Cracking Resistance of Lightweight Aggregate Expansive Concrete

University of Tokyo Student member Zhihai Lin
University of Tokyo Formal member Toshiharu Kishi

1. Introduction

Cracking is still a familiar phenomenon in concrete engineering, and affects the durability and aesthetic of the concrete construction. For decades expansive concrete has been developed to overcome this problem. However, it is not always effective, the cracks still occur sometimes, especially in mass concrete structures. This research was to investigate the causation of failing the expansive concrete to avoid cracking. Based on the understanding of normal aggregate is too hard to exert the ability of expansive agent, lightweight aggregate was thought to be helpful to the performance of expansive agent. It was found that both low stiffness and internal curing of lightweight aggregate can improve the cracking resistance in a large degree.

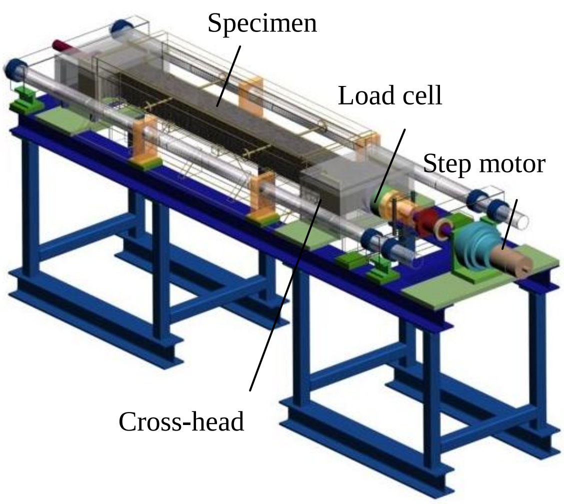

Fig.1 Temperature-Stress Test Machine

2. Experiment detail

Mix proportion is shown in Table 1.

2.1 Experiment device

Special experiment device of Temperature-Stress Testing Machine (TSTM) was constructed according to the original design of Prof. Springeschmid[1)], and is shown in Figure 1. Load cell is used to measure axial force. Two displacement transducers are used to measure the length of the specimen between the cross-heads. The measurement accuracy of stress, deformation and temperature are respectively 0.001MPa, 0.1μm and 0.1℃. Restraint condition is simulated by controlling the moveable cross-head along axial direction with the step motor, and temperature condition is set by a chamber equipped with heater and refrigerator. The control accuracy of displacement and temperature are respectively 0.5μm and 0.1℃.

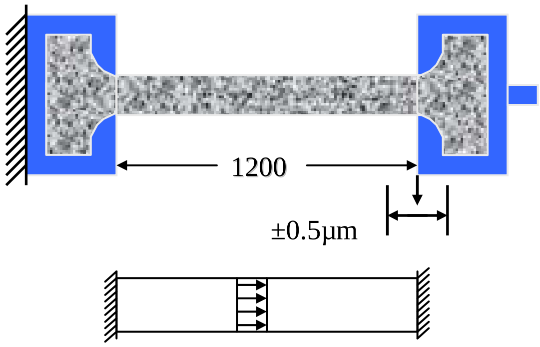

Fig. 2 Simulation of full restraint degree

Table 1 Mix proportion

Type	C	EA	W	G	LA	S	SP
	Kg/m^3						%
C45	400	0	180	950	0	855	3.2
C45L	400	0	180	0	570	855	2
E40C45	360	40	180	950	0	855	3.2
E40C45L	360	40	180	0	570	855	2

2.2 Experimental condition

Full restraint degree was achieved by limiting the deformation of the specimen within ±0.5μm. Both expansion and shrinkage were restrained. The illustration is shown in Figure 2. Low temperature rise was simulated by opening the temperature chamber to release the heat naturally. Semi-adiabatic temperature condition was simulated by keeping the temperature difference between specimen and surrounding air as constant of 0.1℃. Drying shrinkage was excluded by covering wet cloth on the specimen and sealing with plastic sheet. The fresh concrete was cast into the mold of the machine in few minutes after mixing. Lateral and bottom mold boards were separated from the specimen to reduce friction after one day.

Keyword expansive concrete, lightweight aggregate, TSTM, thermal cracking, restrained stress
Contact 〒153-8505 Institute of Industrial Science University of Tokyo Meguroku4-6-1 Tel 03-5452-6098

3. Experimental result

3.1 Low temperature rise

Results are shown in Figure 3. For normal concrete, only a small compressive stress was generated, and tensile stress evolved fast, micro-cracking occurred on the third day when the stress suddenly shrank. The counteracting effect on autogenous shrinkage of lightweight aggregate was confirmed, and the tensile stress was small. 40kg of expansive agent could induce a large compressive stress in both cases. In the case of lightweight aggregate was used, it was observed that compressive stress could increase continually and gradually.

