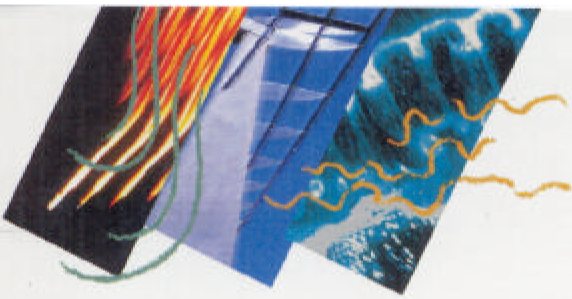

REPORT BIN 179

Performance of *Radmyx*™ Repair Material

IN CONFIDENCE TO

Radcrete Pacific Pty. Ltd.

Prepared by

Radhe Khatri, Vute Sirivivatnanon and Shane Gorman

Cement and Concrete
North Ryde

6 SEPTEMBER 2000

CSIRO

Building, Construction & Engineering

REPORT BIN 179

Performance of *Radmyx^{TM}* Repair Material

IN CONFIDENCE TO

Radcrete Pacific Pty. Ltd.

Prepared by

Radhe Khatri, Vute Sirivivatnanon and Shane Gorman

Cement and Concrete
North Ryde

6 SEPTEMBER 2000

TABLE OF CONTENTS

1. INTRODUCTION

In concrete construction, one of the most common requirements is in the watertightness of certain reinforced concrete members. Concrete can be proportioned to give very low water permeability. Water seepage or leakage, however, can result from the use of poorly proportioned concrete or poorly constructed concrete or both.

Radcrete Pacific has developed a product called Radmyx™, to be used as a repair system. The effectiveness of the product is examined by CSIRO using a range of techniques to simulate various problems commonly faced on site. In a laboratory evaluation, there are always some limitations as to how realistic a simulation can represent site situations. The scope of this work has thus been defined. The results therefore apply to the conditions under which the tests were conducted. The applicability of the results to real site situation is therefore subjected to individual interpretation.

2. OBJECTIVES

The objectives of this study was to evaluate the performance of Radmyx™ as a repair material. The effectiveness of Radmyx™ was evaluated on a nominal grade 20 fly ash concrete. The water permeability of uncracked concrete with and without surface-applied Radmyx™ slurry and Radmyx™ mortar was evaluated. Also the effectiveness of Radmyx™ slurry and Radmyx™ mortar in reducing water leakage through defective construction joints and cracks was evaluated. In both cases, the effectiveness of Radmyx™ repair system applied to the 'active' and 'passive face' of the concrete were examined.

3. SCOPE OF WORK

The performance of Radmyx™ was evaluated only in a static condition. The samples were not subjected to variations in loads nor exposure conditions. A very low strength grade of fly ash concrete, with and without simulated cracks and poor construction joints, was used to represent various problems which demand a waterproofing solution.

4. DETAILS OF EXPERIMENTAL PROCEDURE

The effectiveness of Radmyx™ system was evaluated on uncracked concrete samples and two types of defects : simulated poor construction joints and samples with simulated cracks generated by subjecting concrete cylinders to a tensile splitting (Brazil) test. A nominal grade

20 fly ash concrete mix was prepared with a fly ash content of 120 kg/m^3 to reflect industry norm in Sydney. Table 1 gives the details of the concrete mix proportions.

Table 1 Mix design of concrete mixes in kg/m^3

Mix Identification	R2B
GP	126
Fly Ash	121
20 mm. Agg.	445
14 mm. Aggregate	371
8 mm. Aggregate	314
Coarse Sand	384
Fine Sand	434
Water	133
Water Reducing Admixture	1.2
Water/Binder	0.54
Slump (mm)	110
28 Day Strength (MPa)	17.5

The concrete mix was prepared in accordance with Australian Standard (AS)1012-Part 2. All materials were prebatched and stored in airtight containers in order to ensure that their moisture contents remained unchanged. The containers were kept under standard laboratory conditions (23±2°C and 50±5% relative humidity) for one day prior to mixing. Moisture contents of the aggregates and sand were determined immediately prior to mixing for the individual mixes and actual water contents were calculated. All aggregates were batched having moisture contents higher than saturated surface dry (SSD). Final mix designs were adjusted to take into account additional moisture over SSD.

