REPORT BIN 188

Performance of Radmyx™ Admixture

IN CONFIDENCE TO

Radcrete Pacific Pty. Ltd.

Prepared by

Radhe Khatri and Vute Sirivivatnanon

Cement and Concrete
North Ryde

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CSIRO

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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 an integral waterproofing chemical admixture in concrete. According to the manufacturer, this product is part of the "capillary waterproofing system" and is used in basement and water holding structure, where the permeability of the concrete is the key property. The concrete for such application is expected to be water-tight and should hold the water and minimise any leakage. The effectiveness of the product is examined by CSIRO using a range of testing techniques, including the measurement of water permeability. In a laboratory evaluation, there are always some limitations as to how realistic a simulation can represent site situation. 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 objective of this study was to evaluate the effectiveness of Radmyx™ admixture in improving the water-tightness or the permeability of concrete. Apart from water permeability of concrete, following properties were also evaluated :

- Water demand and air content
- Setting times of concrete
- Compressive strength at 3, 7 and 28 days
- Drying shrinkage up to 56 days

The effectiveness of the admixture was studied on nominal grade 32 fly ash concrete. Fly ash concrete mixes were proportioned with and without water reducing admixture. Furthermore, these two types of concrete were prepared with and without Radmyx™ . Thus four concrete mixes were proportioned and the details are given in Table 1. Control mix-1 was compared to Radmyx-1 and Control mix-2 was compared to Radmyx-2 to evaluate the effect of addition of Radmyx™ admixture.

Table 1 Details of Concrete Mixes

	Water Reducing Agent	Radmyx™ Admixture
Control Mix-1	✗	✗
Radmyx-1	✗	✓
Control Mix-2	✓	✗
Radmyx-2	✓	✓

3. SCOPE OF WORK

The performance of Radmyx™ admixture was evaluated on one single concrete Grade 32 with a typical fly ash content of 95 kg/m^3.

4. DETAILS OF EXPERIMENTAL PROCEDURE

As shown in Table 1, two types of nominal grade 32 concrete mixes were prepared with and without Radmyx™admixture. All concrete mixes were designed to have a typical fly ash content of 30% by weight of the total binder and the remaining 70% of the binder was a GP cement. As recommended by Radcrete Pacific, the dosage of Radmyx™ admixture was 1.5 % by weight of the total binder content. In the Control-2 mix and Radmyx-2, a water reducing admixture (WRA) –Pozzolith 370 was also added at the recommended dose of 400 ml/100 kg of binder. Table 2 gives the mix design of the four concrete mixes in kg/m^3.

Table 2 Mix design of concrete mixes in kg/m³

Mix Identification	Control Mix-1	Radmyx-1	Control Mix-2	Radmyx-2
GP	207	207	210	211
Fly Ash	94	94	95	96
Coarse Aggregate-1	439	442	447	449
Coarse Aggregate-2	367	442	447	376
Fine Aggregate	313	373	377	321
Coarse Sand	385	317	321	395
Fine Sand	376	386	390	386
Water	153	149	138	131
Water/Binder	0.51	0.50	0.45	0.43
Radmyx™ admixture	-	4.51	-	4.59
Water Reducing Admixture	-	-	1.43	1.44
Slump (mm)	110	95	110	110
Air (%)	1.25	1.25	1.5	1.5
28 Day Cyl. Strength (MPa)	31.5	36.0	36.5	41.0

The amount of water added was such that the slump of the concrete was 100±20 mm. Thus the workability of the concrete mixes was similar and hence the water demand was measured.

Concrete mixes were 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.

Procedures described in AS1012-Part 18 were followed to determine the initial and final setting times of the concretes. The first step for the determinations was to separate the mortar portion from the concrete mix sieving the concrete on a 4.75 mm aperture mesh. Once the mortar was separated from the concrete, prismatic specimens measuring 150 x 150 x 140 mm were cast. The initial and final setting times of the concrete were determined by measuring the penetration resistance of the separated mortar with time. Initial set and final set corresponded to the penetration resistance of 3.5 MPa and 28 MPa respectively.

Compression strength testing was carried out in accordance with AS1012-Part 9. Tests were conducted at 4, 7 and 28 days. Tests were performed on two cylindrical specimens measuring 100 mm diameter and 200 mm height. Specimens were restrained using a natural rubber capping system as specified in the Standard. All specimens were continuously moist cured until the time of test.

