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PRODUCT DEVELOPMENT, APPRAISAL AND TESTING OF A NEW AND IMPROVED DRYING SHRINKAGE REDUCING ADMIXTURE FOR CONCRETE

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SUMMARY

Concrete generally undergoes volume changes including contraction shortly after placement due predominantly to drying shrinkage. This potentially leads to cracking particularly under restrained conditions where tensile stresses develop within the concrete matrix. Apart from the obvious issue of aesthetics, this cracking more importantly impacts on the long term durability of the concrete and serviceability of the structure. These issues can lead to compromises in water-retaining structures and chloride ingress in bridges and parking structures to name but a few.

Drying shrinkage cracking has traditionally been controlled by reducing joint spacing, increasing reinforcement, and using expansive cements and admixtures. This paper will focus on the use and application of chemical admixtures known as Shrinkage Reducing Admixtures (SRA's) and specifically summarise the product development, and testing by BASF in developing a new and improved SRA solution. In Australia and New Zealand conventional SRA's have been widely used successfully over the last decade. A new and improved generation of SRA has now been developed and undergone rigorous testing by BASF. This new generation of SRA is shown to be chemically compatible with lignin's, β-naphthalene sulphonate (BNS) and polycarboxylate ether classes of dispersant. Moreover, it can be used along with calcium nitrate (concrete accelerator) and calcium nitrite (corrosion inhibitor).

In this paper, we will present the detailed and comprehensive test data compiled through this development and testing programme which will demonstrate the significant improvements and performance of this New and Innovative solution versus the traditional and current SRA technology. In addition to drying shrinkage, the development of compressive strength and the effects on fresh and plastic concrete properties have been tested and shown to compare favourably with both plain untreated concrete as well as that treated with the conventional SRA technology.

INTRODUCTION

As concrete technology has advanced over the past decade, users expect better concrete performance such as higher strength, workability, flowability and durability alongside increased sustainability. To ensure higher durability, harmful substances such as chloride ions and alkali metal ions must be prevented from ingressing into the concrete and reaching the steel reinforcement.

It is widely recognised that cracking in concrete is one of the major factors that has the potential to reduce durability, by accelerating the neutralization of the concrete and allowing corrosion of the steel reinforcing. The main cause of cracking in concrete is as a result of a reduction in volume due to moisture loss over time after the concrete has attained final set and is commonly known as drying shrinkage. Drying Shrinkage is therefore a phenomenon that occurs constantly in concrete construction and with sufficient restraint can cause cracking if the induced tensile stresses exceed the tensile strength of the concrete.

Over recent years Consulting Engineers, concrete producers and contractors have sought to enhance durability by increasing the cracking resistance of concrete and placing ever tighter limits around controlling and reducing drying shrinkage. To meet this demand for increased reduction in drying shrinkage the authors have attempted to develop an improved SRA solution both in terms of performance and sustainability.

Reducing Drying Shrinkage

Reduced drying shrinkage of concrete has typically been achieved over recent years by a combination of factors including;
The use of quality clean aggregates
Correct material proportioning
The use of special cements
The use of water reducing chemical admixtures
The use of “speciality” Shrinkage Reducing Admixtures (SRA’s)

Researchers over the years have proposed several mitigative methodologies for controlling concrete shrinkage. Above all, the Capillary Tension Mechanism is regarded as the most useful. Current commercially available SRA’s can reduce concrete volumetric changes by reducing the surface tension of the capillary solution in concrete.

Product Development

SRA’s were first developed in Japan in the 1980’s, the main component being a polyoxyalkylene alkylether, a low alcohol alkkylene oxide adduct.

BASF’s current commercially available SRA in the ANZ region utilises raw materials sourced from Japan so the challenge was to source locally available materials which ultimately improves sustainability and reliability whilst also improving on historical performance.