A Pan Mixer was used for mixing concrete for this work. The stages of the mixing procedure are described below.

1. The mixer was initially charged with all the aggregates and sand and they were mixed for 15 seconds.
2. Cement and fly ash was then added and were mixed in for 15 seconds.
3. All materials were well mixed prior to water and after the addition of water the mixing was carried out for further two minutes. During this two minutes the water reducing admixture was added. After this, the mixer was left idle for two minutes followed by a further two minutes of mixing. The concrete slump was then measured. If the slump achieved was not the "target" slump of 100±20 mm then the concrete was mixed for further one more minute and additional water was added during this one minute of mixing.

The consistency of fresh concrete was determined by measuring the slump and the procedure described in AS1012-Part 3 was followed. The compaction for all the specimens cast for the various tests were performed by an external vibrator.

Coefficient of permeability was measured on cylindrical disc samples of 100 mm diameter with a thickness of 50 mm. Tests were conducted on two samples and the average value has been reported. Cylindrical samples of 100 mm diameter and 200 mm long were cast and were continuously cured in saturated lime water for three days. At the age of three days the bottom 50 mm thick portion of the cylinder was sawed off and used for the determination of coefficient of permeability. Testing for the determination of coefficient of permeability commenced at the age of 28 days. Darcy's law was used to calculate coefficient of permeability and the details of the experimental procedure is given elsewhere [1].

The effectiveness of Radmyx™ system was studied by measuring the water permeability of uncracked concrete samples. Coefficient of permeability of two "control" samples were measured without any application of Radmyx™. Water permeability of four concrete samples were also measured after treating the surface with Radmyx™ slurry and a layer of Radmyx™ mortar. Thus the effectiveness of Radmyx™ slurry and Radmyx™ mortar in improving water permeability was determined. For two samples the slurry and mortar was applied on the surface which is exposed to pressurised water (active side) and the remaining two samples the slurry and mortar was applied on the face opposite to the face exposed to pressurised water (passive side). Coefficient of permeability was measured on cylindrical disc samples of 100 mm diameter with a thickness of 50 mm. All tests were conducted on two samples and the average value has been reported. Darcy's law was used to calculate coefficient of permeability.

The effectiveness of Radmyx™ system was also evaluated on two types of defects : simulated poor construction joints and samples with simulated cracks generated by subjecting concrete cylinders to a tensile splitting (Brazil) test.

Three cylinders were subjected to Brazil tensile testing to generate a transverse crack. These cylinders were clamped with two hose clamps on each ends so that the specimens do not open completely. The opening of the samples should be avoided as small loose sand particles could open up the crack further and could come in the way of closing the samples again. The cracked cylinders were cut into half with each of length 100 mm. Thus in total six samples were prepared from three cylinders with a transverse crack produced by Brazil testing. Figure 1 shows schematic diagram of the such six samples.

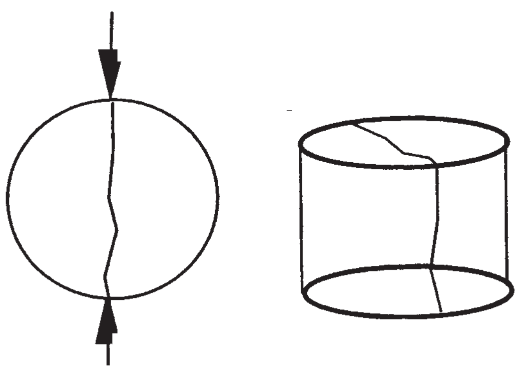

Figure Preparation of samples with crack generated by Brazil testing.

Six cracked samples obtained by Brazil testing were encapsulated with a concrete slab as shown in Figure 2. The encapsulation was carried out to facilitate the measurement of water penetration and the application of Radmyx™ slurry and Radmyx™ mortar. The dimensions of the slab samples were 400 x 300 x 100 mm.