Measurement of drying shrinkage was carried out on prisms of dimensions 75 x 75 x 285 mm which were stored under standard laboratory conditions in a controlled temperature, humidity and air circulation environment conforming to specifications outlined in AS 1012-Part 13. Drying shrinkage was conducted on three prisms and the average values are reported. A horizontal comparator was used to measure the length of the prisms. Specimens were continuously moist cured for seven days followed by exposure to the controlled environment described above.

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].

5. RESULTS

The setting times of concrete mixes prepared with and without Radmyx™ admixture are given in Table 3. Table 3 also gives the water demand, air content, compressive strength and drying shrinkage at various ages. The concrete mixes prepared without Radmyx™ admixture are called hereafter as a Control mix.

Table 3 Properties of concrete with and without Radmyx™ admixture. The two concrete mixes do not contain a water reducing admixture.

		Control (Without Radmyx™ Admixture)	**With Radmyx™ Admixture**
Mix Identification		**Control mix-1**	**Radmyx-1**
Water-to-Binder Ratio		0.51	0.50
Initial setting times (hr:min)		5:50	7:50
Final setting times (hr:min)		7:20	9:50
Water Demand (kg/m^3)		153	149
Air Content (%)		1¼ (1.25)	1¼ (1.25)
Water permeability (m/sec.)	#1	9.2×10^{-12}	5.9×10^{-13}
	#2	9.8×10^{-12}	6.3×10^{-13}
	Average	9.5×10^{-12}	6.1×10^{-13}
Compressive Strength @ 4 days (MPa)		16.0	20.0
Compressive Strength @ 7 days (MPa)		20.0	24.5
Compressive Strength @ 28 days (MPa)		31.5	36.0
Drying Shrinkage @ 7 days (microstrains)		140	120
Drying Shrinkage @ 14 days (microstrains)		230	200
Drying Shrinkage @ 28 days (microstrains)		310	260
Drying Shrinkage @ 56 days (microstrains)		380	340

Table 4 Properties of concrete with and without Radmyx™ admixture. The two concrete mixes were prepared with water reducing admixture.

		Control (Without Radmyx™ Admixture)	With Radmyx™ Admixture
Mix Identification		**Control mix-2**	**Radmyx-2**
Water-to-Binder Ratio		0.45	0.43
Initial setting times (hr:min)		8:30	12:20
Final setting times (hr:min)		10:40	17:10
Water Demand (kg/m^3)		138	131
Air Content (%)		1½ (1.5)	1½ (1.5)
Water permeability (m/sec.)	#1	5.4×10^{-13}	2.8×10^{-13}
	#2	5.0×10^{-13}	3.1×10^{-13}
	Average	5.2×10^{-13}	2.9×10^{-13}
Compressive Strength @ 4 days (MPa)		20.5	22.0
Compressive Strength @ 7 days (MPa)		25.5	27.0
Compressive Strength @ 28 days (MPa)		36.5	41.0
Drying Shrinkage @ 7 days (microstrains)		150	160
Drying Shrinkage @ 14 days (microstrains)		230	280
Drying Shrinkage @ 28 days (microstrains)		290	360
Drying Shrinkage @ 56 days (microstrains)		370	410

It can be seen from Tables 3 and 4 that the water demand of mixes containing Radmyx™ admixture is marginally lower than the control mixes. The lower water demand due to Radmyx™ is evident in both type of mixes, prepared with and without water reducing admixture. Both Control mixes and mixes with Radmyx™ admixture had similar amount of air content and hence the use of Radmyx™ admixture had no effect on the amount of entrained air.

Figure 1 shows the initial and final setting times of Control mixes and mixes prepared with Radmyx™ admixture. It is clearly evident in the Figure that the use of Radmyx™ admixture leads to retardation of setting. Marginal increase in setting times was observed in the case of mixes prepared without water reducing agent, however, significant increase in setting times was observed for the mixes prepared with water reducing agent. It is important to consider the retardation in setting for the timing of form-work removal and also for the timing of further construction.

