STUDY ON THERMAL CRACKING TENDENCY OF SELF-COMPACTING CONCRETE

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1. INTRODUCTION

Self-compacting concrete (SCC) is achieved by using high proportions of powder content and superplasticizers [1]. Due to this, pronounced thermal cracking is anticipated. Thermal cracking in concrete structures is caused by volume change resulting from heat of cement hydration and autogenous shrinkage [2]. This paper presents a study to investigate thermal cracking tendency of a proposed self-compacting concrete using 3D FEM analysis.

2. MATERIALS

Materials used to carry out the study were of confirmed quality and specifications as provided for in the JIS and JSCE standards. Blast furnace slag was used as additive mineral admixture in self-compacting concrete mix. Air entraining agent and polycarboxylic superplasticizer was also used to improve workability. Japanese method of mix proportioning was adopted in SCC as per JSCE SCC guideline 2012. Refer to tables 1 below.

Table 1: Mix Proportions for Self-Compacting Concrete

Mix Proportions for the self-compacting concrete						Unit amount (kg/ m^3)					Chemical Admix.	
Proportions	Max.agg (mm)	W/B (%)	W/P (%)	A.C (%)	Abs. agg (m^3/ m^3)	W	C	BS	S	G	AE (P X %)	SP (P X %)
N+BS30-SCC1	20	31.5	97.0	4.5	0.28	175	389	167	828	739	0.012	0.90
N+BS50-SCC2	20	32.0	97.0	4.5	0.28	175	273	273	828	739	0.012	0.73
N+BS70-SCC3	20	32.5	97.0	4.5	0.28	175	161	336	828	739	0.012	0.65

Table 2: Fresh Properties of Self-Compacting Concrete

Fresh properties of SCC				V-funnel	U-Box (mm)		
Proportion	Slump flow-mm	A.C (%)	S_{500} (sec)	V_{75} -Flow (sec)	Rank1	Rank2	Remarks
SCC1-N+BS30	725	1.9	5.4	24	83.4	322.0	Minor segregation
SCC2-N+BS50	723	4.5	5.9	17.5	140.7	329.3	ok
SCC3-N+BS70	735	3.8	6.3	18.3	147.3	262.0	Minor segregation

3. EXPERIMENT PROCEDURE

Trial mixing and tests were carried out to establish the appropriate proportions for Self-compacting concrete. Actual specimen sample was cast and fresh properties of self-compacting concrete were used to verify self compactability as per JSCE recommendation. Sample specimen was casted in a mold with internal dimensions of 400mmx400mmx400mm made of foamed polystyrene with 200 mm as its thickness. For thermal analysis of the sample specimens, temperature rise due to heat of cement hydration was measured at the central portion of specimens and autogenous shrinkage of the specimen was also measured by using embedded strain gauge. For compressive strength test, cylindrical specimens of diameter 100mm and depth 200mm were made, cured under water at 20 ºC and measurements of compressive strength done at 3, 7, 28 and 91 days. Results were used as input data for 3-D FEM thermal stress analysis.

4. RESULTS AND DISCUSSIONS

4.1 Fresh Properties of Concrete

From the results in table 2, rank 2 properties were adequately satisfied as per JSCE guidelines as provided for [4].

4.2 Concrete properties for thermal Stress analysis

Test results for properties of SCC are as shown in figure 1 – figure 3 with Properties of normal Portland blast furnace slag concrete (BB) which were predicted from JCI 2008 guideline. Generally SCC with low replacement of mineral admixture attained high compressive strength. From figure 1, a low W/B ratio of 30.5% is necessary for BB concrete to attain strength similar to SCC at 28days. From the results in figure 2, it shows that autogenous shrinkage in SCC is less than predicted normal BB concrete. Similarly from figure 3, predicted ultimate adiabatic temperature rise of normal Portland blast furnace slag concrete (BB) at W/B-30.5% is the same as that of SCC at 32% W/B ratio.

Keywords: Self-Compacting Concrete, Adiabatic temperature rise, Autogenous Shrinkage, Thermal Stress Analysis
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However rate of temperature rise is SCC is slower. This is because SCC has less cement and more mineral admixtures than Portland blast furnace slag (BB) concrete.

4.3 Thermal Stress and Cracking Index Analysis by 3-D FEM Method

Temperature rise in concrete causes stress in the entire matrix. Stress increase with restraint boundary conditions in place, leads to crack development [3]. By 3-D FEM stress analysis method, a region with high cracking tendency (Maximum stress) for SCC and Portland blast furnace slag (BB) was evaluated. Their minimum thermal cracking indices are 1.4 and 1.1 for SCC and normal BB concrete respectively. High thermal cracking index indicates lower cracking probability.