Mechanism

The loss of adsorbed water during continued drying has a threefold effect. Firstly, there is the reduced volume through loss of adsorbed water from within the hydrating cement paste itself, Secondly; there is the volume reduction due to an increase in capillary tension and thirdly an increase in the attraction forces between the C-S-H hydration products.

SRA’s function by reducing this capillary tension and the attraction forces that develop within the pore spaces of concrete as it dries during these latter stages. Refer to Figures 1 & 2

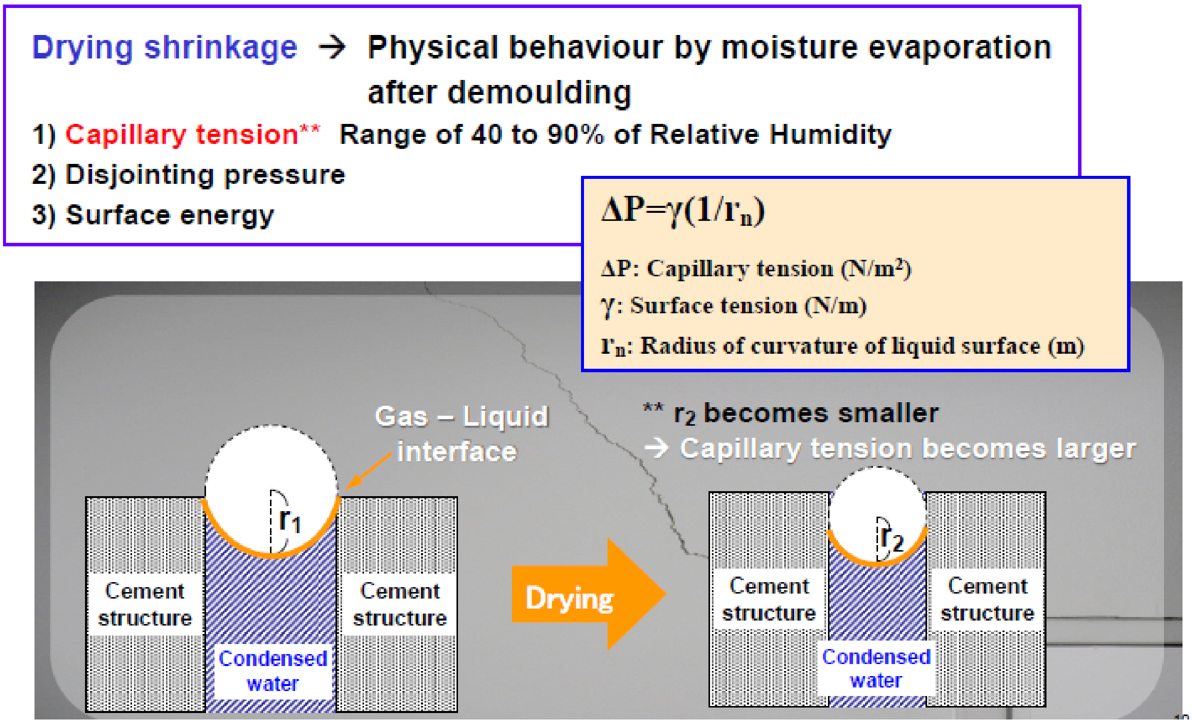


Figure 1

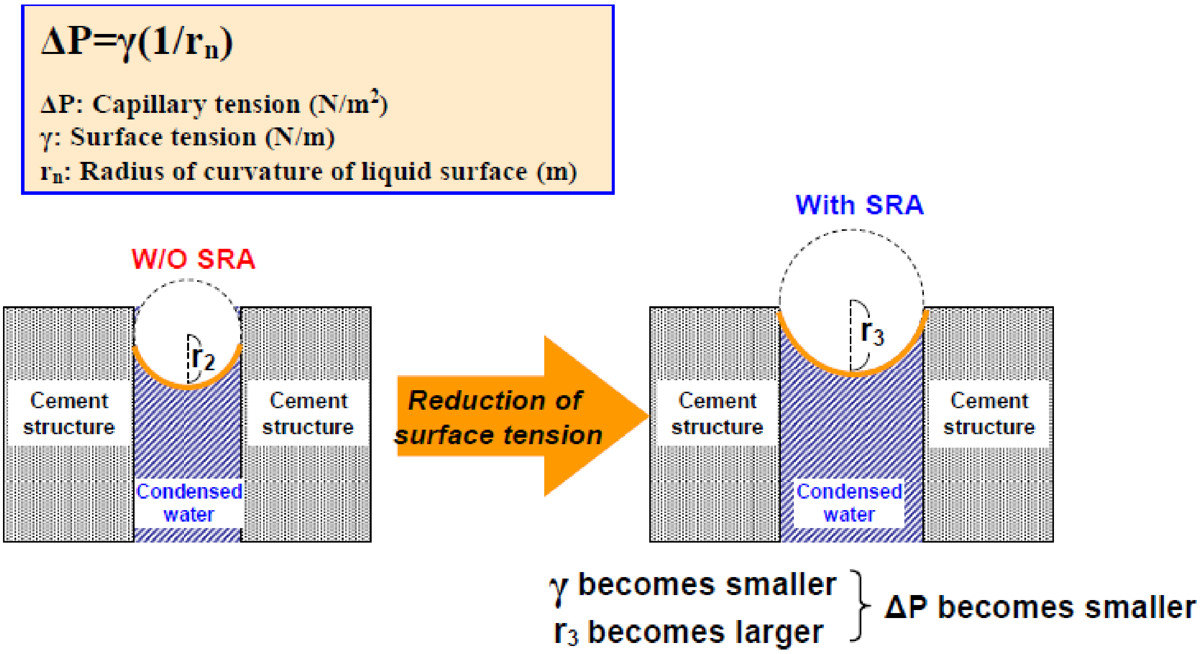


Figure 2

TEST PROGRAMME

Materials and Scope of trials

A sequence of trial mixes was established with the work being carried out at the BASF Technical Services Laboratory (TSL) in Seven Hills Sydney and utilising local and commercially available materials.

Initially total binder was consistent throughout at 360kg/m^3 consisting of General Purpose (GP) cement and locally available Fly Ash and the free W/C ratio was maintained at a constant ~ 0.59. Tests were conducted utilising both a Lignosulphonate and Ligno/PCE based water reducing admixture (WRA).