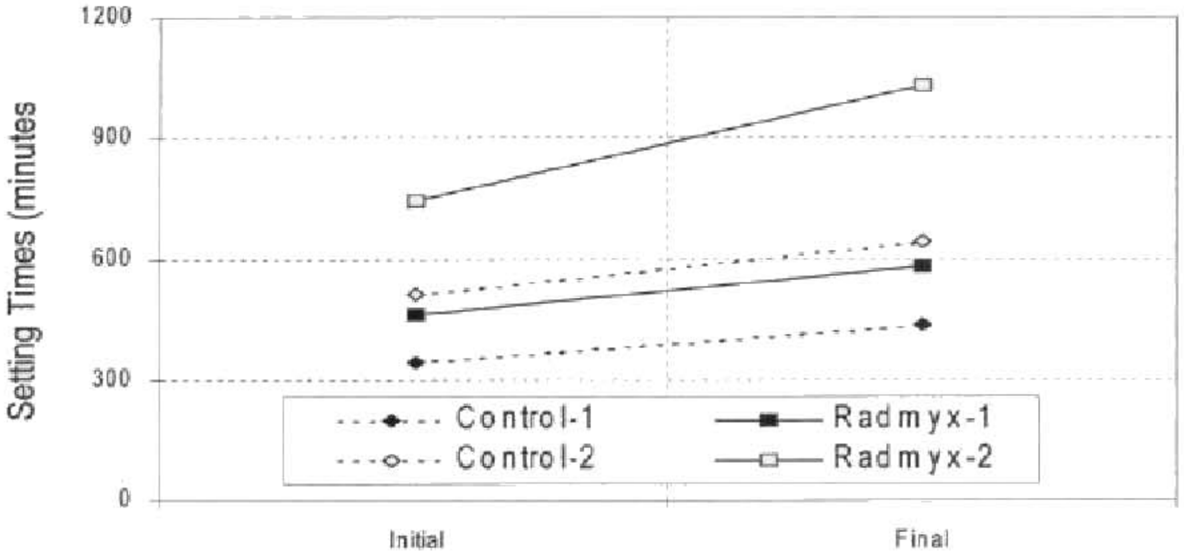

Figure 1 Setting Times of Concrete Mixes

Figure 2 shows the compressive strength development the two concrete mixes (Control and with Radmyx™ admixture) prepared without water reducing admixture. Also Figure 3 shows the compressive strength development of mixes prepared with water reducing admixture. It can be seen that the use of Radmyx™ admixture leads to increase in the compressive strength at various ages.

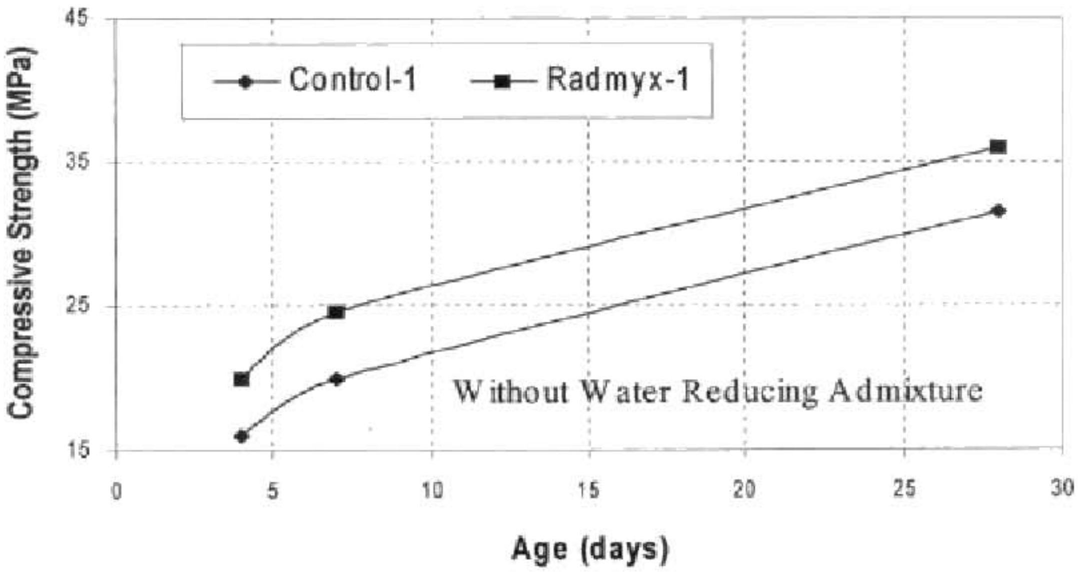

Figure 2 - Effect of the Addition of Radmyx™ Admixture on Compressive Strength Development. These concrete mixes were prepared without Water Reducing Admixture.

