Frost resistance of steam cured fly ash concrete based on CDF-test

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1. INTRODUCTION

Mineral admixtures such as fly ash and blast furnace slag have been taken advantage of to reduce the amount of cement and hence the emission of carbon dioxide. However, the performance of such environment-friendly concrete needs to be investigated. Frost damage is an important durability issue for concrete structure in cold region such as Hokkaido. In addition recently it has been discussed to enhance the productivity of concrete structures on the construction site. From this point of view pre-cast concrete member may be selected to replace concrete of cast in place. However, the effect of fly ash concrete under steam curing on the frost damage is not fully understood.

This research is to investigate the frost-resistance of fly ash concrete. Concretes are cured in steam and then tested in RILEM CDF-test[1,2]. During the cycles, periodical measurements have been done to analysis the deterioration of the specimens considering frost damage[3].

2. EXPERIMENTAL OUTLINE

2.1 Specimen

Three mix proportions are tested, namely H, FB and BB. Three specimens are utilized for each mix proportions in experiments (N=3). The size of each specimen is 150mm×150mm×75mm. Mix proportion is shown in Table 1. FB is made from typeII fly ash according to JIS A 6201. Category of the specific surface area of the blast furnace slag is 4000 cm^2/g according to JIS A 6206. For all specimens, high early Portland cement according to JIS R 5210 is used as cement. Gravel is crashed stone and its maximum size is 20mm. Sand as the fine aggregate, is produced from Tarumae, according to JIS A 5005.

All the specimens are cured by steam in which the maximum temperature is kept at 65℃ for 4 hours followed by decreased to 20℃ for 15 hours. After the steam curing, specimens are cured in the air for 13 days under RH 60±5% and 20±2℃. Compressive strength of the concretes is 56.8, 46.3 and 57.6 N/mm^2 for H, BB and FB at an age of 14days, respectively.

Then specimens are under dry storage by 27 days, during which they are laterally sealed by aluminium foil in order. After that, each specimen is placed in a stainless container on the supporter of 10 mm height for pre-saturation by 7 days, immersed in 3% NaCl solution. The solution is filled into the container to a height of 15±1 mm. During this process, the amount of water uptake is measured. After that, freeze-thaw action takes place. According to RILEM CDF test, temperature cycle of freeze-thaw action is showed in Fig.1.

Table 1 Mix proportions

Series	Slump flow (cm)	Air content (%)	Unit amount (kg/m^3)						
			Water	Water binder ratio (%)	Cement	Fly ash	Blast furnace slag	Sand	Gravel
H	60±5	4.5 ±1.0	160	40.0	400	—	—	838	966
FB			154	35.0	352	88	—	800	959
BB			164	35.0	234	—	234	781	937

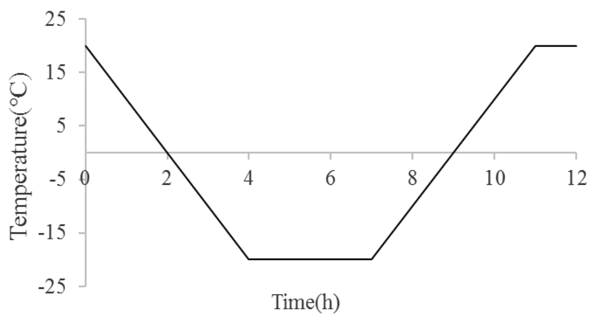

Fig.1 Controlled temperature changes for 1 cycle

2.2 Measurements

(1) Ultrasonic pulse velocity

Ultrasonic transit time is measured along two perpendicular of the specimen with an ultrasonic equipment to judge the internal damage of concrete. The container is filled with the test liquid to a level of 10 mm above the transducers, but not above the top of the specimen. The upper surface of the specimens must be kept dry. Relative dynamic modulus is obtained as an indicator of the internal damage.

(2) Mass loss by surface scaling

Surface scaling is measured when the temperature is above 15℃. The solution comprising the scaled material is filtered to a filter paper. The filter paper containing scaled material is dried at 110±5℃ for 24 h and the mass of the paper is weighed. The amount of scaling is measured every 6-8 cycles.

3. RESULTS AND DISCUSSION

3.1 Amount of water uptake

During pre-saturation process, the amount of water uptake is determined as shown in Fig.2 by seven days of water uptake, all the specimens are still gaining weight, which demonstrate that concretes are still not fully saturated. Among three series, FB series has a relatively larger water absorption.

3.2 Relative dynamic modulus

As shown in Fig.3, the relative dynamic modulus value imply no decrease. This means that the internal damage of all specimens is little occurred.

3.3 Scaling mass loss

Figs.4 to 6 show the change in the scaling mass loss with the number of cycles. The surface scaling is much larger for BB than those for H and FB. This indicates low surface resistance against deicing salt in BB although it is hardly damaged internally. On the other hand, the resistance of FB is similar to that of H.