The new SRA was tested at 3 dose levels, 2, 4 and 6 litres/m^3 according to recommended dose rates and compared against our current commercially available SRA, TAS21 (Table 1) It was also then further tested against other commercially available SRA's, named C1 and C2, but at an increased total binder content of 450kg/m3 and a free W/C ratio of 0.42.(Table 2)

Table 1

MIX	Water Reducer	Dosage	SRA	Dosage	Slump	Air	Fresh Density	w/b	Water	GP Cement	Fly Ash	Fine Agg - Sand	Coarse Agg – 20/7 Gravel
		(ml/100kg)		(L/m3)	(mm)	(%)	(kg/m3)		(l/m3)	(kg/m3)			
A	Pozzolith 80	300		0	115	1.6	2400	0.59	212	300	60	865	980
B			TAS21	2	120	2.2	2370	0.59	208				
C				4	125	2.0	2380	0.59	209				
D				6	120	2.8	2380	0.59	209				
E			SRA200	2	120	2.6	2370	0.59	208				
F				4	130	2.8	2360	0.58	206				
G				6	125	3.0	2360	0.58	205				

Table 2

MIX	Water Reducer	Dosage	SRA	Dosage	Slump	Air	Fresh Density	w/b	Water	GP Cement	Fly Ash	Fine Agg - Sand	Coarse Agg – 20/7 Gravel
		(ml/100kg)		(L/m3)	(mm)	(%)	(kg/m3)		(l/m3)	(kg/m3)			
A	Rheoplus 75	400		0	170	3.0	2400	0.41	185	360	90	828	890
B			C1	6	170	2.0	2370	0.41					
C			SRA200	6	170	2.4	2380	0.41					
D			C2	6	180	2.4	2380	0.41					
E			TAS21	6	155	2.4	2370	0.41					

Results and SRA Performance

All mixes were tested for slump, air content, plastic density, bleed, compressive strength and drying shrinkage strain. Drying Shrinkage was determined in accordance with AS1012.13 by an external third party testing authority.