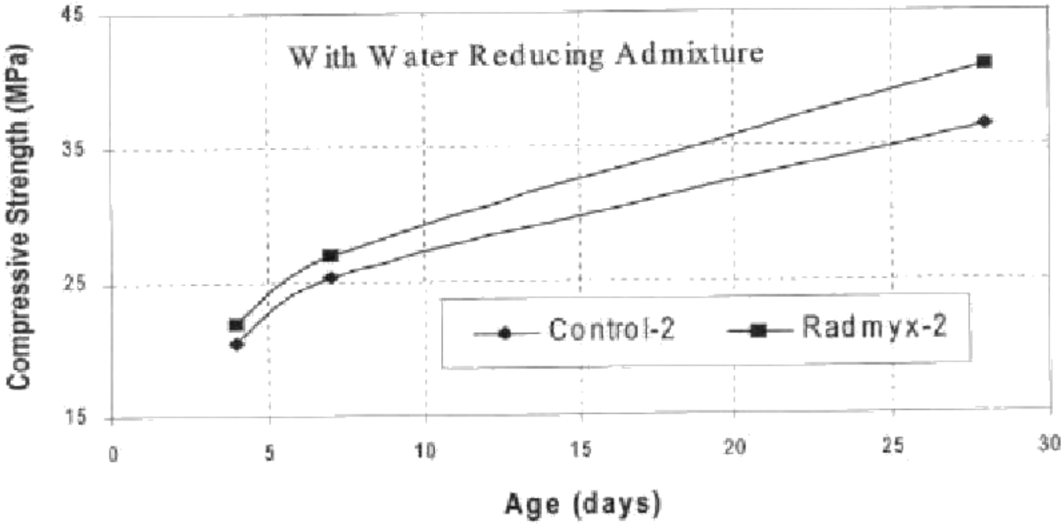

Figure 3 - Effect of the Addition of Radmyx™ Admixture on Compressive Strength Development. These concrete mixes were prepared with Water Reducing Admixture.

Figure 4 shows the compressive strength development of all concrete mixes. Broken lines indicate the control mixes and solid lines indicate mixes with Radmyx™ admixture. The improvement in strength development due to use of Radmyx™ admixture is clearly evident.

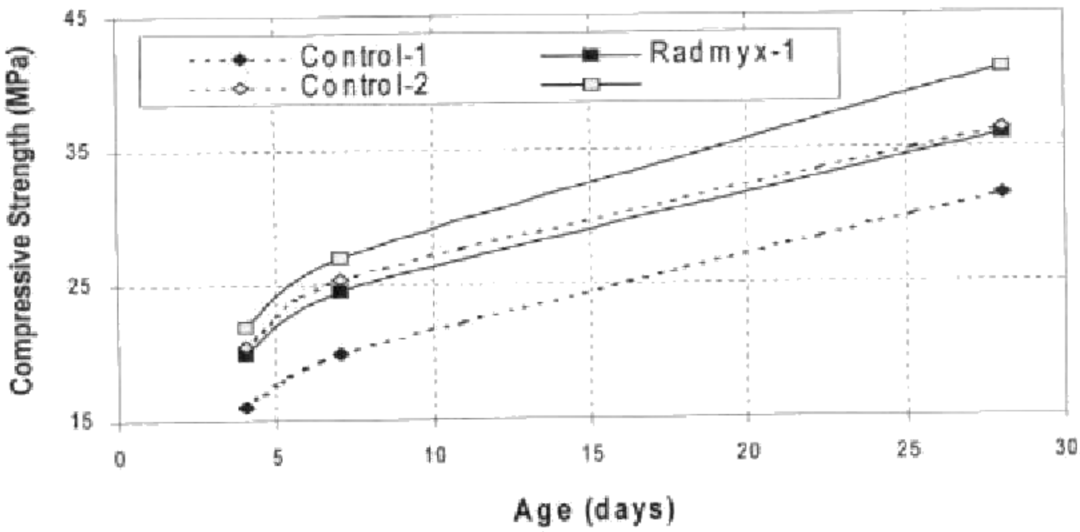

Figure 4 - Effect of the Addition of Radmyx™ Admixture on Compressive Strength Development of all concrete mixes.

