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EFFECT OF ACCELERATED CURING ON ABRASION OF HIGH VOLUME SUPPLEMENTARY CEMENTITIOUS MATERIAL SELF CONSOLIDATING CONCRETE

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Sustainability of precast/prestressed concrete plant can be promoted by using supplementary cementitious material and that significantly reduces the embodied energy of precast/ prestressed concrete products. Usually, up to 25% of the cement can be replaced with supplementary cementitious materials (SCM). Increasing the level of replacement to exceed 25% is considered to be High-Volume SCM. Appropriate testing should be conducted to ensure desired performance of the concrete. This context reports the results of an experimental investigation of effect of accelerated curing on abrasion resistance of High Volume Supplementary Cementitious Material – Self Consolidating Concrete (HVSCM-SCC). Different mixes proportion with supplementary cementitious materials such as Fly Ash, Micro Silica, and lime (Up to 75% of cement replacement) were tested. Rheological properties of the HVSCM-SCC were measured. Mechanical properties at different ages 1, 3, 7, 28, 56, and 90 days were monitored. To investigate the abrasion resistance, 12 x 12 x 3.5 in specimens at age of 28, 56, and 90 days were conducted. The results of abrasion resistance of HVSCM-SCC were compared to the same mixes cured in the moist room. The result showed that the accelerated curing has a significant influence on abrasion resistance of concrete at early ages.

Keywords: Sustainability, HVSCM-SCC, Accelerated curing, Abrasion resistance.

1 INTRODUCTION

Sustainability in concrete products can be improved in several ways; for instance by optimizing the concrete mixture or utilize recycle materials. Engineers would have to consider the three respects (reduce, reuse, and recycle) in all aspects of any construction of a concrete structures. In general, concrete is a mixture consists primarily from cement, sand, coarse aggregate, and water. The principal cementitious material in concrete is Portland cement. However, about 50% of the total CO_2 emitted worldwide comes from use of Portland cement. By reducing the cement content, CO_2 emissions of concrete and energy consumption are reduced. Supplementary cementitious materials that make up a portion of the cementitious component in concrete can satisfy the aspects of sustainability. These materials are by products from other processes material. SCMs such as fly ash, silica fume, ground granulated furnace slag, etc. are called pozzolanic which by themselves do not have any cementitious properties, but when utilize with Portland cement, react to form cementitious component.

SCC is an innovation concrete material used successfully throughout the world. It can be consolidated into every corner of a framework, purely by means of its own weight and without the need for mechanical consolidation (Daczko 2012). One of the solutions to satisfy flowability of SCC is by using sufficient amount of paste (Higher cement content) and to control the heat generation, portion of cement can be replaced with SCMs. Traditionally, up to 25% of the cement can be replaced with SCMs. Exceeding this level is considered to be high volume SCM and appropriate testing should be conducted to ensure desired performance of concrete.

Abrasion may be defined as surface wear that causes progressive loss of material from a concrete surface (Van Dam 2014). The abrasion resistance of concrete is influenced by a number of factors, including compressive strength, properties of aggregate, water/cementitious ratio, the addition of SCMs, and the properties of SCMs (Wei Ting *et al.* 2012).

2 EXPERIMENTAL

2.1 Materials

Type I Portland cement that conforms to the ASTM C-150 was used. A high calcium type C fly ash that meets the ASTM C-618 was used as a binder to produce concrete. Moreover, micro silica fume and hydrated lime type S were used in this investigation. The specific gravities of cement, fly ash, micro silica fume, and hydrated lime used were 3.15, 2.68, 2.3, and 2.5 respectively. Natural sand with 0.25 in (6.35 mm) maximum size and 2.56 specific gravity was used as fine aggregate. The coarse aggregate used in this study was 0.5 in (12.5 mm) maximum size a crushed stone dolomite and it had a 2.77 specific gravity. A commercially available high range water reducer admixture (Plastol 6200 and 5000) was also used to maintain the workability of self-consolidating concrete.

2.2 Mix Proportions

The focus of this study was to explore the effects of replacing various percentages of Portland cement with SCMs to develop a sustainable concrete with long term performance. The control mix used in this study was designed to have 10,000 psi (69.8 MPa) of compressive strength at 28 days. The water to binder ratio (w/b) and aggregate and cement content was held constant for all mixtures. A cementitious content of 850 pcy (504 kg/m^3) was used. Depending on optimum packing density, the fine to total aggregate ratio was determined to be 0.52. Intensive Compaction Tester machine (ICT) was utilized to obtain the maximum packing density of aggregate that satisfy the self-consolidating requirements. Table 1 illustrates all mixtures of this study.