The results of these tests are summarised in the following tables (tables 3-5) and graphs (Figures 3 – 8)

Table 3 – Fresh and hardened concrete properties compared against plain mix

Mix Ref	Shrinkage Reducing Admixture	Dose Rate	Bleed	Initial Set	Final Set	Average Compressive Strength (MPa)			
						3 day	7 day	28 day	56 day
	Evaluated	L/m^3	%	Hr : Min	Hr : Min	17/05/2013	21/05/2013	11/06/2013	9/07/2013
A	-	-	4.69	6:50	8:50	18.0	26.0	36.5	43.5
B	TAS21	2	5.72	7:00	8:50	18.0	25.5	36.5	43.0
C	TAS21	4	5.91	7:30	9:20	15.5	22.0	33.0	40.0
D	TAS21	6	5.29	7:10	9:20	15.5	23.5	35.0	42.0
E	SRA 200	2	5.20	6:40	9:20	18.0	26.0	36.0	43.0
F	SRA 200	4	4.85	7:30	9:40	17.0	23.0	32.5	39.0
G	SRA 200	6	5.59	7:10	9:40	17.5	24.0	34.5	42.0

Table 4 – Drying shrinkage of plain, TAS21 and MasterLife SRA 200

	Average drying shrinkage (microstrain)					
Mix Ref	*7 days*	*14 days*	*21 days*	*28 days*	*56 days*	*90 days*
A	210	340	420	480	560	600
B	170	280	350	420	510	560
C	160	270	350	420	510	570
D	140	250	330	390	480	530
E	170	280	360	430	510	560
F	150	250	330	390	460	510
G	110	200	260	320	390	440

Table 5 - Fresh and hardened concrete properties of plain, C1, C2, TAS21 and MasterLife 200

Mix Ref	Material(2)	Dose Rate	Bleed	Initial Set	Final Set	14 days shrinkage	28 days shrinkage	56days shrinkage	Average Compressive Strength (MPa)			
									1 day	7 day	28 day	
	Evaluated	$liters/m^3$	%	Hr : Min	Hr : Min	microstrain	microstrain	microstrain	21/03/2014	27/03/2014	17/04/2014	
A	-	-	5.30	7:50	9:30	470	590	650	18.0	41.5	59.0	
B	C1	6.0	5.60	7:40	9:00	310	430	500	16.0	39.0	56.5	
C	SRA 200	6.0	6.62	8:20	9:50	290	410	480	16.0	37.0	57.5	
D	C2	6.0	4.14	8:10	9:40	280	400	480	16.0	38.0	58.5	
E	TAS 21	6.0	5.24	8:00	9:00	330	450	540	17.5	40.5	58.0	

