COMPATIBILITY OF LITHIUM-BASED ADMIXTURE WITH OTHER CONCRETE ADMIXTURES

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ABSTRACT

Lithium-based chemicals have long been known to be effective in controlling concrete expansion caused by alkali-silica reaction (McCoy and Caldwell). Lithium chemicals are readily available for this application. However, we need to ensure that lithium admixture can be used together with other chemical admixtures in a concrete mix design. The study in this program showed that Lifetime™ lithium admixture, which is commercially available and specially formulated for concrete applications to control ASR, worked well in concrete. It did not show incompatibility problems with several ASTM Type A (water reducing agent), D (water reducing and retarding agent), F (superplasticizer) and G (superplasticizer and retarding agent) admixtures and an air-entraining agent.

Keywords: Air-entraining agent, alkali-silica reaction (ASR), chemical admixture compatibility, concrete durability, Lifetime lithium admixture, water-reducing agent.

INTRODUCTION

The manufacturing of modern concrete has been accompanied by the extensive use of various chemical admixtures such as water reducing agents, superplasticizers, retarding agents, accelerators and air-entraining agents to achieve desired engineering properties of the concrete. Sometimes, different admixtures are used together in the same mixture. In some cases, the admixtures used in the same batch are not compatible and affect their performance (Baalbaki, M and Aitcin, P.C., 1994).

Limited information on the effect of chemical admixtures on ASR is available. Several reports have shown that superplasticizers based on the chemistry of sulphonated naphthalene formaldehyde (SNF) and sulphonated melamine formaldehyde (SMF) might increase the expansion of mortar bars made with reactive silica aggregate (Perry, C. and Gillott, J.E., 1986; Wang, H. and Gillott, J.E., 1989). Accelerators based on calcium chloride often increase concrete expansion due to ASR (Ramachandran, V.S., 1984; Wang, H. and Gillott, J.E., 1990). Chemicals such as lactic acid, EDTA, oxalic acid and sucrose were found to decrease ASR-induced expansion, particularly, when the specimens were made with highly reactive siliceous aggregate (Wang, H. and Gillott, J.E., 1992). Air-entraining agents were reported to be capable of reducing ASR-induced expansion (Jensen, A.D. et al., 1984; Wang, H. and Gillott, J.E., 1990).

With the widespread problems of concrete deterioration due to ASR, it is unavoidable that practical approaches need to be taken to reduce and control the risk of ASR in new structures. Lithium technology is one of the approaches. To ensure the performance of lithium chemical admixtures in concrete, a series of performance evaluations have been conducted. This paper presents the evaluation results relating to the compatibility of Lifetime lithium admixture (available from FMC Corporation, Gastonia, NC, USA) with an air-entraining agent, and four different water reducing/retarding admixtures.

Materials

Four ASTM Type I portland cements with different alkali contents were used in the concrete mix designs to evaluate the response of lithium to the alkali content in the cement. Designations of the cements are listed in Table 1.

An air-entraining agent (Vinsol Resin) and four commercially available chemical admixtures were selected to evaluate the compatibility with a lithium admixture. The designations of the admixtures are shown in Table 2.

Table 1: Cement designations

Designation	Cement alkali content Na_2O_e(%)
TI53	0.53
TI63	0.63
TI80	0.80
TI102	1.02

Table 2: Designations of chemical admixtures

Designation	Admixture
A-A	ASTM Type A water reducing agent
A-D	ASTM Type D water reducing and retarding agent
A-F	ASTM Type F superplasticizer
A-G	ASTM Type G superplasticizer and retarding agent
AEA	Air-entraining agent
Lifetime	Lithium admixture

Test program

A two-part test program was conducted to evaluate (1) the effect of the combined system of air-entraining agent, chemical admixtures and Lifetime lithium admixture on the workability and air-entraining properties of concrete; (2) setting time and strength development characteristics of these systems. The concrete mix designs are presented in Table 3.

A total of 32 concrete mixtures were prepared and tested in this program. In preparing cement pastes for setting time and strength development tests, the same admixture dosages listed in Table 3 were used.

Table 3: Mix designs of concrete

Cement (kg/m³)	TI53 335		TI63 335		TI80 335		TI102 335	
Lifetime (ml/100kg cem.)	0	3190	0	3790	0	4810	0	6140
AEA(ml/100kg cem.)	50							
Concrete mixes made with A-A and A-D admixtures								
Stone(kg/m³)	1100							
Sand(kg/m³)	740							
Water(kg/m³)	150							
A-A /A-D(ml/100kg cem.)	390/330							
Concrete mixes made with A-F and A-G admixtures								
Stone(kg/m³)	1150							
Sand(kg/m³)	776							
Water(kg/m³)	110							
A-F or A-G(ml/100kg cem.)	1960							

Results and discussions

Concrete made with A-A admixture

Figs. 1-3 show the slump, air-content and setting time of concrete mixes made with admixtures A-A, AEA, and with and without Lifetime admixture. Slump was improved (except a mix made with cement TI80) by the incorporation of Lifetime admixture (Fig.1). The same is true for the air-entrainment (Fig.2). Lifetime admixture increased air-content of concrete made with cements TI53, TI63 and TI102. Lifetime admixture had a tendency to decrease setting time of concrete by about 20-40 minutes (Fig.3). Alkali content in the cement also affected setting time. The higher the alkali content, the shorter the setting time.