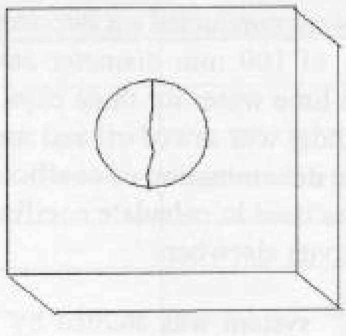

Figure 2 Encapsulation of concrete samples.

Samples were also prepared with simulated poor construction joints. Three cylinders of diameter 100 mm and height 200 mm were cut into halves. Thus six cylindrical blocks of diameter 100 mm and a height 100 mm were obtained. These six samples containing no cracks were also encapsulated with a concrete slab to facilitate the measurement of water penetration. To create a poor construction joint, the samples were wrapped along the circumference with a plastic sheet as shown in Figure 3. Subsequently the sample with plastic sheet was placed in the middle of the mould and the concrete was poured around the sample and was compacted with an external vibrator. One hour after casting the slab, the plastic sheet was pulled out of the mold and in this way a poor construction joint was created along the circumference of the sample. Figure 4 shows the encapsulated sample.

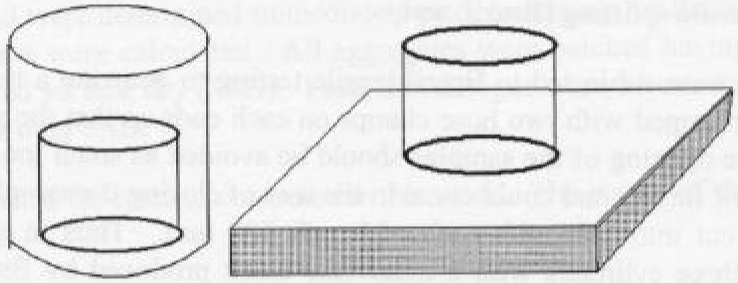

Figure 3 Details of casting for the encapsulation of concrete samples.

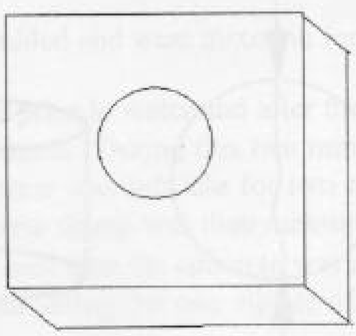

Figure 4 The encapsulated concrete sample with construction joint.

Table 2 shows the mix design and the compressive strength of four concrete mixes which were used to encapsulate the samples. Due to limited number of molds, four separate concrete mixes had to be prepared. Mixes EN1 and EN2 were used to encapsulate sample with simulated poor construction joints and mixes EN3 and EN4 were used to encapsulate samples with transverse cracks generated by Brazil testing.

Table 2 Mix design of concrete mixes in kg/m^3

Mix Identification	EN1	EN2	EN3	EN4
GP	126	.126	126	126
Fly Ash	121	121	121	121
20 mm. agg.	449	446	448	447
14 mm. Aggregate	374	373	373	374
8 mm. Aggregate	317	315	316	315
Coarse Sand	387	385	387	386
Fine Sand	438	436	438	438
Water	130	133	131	130
Water Reducing Admixture	1.2	1.2	1.2	1.2
Water/Binder	0.52	0.54	0.53	0.52
Slump (mm)	110	110	95	100
28 Day Strength (MPa)	17.0	16.5	17.5	18.5

To measure the flow rate a PVC disc was attached on the top surface of the slab using a sealant. The diameter of the disc was 150 mm and it can completely cover the poor construction joint as well as the transverse crack. Figure 5 shows the set-up which was used to measure the flow rate through poor construction joint and the transverse crack. The flow rate was measured prior to repair and was measured again after repair to establish the effectiveness of Radmyx™ system. The flow rate prior to repair was measured twice at the interval of one week to evaluate any "self sealing effect". Subsequently the repair were carried out.