Figure 3

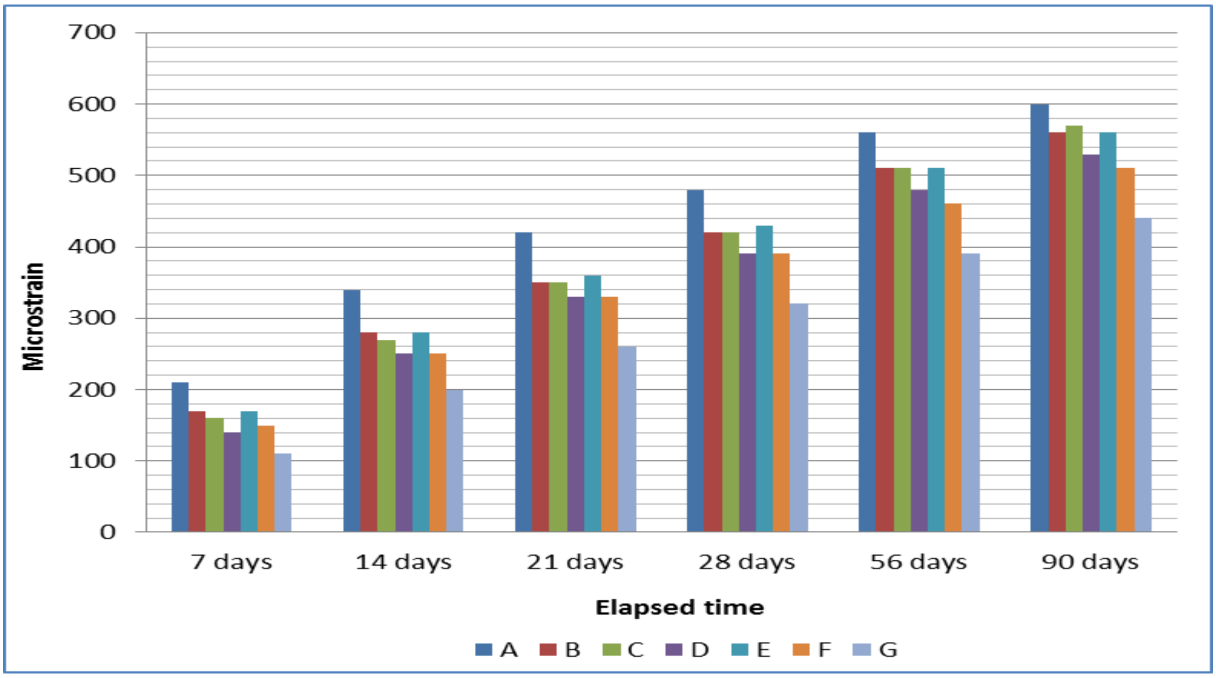


Figure 4

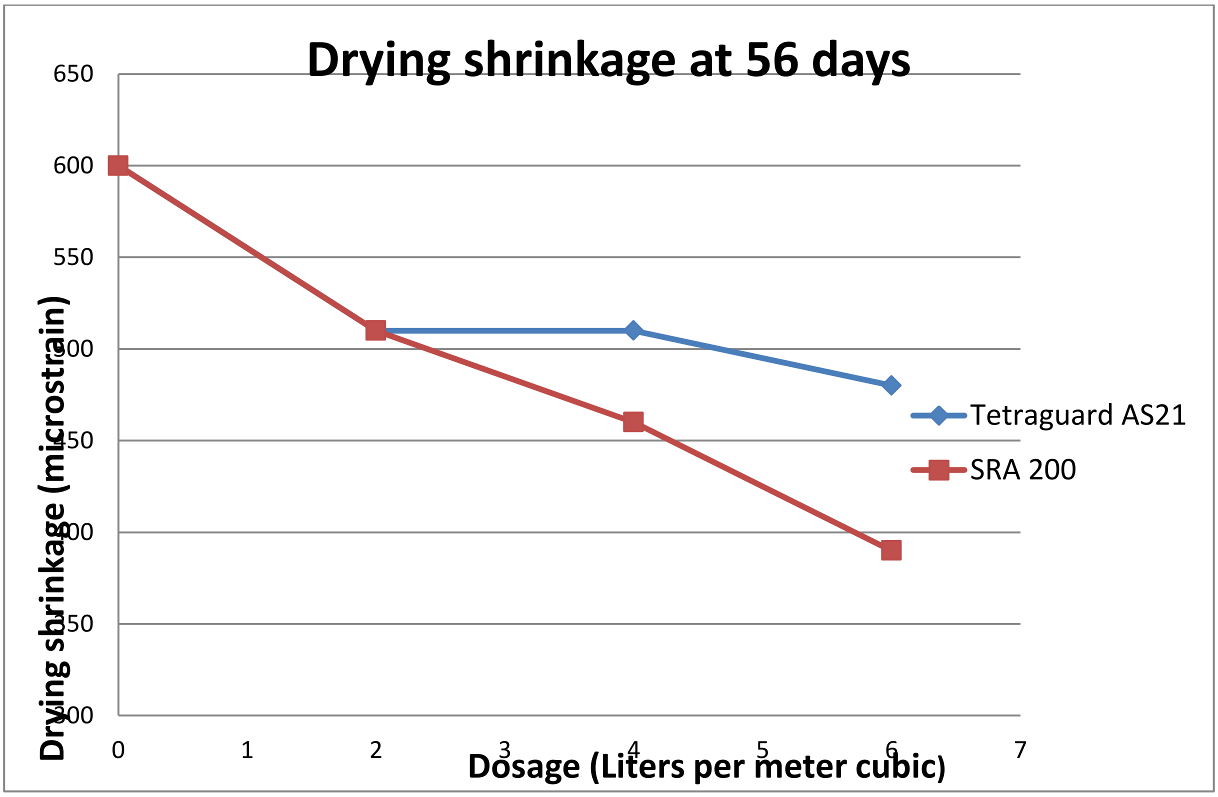