The drying shrinkage characteristics of the both types of concrete mixes are shown in Figures 5 and 6. For mixes prepared without water reducing admixture, the use of Radmyx™ admixture leads to a slight improvement in drying shrinkage characteristics. Whereas, for mixes prepared with water reducing admixture, the use of Radmyx™ admixture resulted in a slight increase in the drying shrinkage. Thus no clear trend exists in the effect of Radmyx™ admixture on drying shrinkage characteristics.

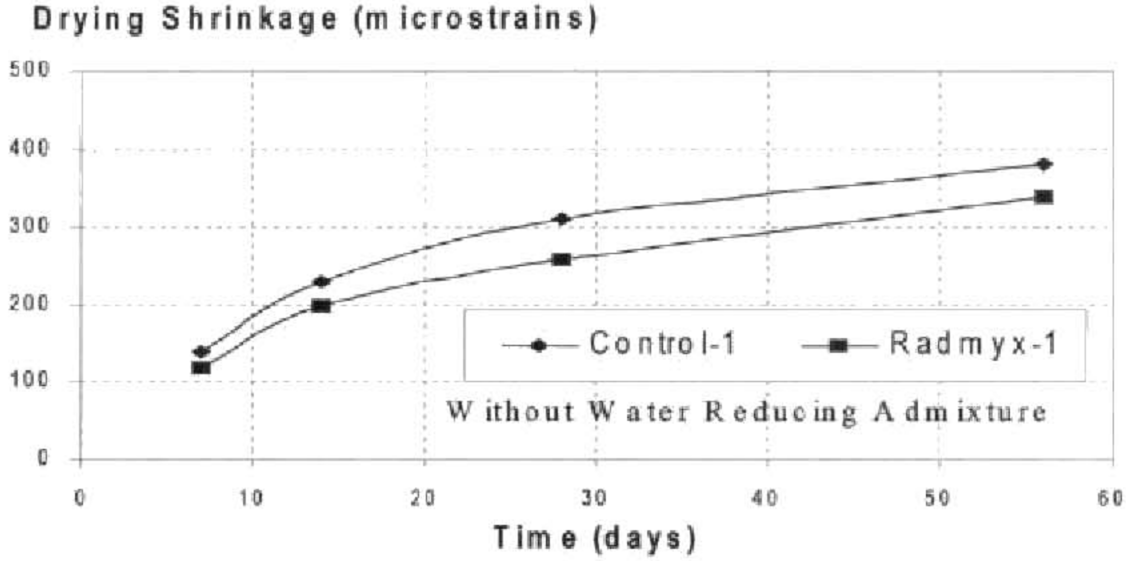

Figure 5 - Effect of the Addition of Radmyx™ Admixture on Drying Shrinkage Characteristics. These concrete mixes were prepared without Water Reducing Admixture.