2.3 Fabrication and Curing

Four specimens were used for this investigation per mix. ASTM C-944 procedure was considered as a guide for this test. Concrete was placed in one layer and optionally rodded to eliminate any entrapped air voids. Two curing conditions were employed in this study to investigate the effect of curing regimes. For accelerated curing (A), hot water system was used to simulate a steam curing of precast applications. Moist curing (M) specimens were covered with wet jute mats as soon as the concrete had set sufficiently that no marring of the surface or distortion resulted. Table 2 displays concrete curing conditions.

Table 1. Mixture proportions.

Mixture compositions (lb/yd3)*						
Composition	**Type**	**Unit**	**Mixtures**			
			M1	**M2**	**M3**	**M4**
Cement	Type I	lb/yd3	850.0	340	212.5	212.5
Fly Ash	Type C	lb/yd3	0.0	425	510	510
Silica Fume	Elkem Micro silica	lb/yd3	0.0	85	85	42.5
Hydrated Lime	Type S	lb/yd3	0.0	0.0	42.5	85
Sand	River Sand	lb/yd3	1475.0	1475	1475	1475
Coarse aggregate	1/2 in. crashed Dolomite	lb/yd3	1360.0	1360	1360	1360
Batch water	Tap Water	lb/yd3	238.00	238	238	238
Water/Cement Ratio		---	0.28	0.7	1.12	1.12
Water/Powder Ratio		---	0.28	0.28	0.28	0.28
HRWR	Plastol 6200 EXT+Plastol 5000	fl oz/cwt	10.35	10.35	10.35	10.35
% of Replacement			0	60	75	75

*Ib/yd3= 0.593 kg/m3

Table 2. Concrete curing condition.

Curing Method	Stage	Details
Accelerated Curing	I	Lab Temperature for 4 hours minimum after water-cement contact
	II	Temperature raised for 2 hours (≤ 20 °C)
	III	Stead Concrete temperature for 18 hours (≤ 70 °C)
	VI	Temperature decreased over 2 hours to lab temperature (≤ 20 °C)
	V	Air Curing in Lab Temperature 23 ± 2 °C until testing ages
Moist Curing	I	Twenty four hours in molds with wet jute mats at 23 ± 2 °C
	II	Moist room curing at 23 ± 2 °C and 100%H until 28 days testing age

3 TEST RESULTS AND DISCUSSION

Test results of slump flow, T50, J-Ring, L-Box, density, and temperature are presented in Table 3. The mixtures with SCMs exhibited better rheological properties than 100%

cement mixture. Mechanical properties "Compressive strength, modulus of elasticity, tensile splitting, and modulus of rupture", were conducted according to ASTM specification. Table 4 illustrates the mechanical properties results at 28 days of both accelerated and moist curing regimes. The compressive strength of tested mixtures was monitored at various ages 1, 3, 7, 28, 56, and 3 months. It was found that, in general, each mix developed high early strength for accelerated curing. However, moist curing mixes performed high strength than accelerated over late ages.

Table 3. Measured rheological properties.

Rheological properties	Unit	Mixtures			
		M1	M2	M3	M4
Slump Flow	in	27.0	26	26	25.5
T50	sec	4.6	2.12	1.87	2.58
J-Ring	in	25.0	23	23	23
T50 (J-Ring)	sec	14.5	4.3	5.3	3.53
L-Box	%	~ 0.8	~ 0.8	~ 0.8	~ 0.8
Air Content	%	1.4	3.4	4.2	4.5
Density	lb/ft3	153.40	148.8	146.4	145.4
Temperature	F°	65.90	66.9	66.4	65.6

Table 4. Measured mechanical properties at 28 days.

Mechanical Properties	Unit	Mixtures							
		M1		M2		M3		M4	
		A	M	A	M	A	M	A	M
Compressive strength	psi	10187	10059	8572	8595	7054	6720	7034	6305
Tensile splitting test	psi	586	1060	406	400	570	449	549	356
Modulus of elasticity	ksi	6117	6867	5900	6825	6217	6192	6050	5950
Modulus of rupture (4x4x14 in Beam)	psi	794	641	1071	724	707	716	832	684

For abrasion value measurement, mass loss was considered as a measure rather than wear depth because of the precise measurement. Each cycle lasted two minutes. A load of 44 lb, defined as a double load in ASTM C944, was applied at a rate of 300 rpm using a drill press. Tests were carried out at ages of 28, 56, and 90 days. The abrasion test of ages 28 and 56 days was conducted on a finished surface. However, formed surface was conducted to 90 days tests. Figure 1 shows the results of cycle number one of each mix and it was chosen because of majority of mass loss due to abrasion was from the cement paste and cycle one for each test had the greatest amount of mass loss.