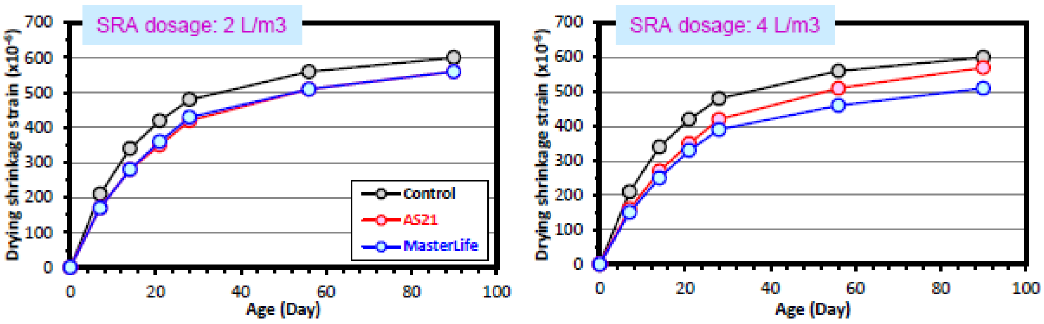
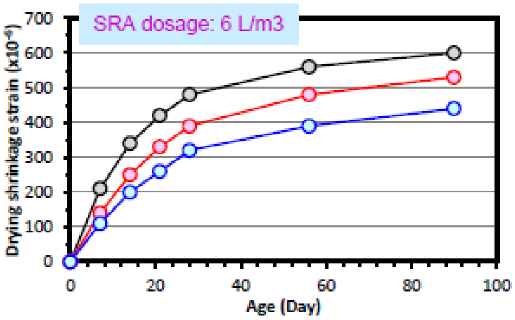