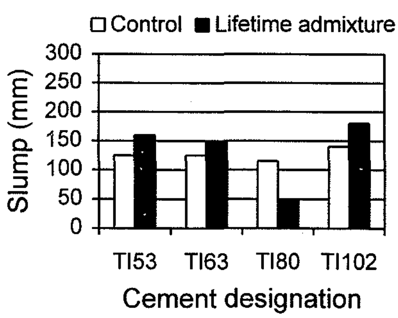

Fig. 1: Effect of Lifetime on slump in the specimens made with A-A admixture

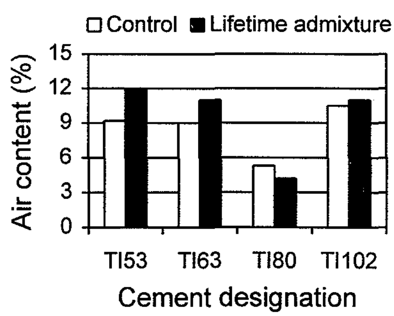

Fig. 2: Effect of Lifetime on air content in the specimens made with A-A admixture

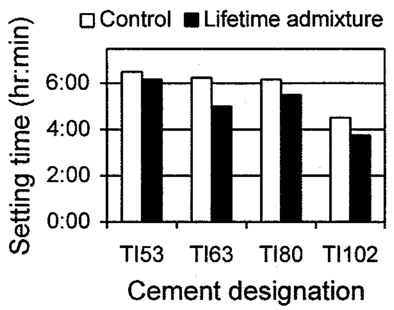

Fig. 3: Effect of Lifetime on setting time in the specimens made with A-A admixture

Table 4 shows the effect of Lifetime admixture on strength development. Generally speaking, Lifetime admixture did not significantly alter the strength development characteristics. Depending the cement, it showed increased and decreased strength in different specimens.

Table 4: Effect of Lifetime admixture on strength development of specimens made with A-A admixture

Specimen made with cement	Strength (MPa)							
	Control				Lifetime lithium admixture			
	1d	3d	7d	28d	1d	3d	7d	28d
TI53	18	32	43	69	13	26	50	76
TI63	15	34	45	66	17	30	43	52
TI80	12	31	42	59	16	25	35	41
TI102	23	38	46	52	24	35	41	53

Concrete made with A-D admixture

In this series of tests, it was found that Lifetime increased workability in general except the one specimen made with cement TI102 (Fig.4). There was no significant effect of Lifetime admixture on the air-entrainment properties (Fig. 5). Table 5 shows the effect of Lifetime admixture on strength development. Again, Lifetime admixture did not show significant effect on strength development.

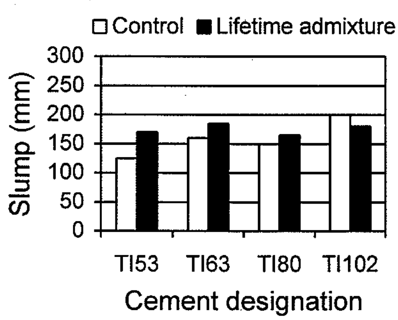

Fig. 4: Effect of Lifetime on slump in the specimens made with A-D admixture

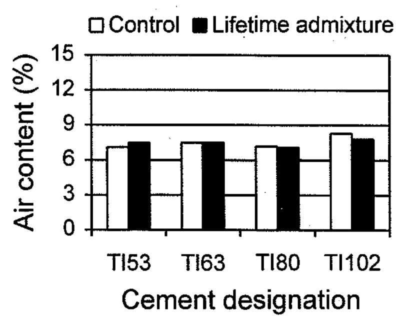

Fig. 5: Effect of Lifetime on air content in the specimens made with A-D admixture

Table 5: Effect of Lifetime admixture on strength development of specimens made with A-D admixture

Specimen made with cement	Strength (MPa)							
	Control				Lifetime lithium admixture			
	1d	3d	7d	28d	1d	3d	7d	28d
TI53	14	31	44	69	9	29	48	76
TI63	12	32	48	59	16	30	45	57
TI80	8	32	51	63	12	28	38	49
TI102	23	37	46	59	27	37	42	54

Concrete made with A-F admixture

Superplasticizer admixture is frequently used as a concrete additive in manufacturing high strength concrete. This series of tests were designed to evaluate the compatibility of Lifetime admixture with superplasticizer. Fig. 6 shows that there was very little effect of Lifetime admixture on slump when concrete was made with cements TI53, TI63 and TI80, but Lifetime admixture significantly reduced the slump when concrete was made with cement TI102, a high alkali cement. It was difficult to entrain air when A-F admixture was in the system. Lifetime admixture slightly improved air-entrainment (Fig.7). Setting time was shortened in all concretes made with Lifetime admixture by about 40 - 90 minutes depending on the particular cement and alkali content in the cement (Fig. 8). The effect of Lifetime admixture on strength development depends on the cement used. Lifetime admixture did not affect strength development of specimens made with low alkali cements and slightly reduced strength of specimens made with high alkali cements (Table 6).