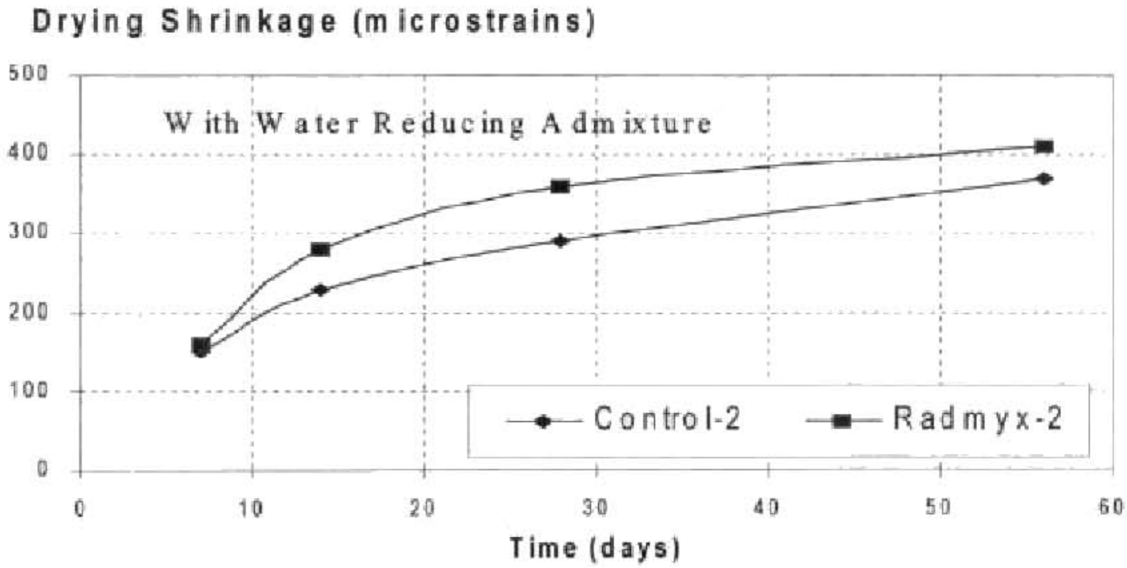

Figure 6 - Effect of the Addition of Radmyx™ Admixture on Drying Shrinkage Characteristics. These concrete mixes were prepared without Water Reducing Admixture.

Figure 7 shows the drying shrinkage characteristics of all concrete mixes. Broken lines indicate the Control mixes and solid lines indicate mixes with Radmyx™ admixture. All concrete mixes had very low 56-day drying shrinkage of less than 420 microstrains. Furthermore the drying shrinkage characteristics of all concrete mixes are not significantly different. Thus significant changes are not expected in drying shrinkage characteristics due to use of Radmyx™ admixture.

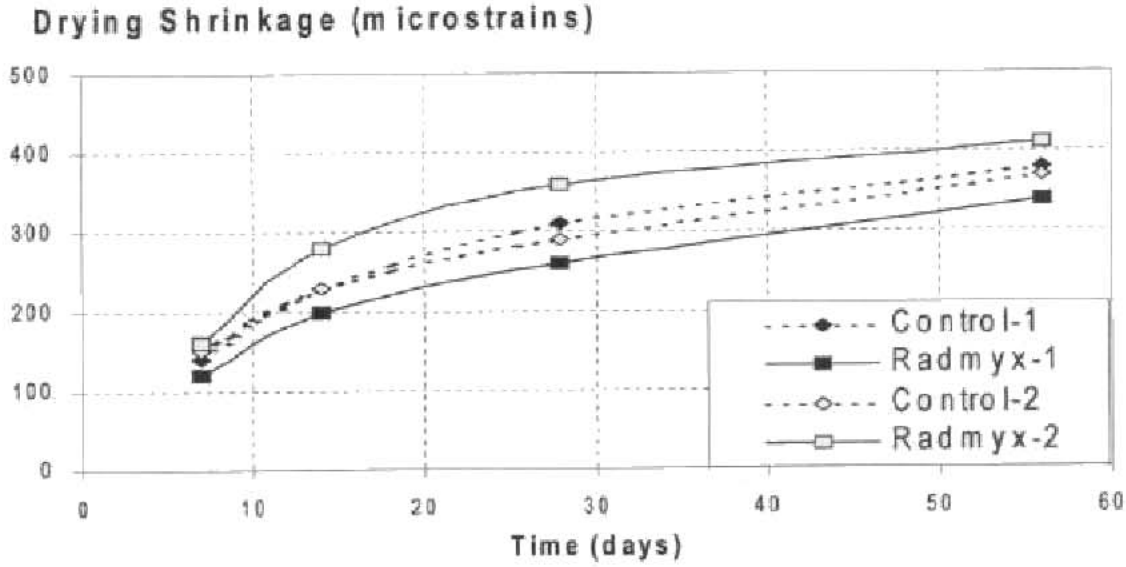

Figure 7 - Effect of the Addition of Radmyx™ Admixture on Drying Shrinkage Characteristics of all concrete mixes.

Figure 8 shows the water permeability of all concrete mixes. The use of Radmyx™ admixture leads to improvement in permeability, reflected in the reduction in coefficient of permeability. The reduction is significant in the case of concrete mixes prepared without water reducing admixture and marginal reduction was observed for concrete mixes prepared with water reducing admixture.