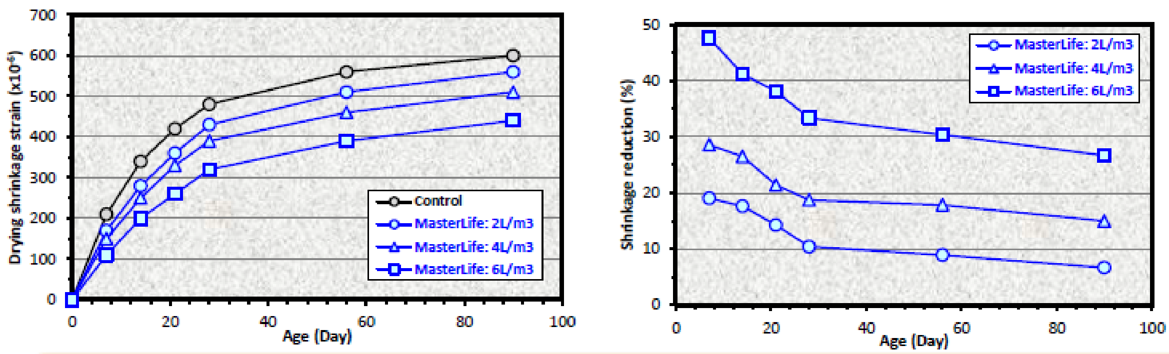
Figure 5





» **MasterLife® SRA 200 showed lower drying shrinkage strain than Tetraguard AS21 at 4 and 6 L/m³.**

Figure 6



- » **4 L/m³ of MasterLife® SRA 200 reduces drying shrinkage strain by 100 micros at 90 days**
- » **6 L/m³ MasterLife® SRA 200 reduces drying shrinkage strain by 160 micros at 90 days**
- » **MasterLife® SRA 200 can reduce drying shrinkage by 30% to 50% at 6 L/m³**
- » **Shrinkage is lower as we progress to 90 days for all dosage levels**

