Thermal Stress Analysis of High Volume Fly Ash Concrete (HVFA) Made with Different Water-Cementitious Material Ratio

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1. Introduction

Compared with conventional cement concrete, concrete made with fly ash has low strength at early age. In particular, high volume fly ash (HVFA) concrete must have significant low early-age strength development. Limestone filler activates hydration of alite in cement concrete and contributes strength development at early age. Use of the limestone filler may be effective for increasing strength of HVFA concrete at early age[1)]. In addition, HVFA concrete made with limestone aggregate may be recycle in Portland-cement production. To address the applicability of the HVFA concrete, the present study discusses thermal stress of the HVFA concrete using typical massive structures such as slab wall and bridge pier models. The numerical simulation uses the test result of uniaxial tensile strengths, tensile Young's modulus adiabatic temperature rise and coefficient of thermal expansion (CTE).

2. HVFA Concrete

2.1 Mixture proportions and Materials

Table 1 gives mixture proportions of HVFA and control concretes. The HVFA concrete in the study are made with a cement replacement ratio of 0.5 by mass. The fly ash used in the study is classified in type II in JIS. Fine and coarse aggregate of limestone were used in the concrete as well as limestone filler.

2.2 Properties of HVFA Concrete

The uniaxial tension test was performed to examine tensile strength and Young's modulus. Dimensions of concrete specimen for the test are 100x100x1560 mm and a reinforcing bar (D 13) was embedded into prismatic specimen. Two

Table 1 Mixture proportions

Mix. ID	*w/cm*	Unit weight (kg/m^3)							
		W	C	FA	LP	S	G	Ad	AE
49FA0-N	0.49	165	337	0	0	816	996	3.37	0.02
49FA50-N	0.49	165	169	169	100	737	914	1.69	0.27
45FA50-N	0.45	168	187	187	100	713	892	3.37	1.01
38FA0-N	0.38	170	447	0	0	790	916	2.24	0.03
38FA50-N	0.38	170	224	224	100	676	845	4.93	1.34

Mix. ID: *w/cm*, FA replacement ratio, LP: Limestone powder

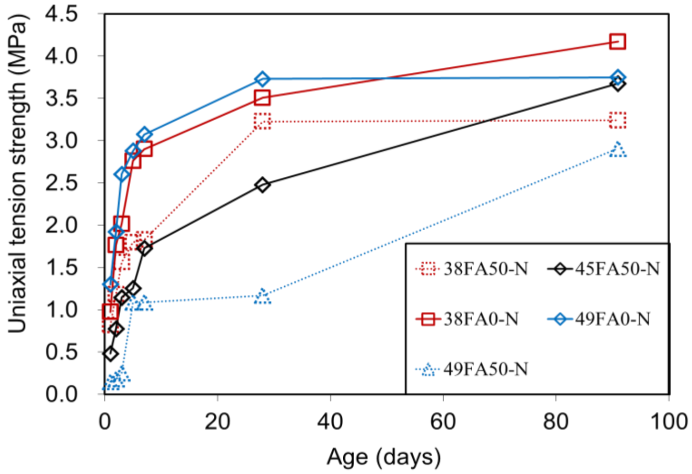

Fig. 1 Uniaxial tensile strength

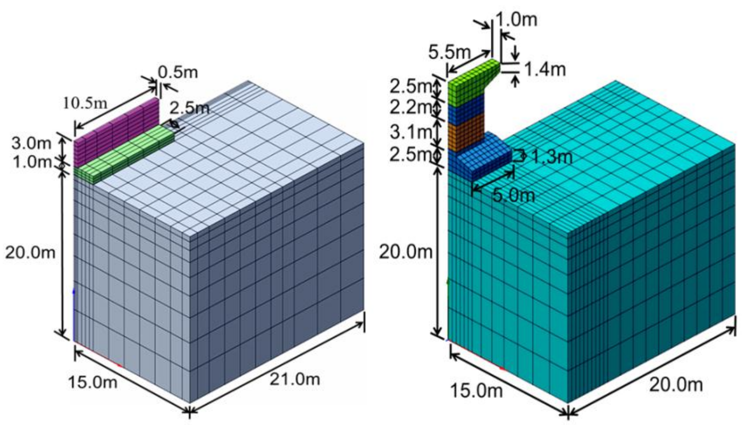

Fig. 2 Models for FE Simulation

specimen were used at each test age (1, 2, 3, 5, 7, 28, 91 days). **Figure 1** illustrates the uniaxial tensile strength development.