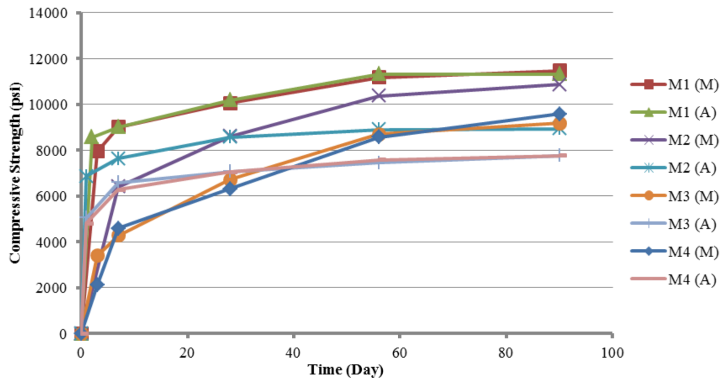

Figure 1. Compressive strength results at different curing regimes.

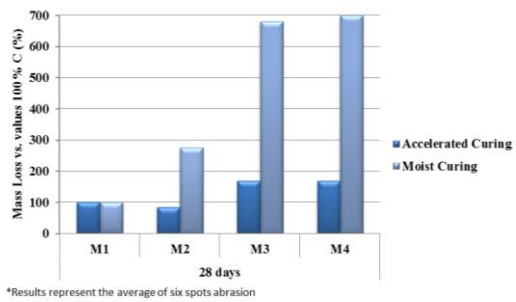

Figure 2. Abrasion resistance at 28 days.

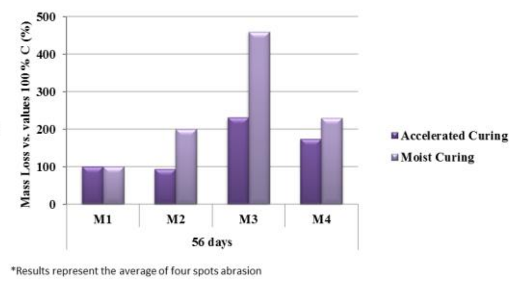

Figure 3. Abrasion resistance at 56 days.

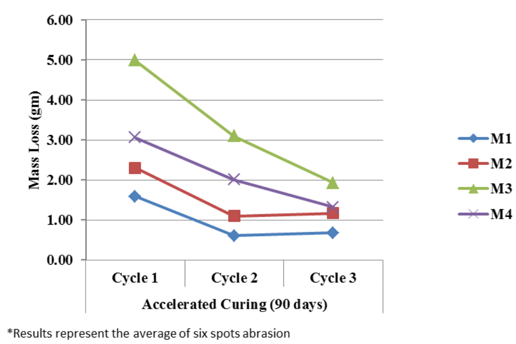

Figure 4. Results of accelerated curing.

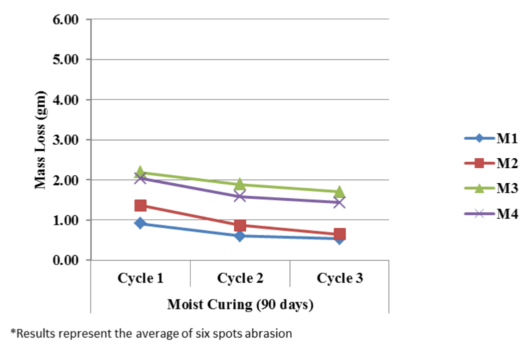

Figure 5. Results of moist curing.

As can be seen in Figure 2 and 3, accelerated curing has a significant effect on abrasion resistance at 28 and 56 days than moist curing because of high gained strength at early ages. However, moist curing mixtures exhibited high abrasion resistance than accelerated at 90 days for all mixtures cycles as presented in Figures 4 and 5.

Observation of abrasion test results shows that, mixes of 75% replacement, the mix containing 10% SF exhibited a high abrasion resistance than the same percentage of replacement with 5% replacement at ages 56 and 90 days. This difference might only because inclusion SF results in a denser microstructure with fewer pores, thereby enhancing abrasion resistance (Lin *et al.* 2012).

4 CONCLUSIONS

The purpose of this study was to compare properties of mixes with different percent of SCMs as cement replacement and see the effect of accelerated curing on abrasion resistance. Based on the results of this study, the following conclusions are presented:

1. Mixes with SCMs showed better rheological properties than 100%C mix.
2. The relation between mass loss and number of cycles close to be linear.
3. The accelerated curing has a significant influence on abrasion resistance of concrete at early ages.
4. At 90 days, most curing mixes have a high abrasion resistance than accelerated curing mixes.
5. Mix with 60 % replacement level "M2", showed better abrasion resistance than 100%C and 75% replacement at ages 28 and 56 days.
6. Inclusion 10% silica fume increases the abrasion resistance of concrete.

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