The repair was carried out by Radcrete Pacific Pty. Ltd. The first step in the repair involved removal of concrete adjacent to the cracks. Thereafter, a coat of Radmyx™ slurry was applied. Once the coating was dry, the cracks and construction joints were completely covered with Radmyx™ mortar. After the repair, the samples were kept wet as instructed by Radcrete Pacific Pty. Ltd. One week after the repair the flow rate was measured. Flow rate was also measured two and three weeks after the repair to evaluate the improvement with time. Figure 6 shows the measurement of flow rate.

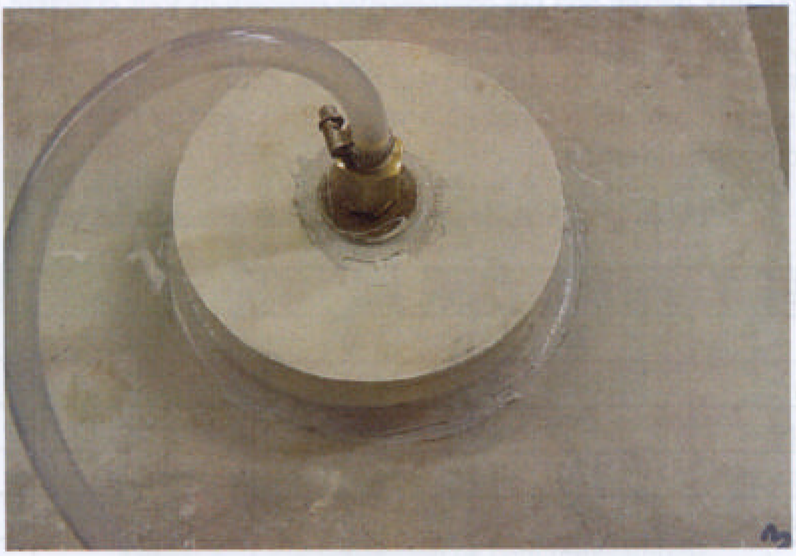

Figure 5 Set-up for the measurement of flow rate through construction joint and crack generated by Brazil testing.

Figure 6 Measurement of Flow rate.

5. RESULTS

The effectiveness of Radmyx™ slurry and Radmyx™ mortar was evaluated on uncracked concrete samples and two types of defects : simulated poor construction joints and samples with simulated cracks generated by subjecting concrete cylinders to a tensile splitting (Brazil) test. This study was carried out on concrete mix R2B and the details of this concrete mix is given in Table 2.

Coefficient of permeability of uncracked concrete samples were measured. Firstly the coefficient of permeability of sample without any application of Radmyx™ slurry and Radmyx™ mortar was measured. Also the coefficient of permeability of samples after the application of Radmyx™ slurry and Radmyx™ mortar was evaluated to establish the effectiveness of slurry and mortar in improving the water permeability. Radmyx™ slurry and Radmyx™ mortar were applied on both the active (surface exposed to pressurised water) and passive side (surface opposite to pressurised water) of the samples to evaluate their effectiveness. Coefficients of permeability of various samples are shown in Table 3 and the reported values are the average value of the two samples.

Table 3 Coefficient of Permeability of samples in m/s.

	Coefficient of Permeability (m/s)
Without Radmyx™ slurry and Radmyx™ mortar	7.17×10^{-11}
Radmyx™ slurry and Radmyx™ mortar applied on **active** side	3.45×10^{-11}
Radmyx™ slurry and Radmyx™ mortar applied on **passive** side	4.69×10^{-11}

It is clear that the application of Radmyx™ slurry and Radmyx™ mortar leads to significant improvement in the water permeability. As expected, application on active side is more effective than the application on the passive side.

Radmyx™ slurry and Radmyx™ mortar were also tested for their effectiveness in the repair of existing defects. As mentioned before, two types of defects were tested and they were : a simulated poor construction joint and a transverse crack. Similar to water permeability, Radmyx™ slurry and Radmyx™ mortar were applied on both the active and passive side of the samples to evaluate their effectiveness. Table 4 gives the flow rate under a head of 5 meters before and after the repair. The flow rate is given in meter^3 per unit length of crack or construction joint in meter and per unit second.