Figure 7

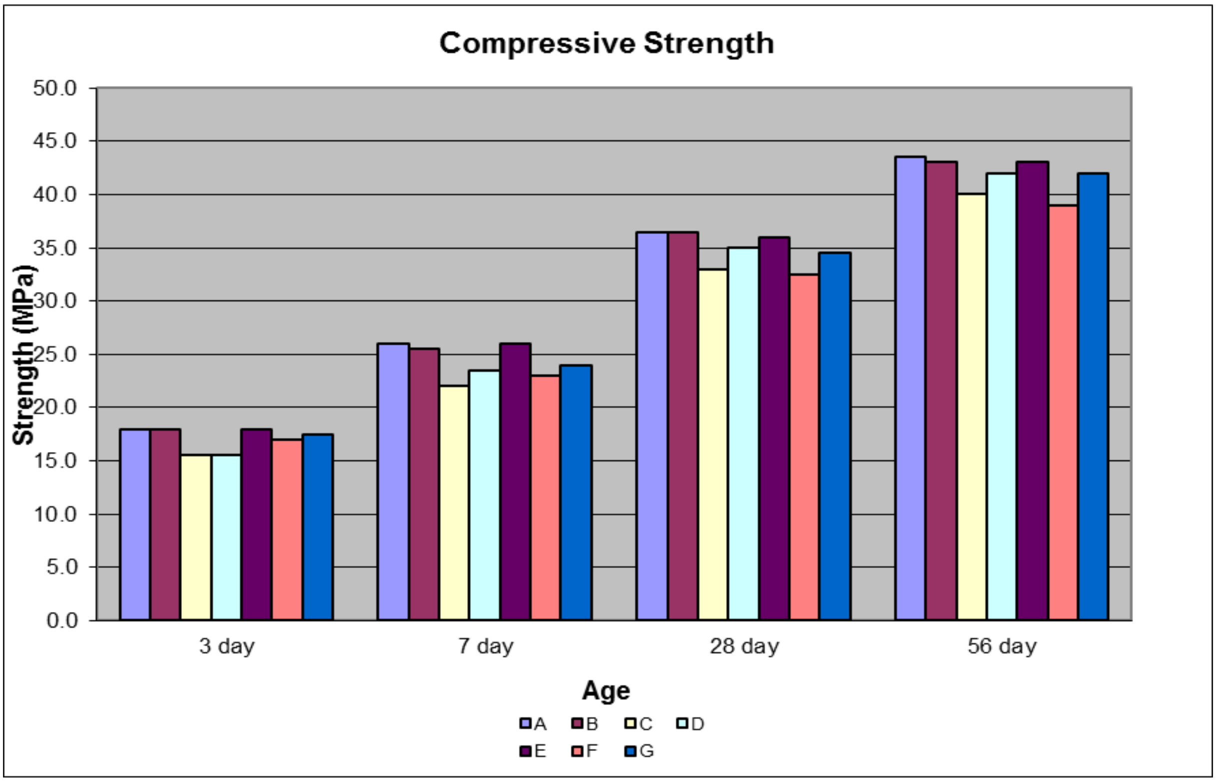
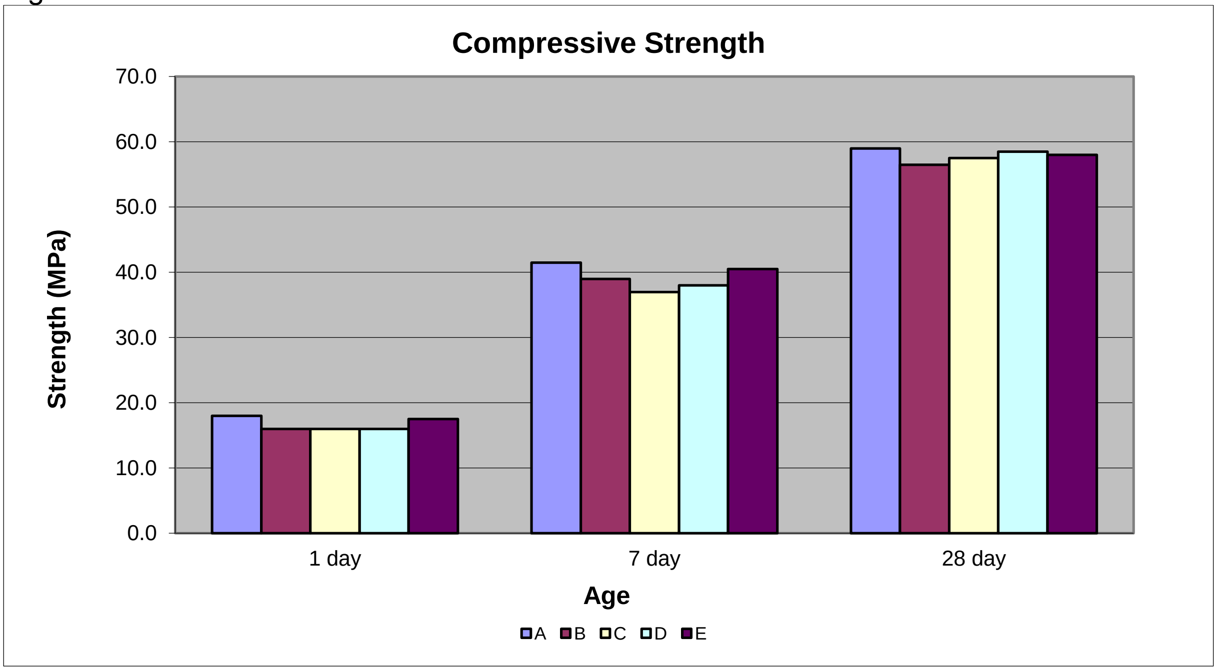


Figure 8



CONCLUSIONS

The new and improved SRA exhibits linear shrinkage reduction between 2L/m3 and 6L/m3.

The new SRA yields better drying shrinkage reduction than other commercially available SRA's at 4 and 6L/m3.

The new SRA yields shrinkage reductions in the range 10% to 50%.

Concrete containing the new SRA shows similar strength development albeit marginally lower than the untreated control but consistent with other commercially available SRA's.

Total bleed tends to be slightly higher with all SRA's compared to control due to the slightly increased setting times that all SRA's tend to exhibit but the new SRA is consistent with the other commercially available SRA's.

The new SRA is made with locally available raw materials so will be more sustainable and consistent in the ANZ region.

The new SRA has limited negative effects on the hardened and fresh concrete properties.

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