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Commercial in Confidence

USE OF AQURON 2000 AS A CURING AGENT

For:

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TABLE OF CONTENTS

	Page No
1 INTRODUCTION	2
2 METHODOLOGY	2
3 TEST RESULTS	4
3.1 Visual Appearance of Surface	4
3.2 Compressive Strength	4
3.3 Drying Shrinkage	5
3.4 Abrasion Resistance	6
4 CONCLUSION	7

1 INTRODUCTION

The ACCI has been appointed by Markham Distributing Ltd of New Zealand to assess the affects of using Aquron 2000 as a curing agent.

The test program compares some properties of slabs cast in the laboratory treated with Aquron 2000 at final set as a curing compound to slabs where curing was done by the application of a spray of water then covered with polyethylene sheeting.

We take this opportunity to thank David Rappolt from Aquron Applicators of Girraween NSW for assistance in applying the Aquron 2000.

The slabs were then sampled and tested for strength development, drying shrinkage and abrasion resistance.

2 METHODOLOGY

The curing process is known to influence a number of properties of hardened concrete. Three properties considered in this testing program are compressive strength, drying shrinkage and abrasion resistance.

Three slabs, each measuring 2 metres x 1 metre x 200mm deep were cast at the ACCI Laboratory in Randwick from premixed concrete. The concrete was ordered as having a 28 day compressive strength of 32MPa. The concrete was required to be of a standard commercial grade. No restrictions were placed on any constituents, however, the concrete supplier advises that up to 10% Fly Ash is often added in the batching process to improve the plastic properties of the concrete.

The three slabs were cast side by side in the same environment and were finished with a steel trowelled finish.

Companion compression cylinders and drying shrinking specimens were cast.

Three curing conditions were considered:

- Aquron 2000 used as a curing compound, applied at a rate of 0.2 litres/m² then left uncovered to air cure.
- Water sprayed onto the concrete surface, applied at a rate of 5 litres/m² then a polyethylene sheet wrapped loosely over the surface for 14 days then removed and air cured. We understand that this is referred to as “Wet Cured” by some in the construction industry.
- Aquron 2000 used as a curing compound, applied at a rate of 0.2 litres/m² then a polyethylene sheet laid loosely over the surface for 14 days then removed and air cured.

The dosage of applied liquid (either water or Aquaron 2000) was controlled by placing the measured volume of liquid into a pump air sprayer then spray applied using the application method in the manufacturer's literature until all the liquid was applied.

The companion strength specimens were continuously water cured until test by full immersion in a temperature controlled water tank maintained at 23 degrees Celsius.

The drying shrinkage specimens were kept under moist conditions until 24 hours when one half of the specimens were dipped in Aquaron 2000 and the other half were dipped in water, until first measurement. Due to the peculiarities of the comparison the specimens were allowed to air dry from 24 hours after casting (demoulding). The first measurement was taken in SSD condition by wiping the specimens and then air drying in the ACCI's climate control chamber.

A direct consequence of commencing the drying shrinkage measurements at 24 hours instead of 7 days as required by the Australian Standard is a much higher drying shrinkage strain. However as these measurements are comparative the non-standard treatment is not of consequence considering it is consistent across all specimens. Accordingly, the relativity of the drying shrinkages should not be taken as achievable in other concretes.

The slabs were photographed at 14 days to obtain a comparison of the surface appearance and cored at 14 and 28 days to obtain compression specimens for comparison against standard moist cured cylinders.

At 28 days the slabs were tested using the Chaplin Abrasion Testing machine. Chaplin Abrasion is a world recognised test method for measuring the abrasion resistance of flat floors and is useful in assessing surface treatments.

The slabs were retested for both Chaplin Abrasion and core compression strength at 217 days

3 TEST RESULTS

3.1 Visual Appearance of Surface

One of the concerns raised is the tendency of the sheeting used in the wet curing process to “stain” the surface with efflorescence. The visual appearance of the slabs reflected this with the slab treated with Aquron 2000 and air cured not showing any surface efflorescence.