Table 4 Flow rate (x 10^{-9} m^3/m/sec.) in samples before and after repair

Simulated Poor Construction Joints					
Sample No.	Before Repairs		After Active Repairs		
	Immediately	1 week later	1 week after repair	2 week after repair	3 week after repair
1	4600	4800	32	7.5	5.4
2	290	270	54	32	12
10	470	110	32	8.6	5.4
	Before Repairs		After Passive Repairs		
	Immediately	1 week later	1 week after repair	2 week after repair	3 week after repair
3	10000	11000	32	21	6.4
7	110	48	54	32	21
11	400	660	59	32	38
Transverse Crack Generated by Splitting Tensile or Brazil Testing					
Sample No.	Before Repairs		After Active Repairs		
	Immediately	1 week later	1 week after repair	2 week after repair	3 week after repair
4	710	290	140	8.4	8.4
6	5800	2900	51	10	8.4
8	300	140	Sample cracked and no measurements could be performed		
	Before Repairs		After Passive Repairs		
	Immediately	1 week later	1 week after repair	2 week after repair	3 week after repair
5	290	190	51	27	24
9	2600	2100	59	51	29
12	140	67	51	17	20

Figure 7 shows the flow rate prior to and after the repair. It can be seen from the Table 4 and Figure 7 that after repair there is significant improvement in the flow rate for both construction joint as well as for the transverse crack. A reduction of 10 to 1000 times in the flow rate was observed after the repair.

The flow rate after the repair has been replotted in Figure 8, with the axis of flow rate being magnified. It is clear from the figure that there is further improvement in the repair with time as reflected in the decrease in the flow rate. Also it can be seen from the figure that the active repair is more effective than passive repair.