3. FE Simulation

3.1 Simulation Models

Figure 2 shows two models for the simulation, such as a concrete slab-wall and T-shaped bridge pier. The data of adiabatic temperature and CTE were employed in FE simulation as well as physical test results.

3.2 Simulation Results

Figures 3 and **4** show the cracking index (***CI***) of both models. The definition of (***CI***) is below:

$$CI(t) = \frac{F_t(t)}{S_{th}(t)}$$

where, $\boldsymbol{S_{th}}$ is thermal stress of each element. $\boldsymbol{F_t}$ is the tensile strength of concrete.

According to the Japanese specification[2], the ***CI*** of 1.85 or higher value contribute to preventing thermal cracks. The **Figure 3** shows that the HVFA concrete of 38FA50-N has cracking index of 1.1 at early age and 0.9 at mature age. On the contrary, control concrete (38FA0-N) displays cracking index lower than 1.0 from early age to mature age.

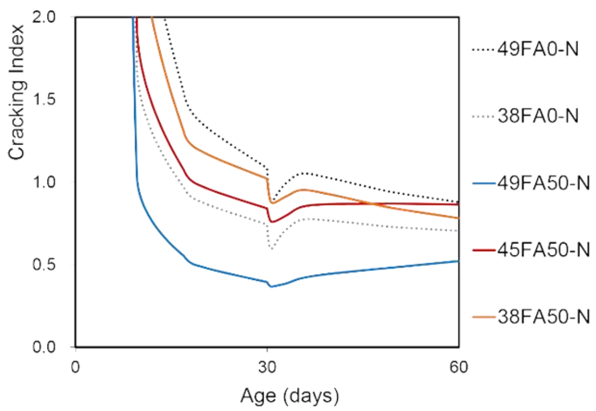

Fig. 3 Cracking index of slab-wall model

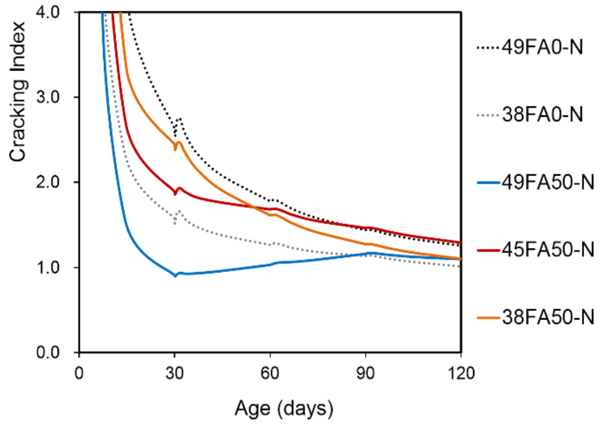

Fig. 4 Cracking index of bridge pier model

With regard to cracking index of bridge pier model shown in **Fig. 4**, the cracking index of HVFA concrete (45FA50-N) displays approximately 2.0 at early age and 1.5 at mature age, namely adequate cracking resistance. The HVFA concrete (49FA50-N) indicates the lowest cracking index results shown in **Fig. 3** and **Fig. 4**. The cracking index is caused from low strength development of HVFA concrete (49FA50-N) at early-age, while the concrete has the lowest heat of hydration.

4. Conclusions

(1) The uniaxial tensile strength of HVFA concrete indicates 90% strength of conventional mixture concrete at 28 days while the strength is significantly lower than the strength of the control concrete at early age.

(2) The simulation results confirm that cracking index is influenced by the strength development as well as the temperature rise due to hydration.

(3) The simulation using the slab-wall model illustrates that the HVFA concrete (38FA50-N) has some advantages of cracking resistance compared with control concrete (38FA50-N). In addition, the simulation using the bridge pier model shows that the HVFA concrete (45FA50-N) indicates the lowest possibility of thermal cracking.

References

1) Yoshitake I. *et al.*, Tensile Properties of High Volume Fly-Ash (HVFA) Concrete with Limestone Aggregate, *Construction and Building Materials*, Vol.49, pp.101-109, 2013.12.

2) Japan Society for Civil Engineers (JSCE), Standard specifications for concrete structures –Design, pp.303-318. 2013.2. (in Japanese)