Of interest was the appearance of efflorescence on the slab treated with Aquron 2000 then covered with polyethylene. I believe this may be due to the condensation of moisture under the polyethylene sheet (probably from evaporation off the concrete surface), depositing mineral ions **onto** the slab surface, once the moisture evaporates these ions from salts and accrete on the surface leaving efflorescence.

3.2 Compressive Strength

The following table summarises the strength development of the concrete under different curing conditions:

14 Day Compression Strengths (MPa)							
Aquron 2000 - Wet Cure		Aquron 2000 - Air Cure		Wet Cure Only		Water Cured (Immersion) cylinders	
Spec. No	Strength MPa	Spec. No	Strength MPa	Spec. No	Strength MPa	Spec. No	Strength MPa
AW14-1	24.49	AD14-1	21.64	W14-1	21.41	WC14-1	28.41
AW14-2	24.37	AD14-2	22.07	W14-2	21.66	WC14-2	24.61
AW17-3	24.04	AD14-3	22.30	W14-3	22.34	WC14-3	24.68
	24.30		22.01		21.80		25.90
28 Day Compression Strengths (MPa)							
Spec. No	Strength MPa	Spec. No	Strength MPa	Spec. No	Strength MPa	Spec. No	Strength MPa
AW28-1	32.52	AD28-1	33.39	W28-1	30.85	WC28-1	37.72
AW28-2	33.54	AD28-2	33.69	W28-2	30.85	WC28-2	33.86
AW28-3	34.87	AD28-3	32.09	W28-3	24.56	WC28-3	35.79
	33.64		33.06		28.75		35.79

As can be seen from the table the best results up to 28 days are achieved by the Cylinder strengths. This is to be expected as they are immersed in water to testing age, so that not only no losses in moisture occur, but additional water is provided to continue hydration. Of the cores, those taken from the slab cured using Aquron 2000 then covered in polyethylene achieved slightly higher strengths than those cured using Aquron 2000 but allowed to air dry. The lowest strengths were obtained from those from the “wet cured” or wrapped slab.

The later age strengths are shown in the table below:

217 Day Compression Strengths (MPa)					
Aquron 2000 - Wet Cure		Aquron 2000 - Air Cure		Wet Cure Only	
Spec. No	Strength MPa	Spec. No	Strength MPa	Spec. No	Strength MPa
AW K	54	AD-G	50	W-I	52.5
AW L	55	AD-H	50	W-J	53
	54.5		50		52.8

The strengths achieved in the above tests show continued strength developments of the concrete in the slabs indicating the concrete contains a significant but unknown amount of pozzolanic material, probably Fly Ash. The strength development of the concrete at 217 days is somewhat consistent where the strength of the Aquron 2000 treated / “wet” cured concrete is higher than the Aquron 2000 treated / air cured. As anticipated the slab not treated Aquron 2000 but wet cured achieved similar but slightly lower strength than the Aquron 2000 treated / “wet” cured slab. The reason for this is that while at earlier age the strength of the Aquron treated slabs is enhanced by significantly lower evaporation afforded by the Aquron 2000, the hydration effects if the additional water applied in the “wet” curing process has a similar result. However, it is clear that the three treatments provide similar results with the advantage in the case of the Aquron 2000 treated / air cured slab of quick unhindered access to the slab well before the polyethylene sheet wrapping is removed at 14 days.

3.3 Drying Shrinkage

The following table summarises the results of the drying shrinkage measurements. Shrinkage is shown in microstrain or mm of shrinkage per metre length.

Age (days)	1	4	7	21	35	56
Water Cure	153	373	551	896	990	1050
Aquron 2000 cured	27	127	149	201	210	241

The relative development of drying shrinkage shows a definite improvement in the specimens treated with Aquron 2000. This is due to the pore blocking action of the Aquron 2000 dramatically slowing drying of the shrinkage specimens. Note that the shrinkage does not stop, however, the shrinkage is slowed which allows a greater mitigation of the tensile forces generated by the inherent creep of the concrete resulting in fewer shrinkage cracks.

