments

Drawing of Trial slab reinforcing layout.
MMPL DC No. 2471 – Comments on Leighton Xypex Report
Xypex Standard Concrete Waterproofing Specifications – Xypex Admix C-1000NF / C-2000NF
Xypex Procedure for Supervision of Xypex Admix Pours
Xypex – Introduction to Xypex Waterproofing by Crystallisation
CSR Report on Xypex Concrete Trial – 23/09/2000
CSR Batch Record – Xypex Concrete S40MXYP

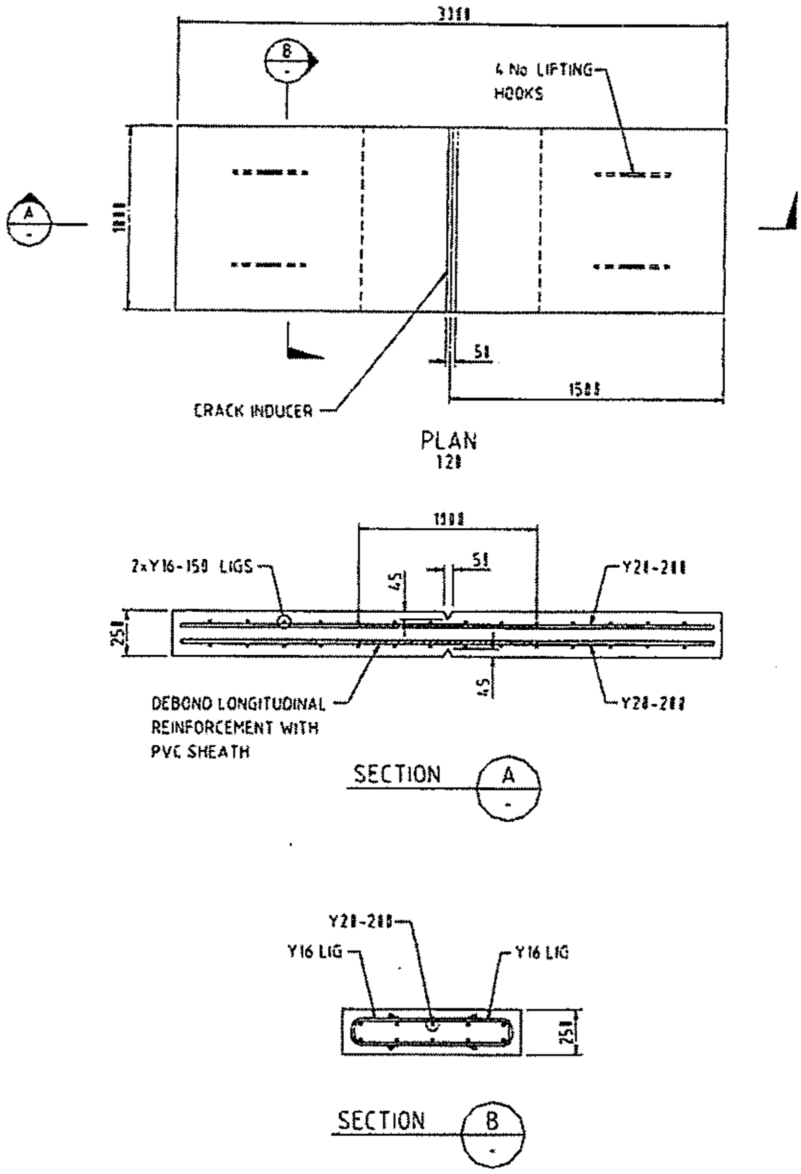

Figure 1 Proposed Restrained Slab Configuration for Xypex Testing

CSR
Readymix Concrete

CERTIFICATE OF MIX DESIGN

Date:	24 May, 2000
Client:	Leighton Contractors Pty. Ltd.
Contract:	Inner City Bypass
Attention:	James Hamilton
Facsimile:	07 3872 2700

We are pleased to submit for your approval, the following details of the concrete mix we propose for use to the above, from our despatch depot at Albion and Geebung.

MATERIALS

Material	No	Supplier	Works, Quarry, Pit	Specification
Type GP Cement	1	QCL	Bulwer Island	AS3972
Fly Ash	2	Pozzolanic	Tarong	AS3582.1
20mm Aggregate	3	CSR Readymix	Petrie	AS2758.1
10mm Aggregate	4	CSR Readymix	Petrie	AS2758.1
Coarse Sand	5	CSR Readymix	Tivoli	AS2758.1
Fine Sand	6	CSR Readymix	Oxley Creek	AS2758.1
Not in use	7	-	-	-
Not in use	8	-	-	-
Water Reducer	9	WR GRACE	Archerfield	AS1478/79
Air Entrainer	10	WR GRACE	Archerfield	AS1478/79
Not in use	11	-	-	-

MIX DESIGN

Mix Description	Slump (mm)	Mass of Materials (kg/m3)								Admix. (mL/m3)		
		1	2	3	4	5	6	7	8	9	10	11
N20/20 - N202GMRS	80	180	80	770	350	550	400			1560	100	-
N25/20 - N252GMRS	80	205	85	770	350	530	380			1740	100	-
* N32/20 - N322GMRS	80	225	95	780	350	520	370			1890	100	-
N40/20 - N402GMRS	80	260	110	780	360	500	350			2220	0	-
N50/20 - N502GMRS	80	320	140	810	360	460	300	-	-	2760	0	-

Comments: Coarse and fine sand moisture contents are at 6% and 8% respectively (subject to change).
Above figures , including the Aggregate, and Admixture combinations and quantities, are subject to change to ensure compliance with AS3902 and AS1379 requirements.
Water Reducer (Wrre) dose will vary to control set time properties.

Yours Faithfully,

Todd McGurgan
CSR Readymix Concrete