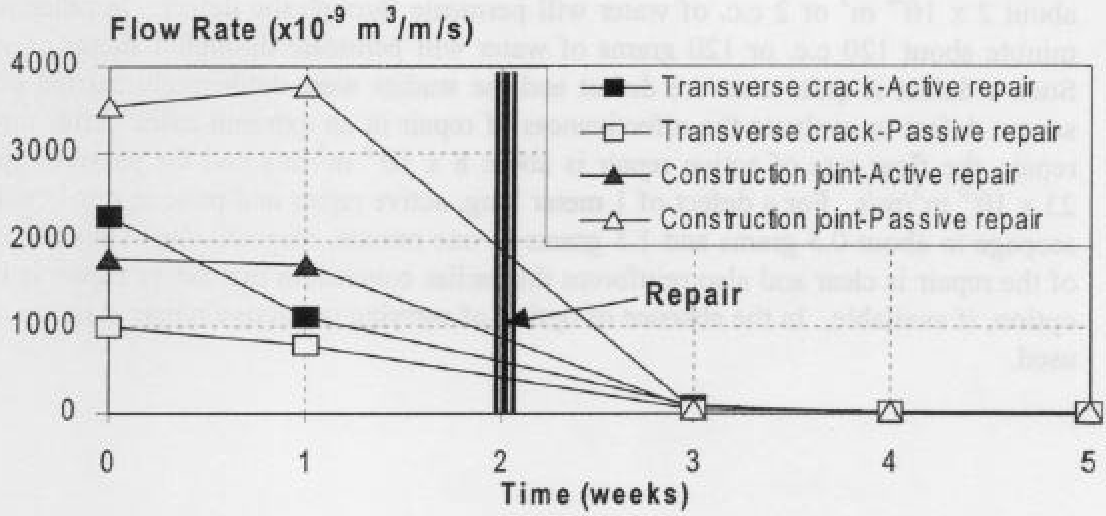

Figure 7 Flow rate prior to and after the repair

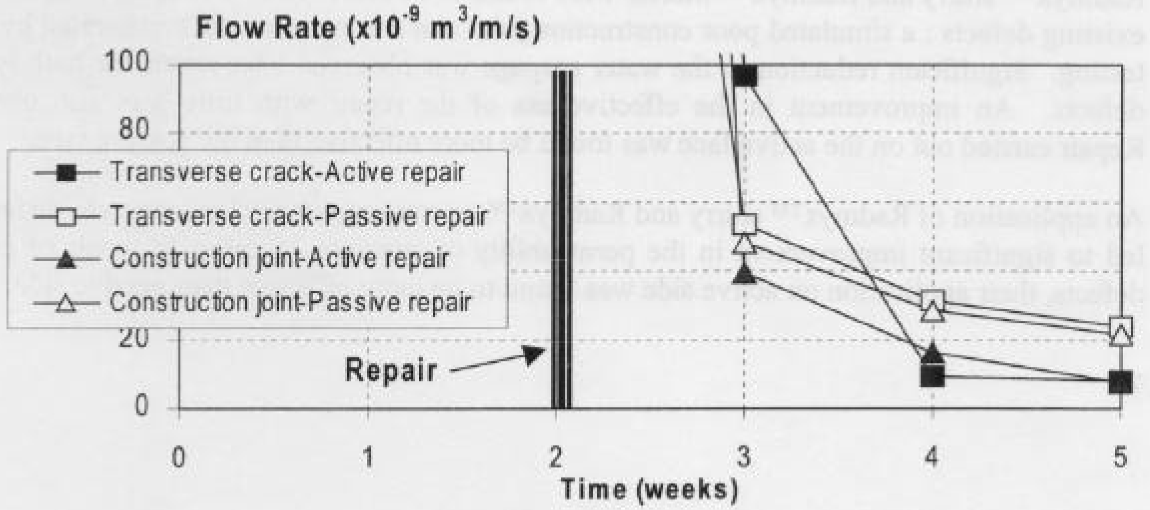

Figure 8 Flow rate after the repair

6. DISCUSSION

Radmyx™ slurry and Radmyx™ mortar were tested for their effectiveness in the repair of existing defects. Two defects were studied and they were : a simulated poor construction joint and a transverse crack generated by Brazil testing. The effectiveness of the repair was evaluated by measuring the flow rate, under five meters of head, through these defects, prior to and after the repair. Prior to repair the flow rated were of the order of 2000 x 10^{-9} m^3/m/s or 2 x 10^{-6} m^3/m/s. This flow rate indicates that if there is a crack of 1 meter long then in 1 second about 2 x 10^{-6} m^3 or 2 c.c. of water will permeate through the defect. In other words in one minute about 120 c.c. or 120 grams of water will permeate through 1 meter of such defects. Such a defect is quite a severe defect and the studies were deliberately carried out on such a severe defect to evaluate the effectiveness of repair in an extreme case. After three weeks of repair, the flow rate of active repair is about 8 x 10^{-9} $m^3/m/s$ and for passive repair is about 23 x 10^{-9} $m^3/m/s$. For a defect of 1 meter long, active repair and passive repair will reduce the seepage to about 0.5 grams and 1.5 grams in one minute, respectively. Thus the effectiveness of the repair is clear and also reinforces the earlier conclusion that active repair is the preferred option, if available. In the absence of option of carrying out active repair, passive repair can be used.

7. CONCLUSIONS

Radmyx™ slurry and Radmyx™ mortar were found to be effective in the repair of two types of existing defects : a simulated poor construction joint and a transverse crack generated by Brazil testing. Significant reduction in the water seepage was observed after repair for both types of defects. An improvement in the effectiveness of the repair with time was also observed. Repair carried out on the active face was found be more effective than the passive face.

An application of Radmyx™ slurry and Radmyx™ mortar onto uncracked concrete surface also led to significant improvement in the permeability of concrete. Similar to repair of existing defects, their application on active side was found to be more effective than passive side.

8. REFERENCES

1. Khatri, R.P. and Sirivivatnanon, V., "Methods for Determination of Water Permeability of Concretes", American Concrete Institute Materials Journal, Vol. 94, May-June, 1997, pp. 257-261.