3.2 High temperature rise

Results are shown in Figure 4. Both tensile stresses of C45 and E40C45 evolved fast and were close to -3MPa after the temperature returned to 20℃, even if a large compressive stress was reached in the beginning. C45 cracked before the temperature returned to 20℃. The stress of C45L was close to -2MPa at 20℃, while that of E40C45L reached -0.2MPa despite suffering from a high temperature rise. Its tensile stress reached -2.1MPa at -5℃ after being frozen, and survived from cracking. The combination of expansive agent and lightweight aggregate showed a good performance on resisting cracking.

3.3 Effects of low stiffness and internal curing

Results of expansive concretes respectively mixed with sealed, wet lightweight aggregate and normal aggregate are shown in Figure 5, the expansive agent amounts were same. In the case of normal aggregate, higher compressive stress could be generated, but tensile stress evolved fast and was close to -3MPa in the end. In the case of sealed lightweight aggregate, even though compressive stress was smaller, the tensile stress just developed to -1MPa. This is because the stiffness of lightweight aggregates is much lower than that of normal aggregate. In the case of wet lightweight aggregate, tensile stress is smallest and is thought to attribute to the additional internal curing effect[2] which can continually supply water while temperature is decreasing, and expansive agent can expand more efficiently, thermal and autogenous shrinkage can be counteracted well.

4. Conclusion

Expansive concrete mixed with normal aggregate can not counteract thermal stress well while temperature rise is high. Lightweight aggregate can improve the cracking resistance in a large degree by the effects of low stiffness and internal curing.

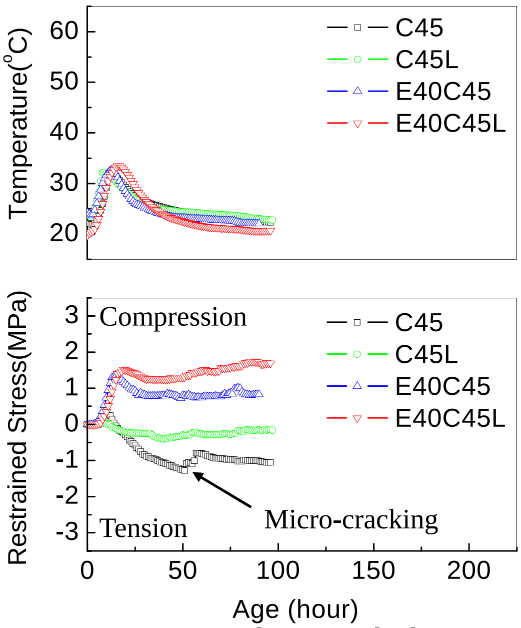

Fig.3 Restrained stress under low temperature rise condition

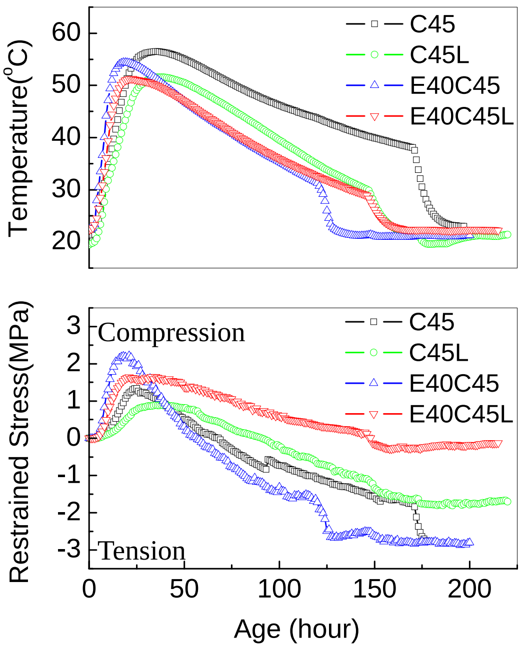

Fig.4 Restrained stress under high temperature rise condition

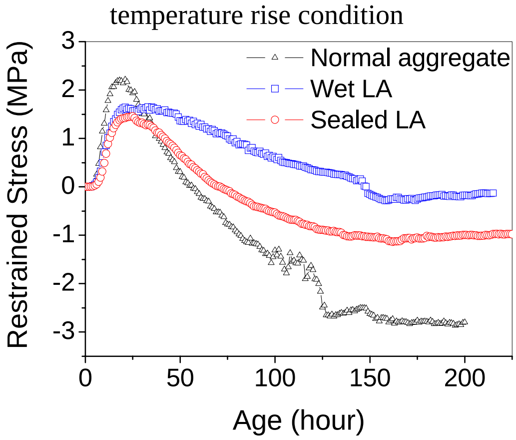

Fig.5 Effect of low stiffness and internal curing

Reference

1) R.Springenschmid: Thermal Cracking in Concrete at Early Ages, E&FN SPON Inc., pp.137~144, 1994
2) O. M. Jensen: Water-entrained Cement-based Materials I., Cement and Concrete Research, Vol. 31, pp.647-654, 2001