3.4 Abrasion Resistance

The following table summarises the Chaplin Abrasion results at 28 days:

	Aquron 2000 – Wet Cure			Aquron 2000 – Air Cure			Wet Cure Only		
	Run 1	Run 2	Ave	Run 1	Run 2	Ave	Run 1	Run 2	Ave
Min Depth (mm)	0.93	0.26	0.60	1.01	1.35	1.18	1.13	1.77	1.45
Max Depth (mm)	2.57	1.32	1.95	2.85	3.16	3.01	3.03	2.58	2.81
Average Depth (mm)	1.47	0.74	1.11	2.29	2.31	2.30	2.19	2.24	2.22

As anticipated the best results were where the combination of Aquron 2000 and “wet” curing or wrapping were used. The Aquron 2000 only and “wet cure” only slabs displayed similar abrasion resistances. This result should be seen in light of the high variance in the results. Chaplin Abrasion results are often highly variable. If we compare the minimum values (i.e. least wear values) we see the following ranking:

- 1: Aquron 2000 – Wet Cure
- 2: Aquron 2000 – Dry Cure
- 3: Water cure only

The following table summarises the 217 day Chaplin Abrasion results:

	Aquron 2000 – Wet Cure			Aquron 2000 – Air Cure			Wet Cure Only		
	Run 1	Run 2	Ave	Run 1	Run 2	Ave	Run 1	Run 2	Ave
Min Depth (mm)	0.72	0.75	0.74	0.94	0.64	0.79	0.96	1.02	0.99
Max Depth (mm)	1.79	1.97	1.88	2.28	1.07	1.67	2.02	2.08	2.05
Average Depth (mm)	1.06	1.10	1.08	1.33	1.27	1.30	1.08	1.42	1.25

While all three slabs showed improvement in the abrasion resistance over time, the Aquron 2000 – Wet cure slab showed the least improved with results that could be interpreted as equivalent to the 28 days results. As in the 28 days results the Aquron 2000 – air cured slab and the “wet” cure only slab are essentially equivalent.

At any given age abrasion resistance is a complex inter-relationship determined by the hardness of the sand as well as the bond between the sand and cement paste and even the presence or not of coarse aggregate in the track of the abrasion machine. Abrasion resistance is a surface characteristic. One of the

principal causes of low abrasion resistance in concrete pavements is poor curing and rapid drying of the surface. Even drying the first few microns of paste can cause micro-cracking which will result in early surface loss, i.e. abrasion.

4 Conclusion

The test results clearly show that using Aquron 2000 as a curing compound yields properties which are at least equivalent and at best superior to the wrapping method as described as “wet curing”.

Curing using Aquron 2000 improves achieved compressive strength and more closely approaches the maximum 28 day compressive strength than cores taken from a “wet” cured or wrapped slab. Long term core strength measurements show that the use of Aquron 2000 as a curing compound with subsequent air curing achieves similar strengths to “wet” curing.

Drying shrinkage is dramatically reduced using Aquron 2000. This is due to the pore blocking action of the Aquron 2000 dramatically slowing drying of the shrinkage specimens.

Curing using Aquron 2000 improves abrasion resistance and core compressive strengths more closely approaching the maximum 28 day cylinder compressive strengths than cores taken from a “wet” cured or wrapped slab. Later age abrasion testing shows that Aquron 2000 as a curing compound with subsequent air curing achieves similar abrasion resistance to “wet” curing.

The physical appearance of the Aquron 2000 treated slab does not exhibit the efflorescence shown on the slabs covered with polyethylene sheets.

The testing shows that curing using Aquron 2000 and air drying is at least equivalent to “wet” curing by wetting the concrete and wrapping in polyethylene for 14 days with the added advantage of a better overall appearance and quicker access to the slab.