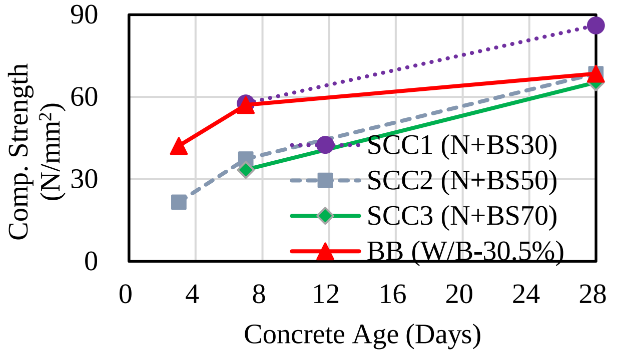

Figure 1: Compressive Strength of Concrete Samples

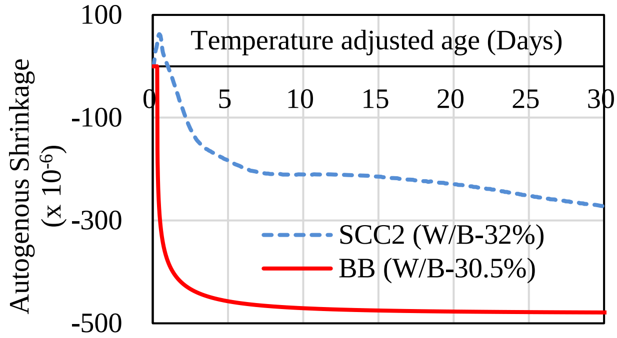

Figure 2: Autogenous Shrinkage of the Concrete Sample

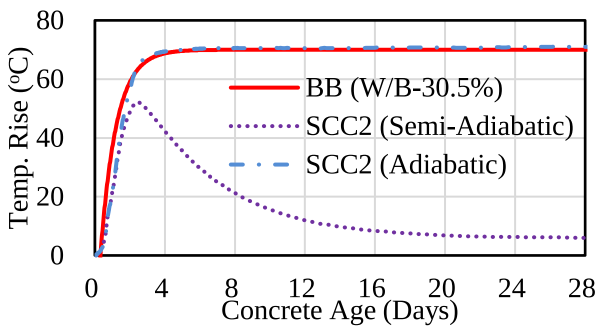

Figure 3: Adiabatic/Semi-Adiabatic Temperature Rise

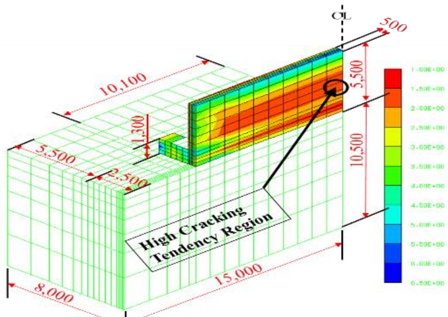

Figure 4:Model/High Thermal Cracking Tendency Region

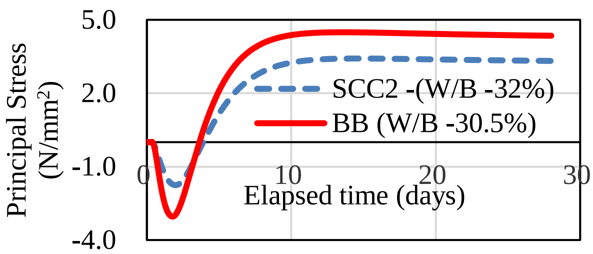

Figure 5: Maximum Principal Stress

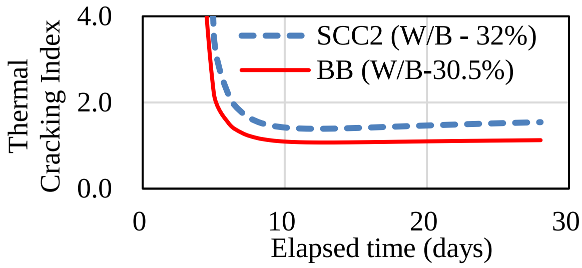

Figure 6: Thermal Cracking Index (Icr)

5. CONCLUSIONS

1) Self-compacting concrete at W/B of 32% has lower thermal cracking tendency than Portland blast furnace slag (BB) concrete at W/B 30.5%
2) The difference in thermal cracking tendencies of both concrete samples can be explained by the difference in rate of adiabatic temperature rise at early ages and difference in autogenous shrinkage.

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