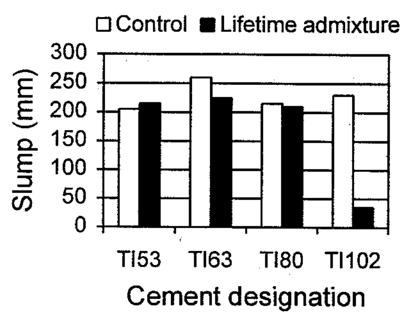

Fig. 6: Effect of Lifetime on slump in the specimens made with A-F admixture

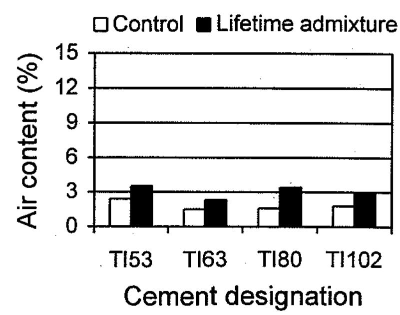

Fig. 7: Effect of Lifetime on air content in the specimens made with A-F admixture

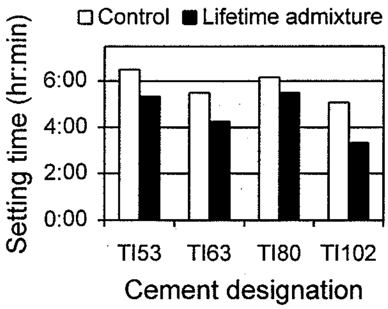

Fig. 8: Effect of Lifetime on setting time in the specimens made with A-F admixture

Table 6: Effect of Lifetime admixture on strength development of specimens made with A-F admixture

Specimen made with cement	Strength (MPa)							
	Control				Lifetime lithium admixture			
	1d	3d	7d	28d	1d	3d	7d	28d
TI53	17	35	50	71	20	38	52	72
TI63	16	36	49	61	20	34	44	58
TI80	10	32	47	63	14	35	41	47
TI102	22	39	49	62	26	37	42	50

Concrete made with A-G admixture

No notable effect of Lifetime admixture on slump was observed in the specimens made with cement TI53, TI63 and TI80, but Lifetime admixture significantly reduced slump of specimen made with cement TI102 (Fig.9). There was no significant effect of Lifetime admixture on air-entrainment properties (Fig. 10). Again, Lifetime admixture did not affect strength development of specimens made with low alkali cements, and slightly decreased strength of specimens made with high alkali cements (Table 7).

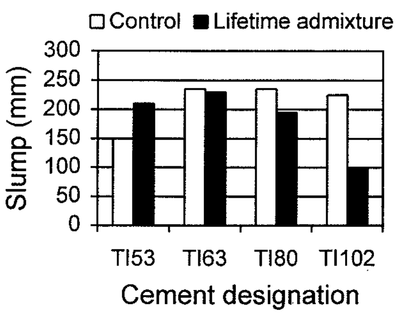

Fig. 9: Effect of Lifetime on slump in the specimens made with A-G admixture

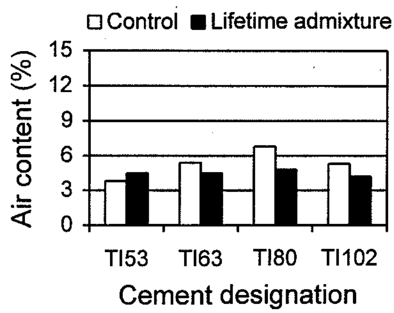

Fig. 10: Effect of Lifetime on air content in the specimens made with A-G admixture

Table 7: Effect of Lifetime admixture on strength development of specimens made with A-G admixture

Specimen made with cement	Strength (MPa)							
	Control				Lifetime lithium admixture			
	1d	3d	7d	28d	1d	3d	7d	28d
TI53	16	33	49	75	13	29	51	77
TI63	12	36	50	61	19	38	40	59
TI80	7	32	52	65	14	33	44	54
TI102	21	37	45	57	25	34	41	49

Generally speaking, Lifetime admixture did not show adverse effects on concrete properties, and was compatible with the air-entraining agent and water reducing/retarding agents used in this program. Depending on the cement and its alkali contents, some variations were observed.

Conclusions

- Lifetime admixture could be used directly as an additive in the concrete mix designs.
- No significant effect of Lifetime admixture on concrete properties such as workability, strength development and air-entrainment, etc. was found in this test program. Depending on the cement and its alkali contents, some variations may be experienced.
- Slightly shortened setting time may be experienced with the application of Lifetime admixture. This shortened setting time may not affect concrete placement operation and can be corrected if it is necessary. In some applications, shortened setting time may be an advantage for accelerating purpose.
- Lifetime admixture can be used in conjunction with other admixtures, such as the materials tested in this program, without causing incompatibility problems.
- Further fundamental research is needed to understand and clarify the effect of Lifetime admixture on cement hydration.

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