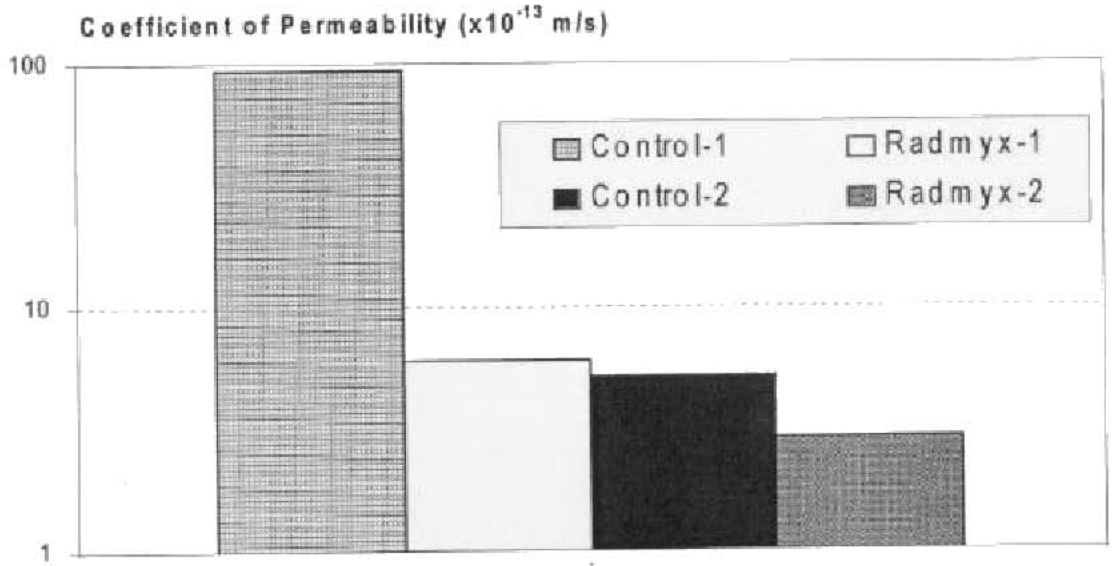

Figure 8 - Coefficient of Permeability of all concrete mixes.

6. DISCUSSION

The objective of this study was to evaluate the effectiveness of Radmyx™ admixture in improving the water-tightness or the permeability of concrete. To evaluate the effectiveness, fly ash concrete were proportioned with and without water reducing admixture. Furthermore, these two types of concretes were prepared with and without Radmyx™ admixture. Thus four concrete mixes (two control mixes and two prepared with Radmyx™ admixture) were prepared and studied. The effectiveness of the admixture was studied on a nominal grade 32 fly ash concrete, however the 28-day strength ranged from 31.5 to 41 MPa. For all concrete mixes, the total binder content was kept constant (300-305 kg/m^3) and also the amounts of various aggregates were similar. The concrete mixes were prepared for similar workability measured by slump and the water demand was determined. Thus the basis of comparison was similar total binder content, similar aggregate content and similar workability. Consequently the water to binder ratios and 28-day strengths were different.

The use of Radmyx™ admixture leads to improvement in permeability of the concrete, which is reflected in the reduction in coefficient of permeability. The reduction is significant in the case of concrete mixes prepared without water reducing admixture and marginal reduction was observed for concrete mixes prepared with water reducing admixture.

The use of Radmyx™ admixture leads to retardation of setting. A marginal increase in setting time was observed in the case of mixes prepared without water reducing agent, however, significant increase in setting times was observed for the mixes prepared with water reducing agent.

Inclusion of Radmyx™ admixture leads to increase in the compressive strength at various ages. All concrete mixes were found to have very low 56-day drying shrinkage of less than 420 microstrains. However no clear trend in drying shrinkage characteristics due to use of Radmyx™ admixture is visible.

7. CONCLUSIONS

The addition of Radmyx™ admixture leads to improvement in permeability of the concrete, which is reflected in the reduction in coefficient of permeability. The reduction is significant in the case of concrete mixes prepared without water reducing admixture and marginal reduction was observed for concrete mixes prepared with water reducing admixture.

Radmyx™ admixture also leads to retardation in setting time in concrete proportioned with water reducing admixture. However its addition had no effect on the amount of entrained air. Radmyx™ admixture leads to improvement in the compressive strength development and reduction in water demand. Whereas, significant changes are not expected in drying shrinkage characteristics due to use of Radmyx™ admixture.

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.