4. CONCLUSIONS

During the pre-saturation, dry concrete surface have a capacity of high absorption by observing the scaling. Blast furnace slag(BB) concrete under steam curing shows weak frost resistance against surface scaling, while normal concrete and fly ash concrete(FB) shows similar frost-resistance against surface scaling. However, within 56 freeze-thaw cycles, every concrete under steam curing still preserve an adequate internal structure.

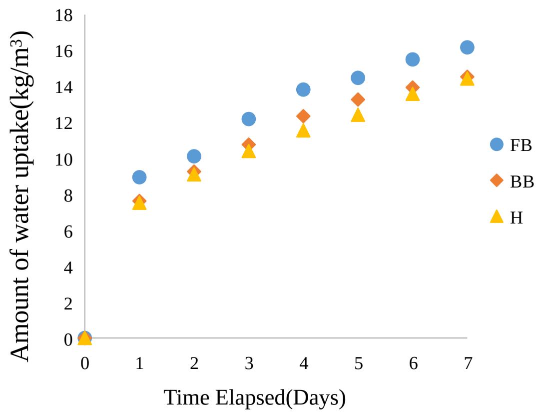

Fig.2 Increase of water uptake during pre-saturation

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(2) M.J.Setzer, P. Heine, S.Kasparek, S.Palecki, R.Auberg, V.Feldrappe and E.Siebel:Test methods of frost resistance of concrete: CIF-Test:Capillary suction, internal damage and freeze thaw test - Reference method and alternative methods A and B, Material and Structures, Vol.37, pp 743-753,Dec 2004

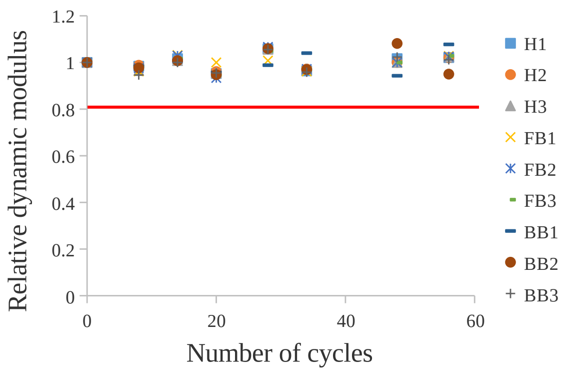

Fig.3 Change in relative dynamic modulus

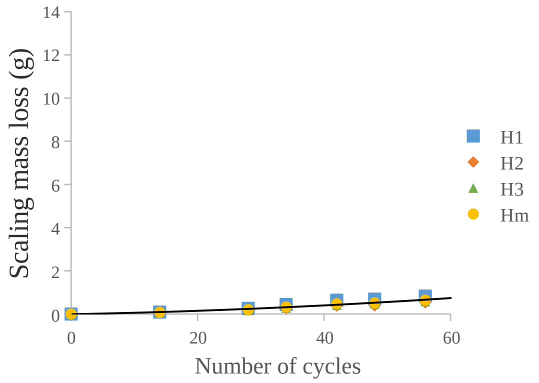

Fig.4 Surface scaling (H)

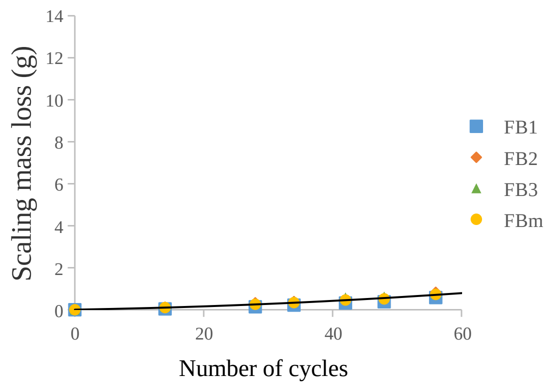

Fig.5 Surface scaling (FB)

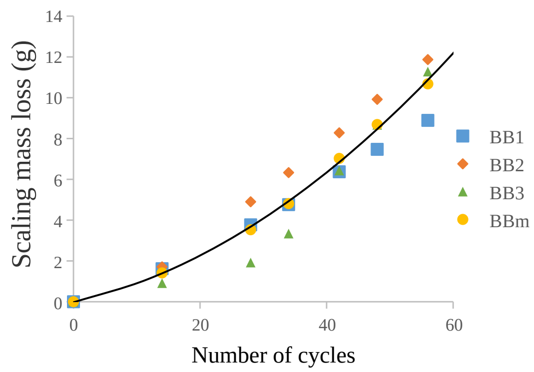

Fig.6 Surface scaling (BB)

(3) John J. Valenza II ,George W.Scherer: A review of salt scaling:II Mechanisms, Cement and Concrete Research 37, pp1022-1034, 2007