Comparison on Heat of Hydration between Current Concrete for NPP and High Fluidity Concrete including Pozzolan Powders

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1. Introduction

Nuclear power plant (NPP) concrete structures are exposed to many construction factors that lower the quality of concrete due to densely packed reinforcements and heat of hydration since they are mostly constructed with mass concrete. The concrete currently being used in Korean NPPs is mixed with Type I cement and fly ash [1]. However, there is a demand to improve the performance of concrete with reduced heat of hydration and superior constructability. Many advantages such as improving workability and durability of concrete and decreasing heat of hydration are introduced by replacing cement with pozzolan binders [2]. Therefore, the manufacturing possibility of high fluidity concrete should be investigated through applying multi-component powders blended with pozzolan binders to the concrete structure of NPPs, while the researches on properties, characteristic of hydration, durability and long-term behavior of high fluidity concrete using multi-component cement should be carried out. High fluidity concrete which is made using portland cement and pozzlonan powders such as fly ash and blast furnace slag has better properties on heat of hydration than the concrete currently in use for NPPs.

2. Methods and Results

2.1 Mix Proportions and Material

The properties of the binder used in the experiment are as shown in Table 1. River sand was used as the fine aggregate and crushed stones with maximum size of 20 mm were used as the coarse aggregate.

Table 1. Properties of binders

Binder	Specific gravity	Fineness (㎠/g)
Cement (Type I)	3.15	3,720
Fly ash	2.30	3,210
Blast furnace slag	2.93	6,000

Three mix proportions as Table 2 were used in this study. KNC is the concrete currently using for nuclear power plants and HFP and HFM are high fluidity concrete. Polycarboxylate superplasticizer is added in HFP concrete, and melaminic superplasticizer is added in HFM concrete.

Table 2. Mix proportions

Mix		HFP	HFM	KNC
Water binder ratio (%)		37	38	39.4
S/a(%)		53	53	42
unit weight (kg/㎥)	Water	185	190	185
	Cement	200	200	376
	Fly ash	100	100	94
	Blast furnace slag	200	200	-
	Superplasticizer	6.5	10.5	2.82
	Viscosity agent	0.25	0.25	-

2.2 Measurement Method

The instrument used for measuring the heat of hydration is shown in Fig. 1. The speed of temperature increase due to the heat of hydration of concrete was measured by placing the adiabatic container, after filling it with concrete, inside the chamber where the adiabatic state is maintained.

Fig. 1 Adiabatic state temperature rise

The sensors for the entire specimen were installed as follows: two sensors inside, one sensor each on the outer upper and lower sides, and one each on the left and right sides, for a total of six sensors. The adiabatic state is maintained by the accumulation of heat given off by the hydration reaction of the concrete which is conserved by increasing the outside temperature in correlation with the temperature rise inside the concrete.

To compare the mixes using melaminic and polycarboxylate superplasticizer, heat of hydration of these mixes was measured against the existing nuclear power plant concrete mix for 2 days.

2.3 Measurement Results

Fig. 2, showing the test results of the heat of hydration, displays the measurement results of the temperature rise for 3 types of concrete mix inside the test instrument in which adiabatic temperature state is maintained for 2 days.

Under the condition of maintaining the adiabatic temperature, the temperature rises depending on the occurrence of heat of hydration. Therefore, when the increased temperature is differentiated according to time, the adiabatic temperature rise test results of Fig. 2 are expressed as the adiabatic temperature rise speed as shown in Fig. 3.

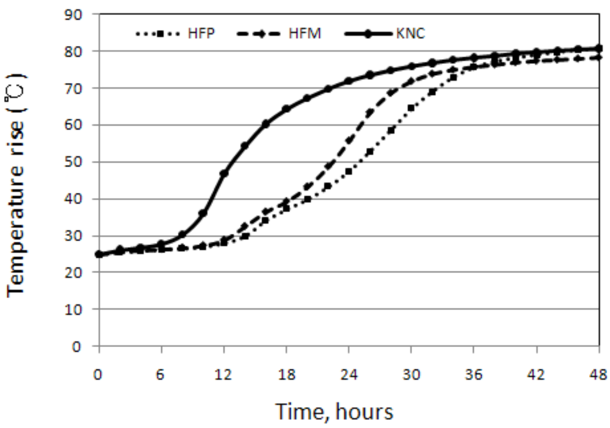

Fig. 2 Adiabatic state temperature rise

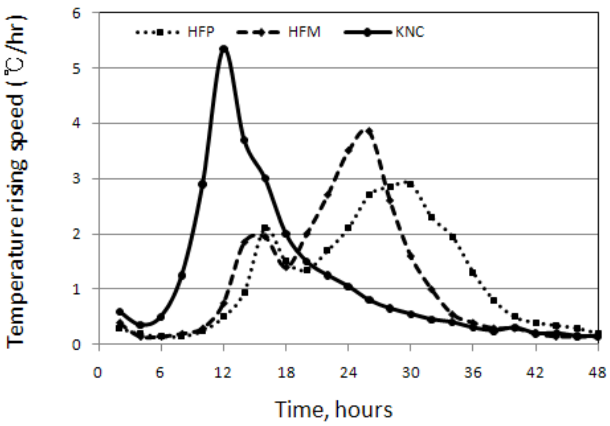

Fig. 3 Temperature rising speed by heat of hydration

In Fig. 3, the adiabatic temperature rose the most for KNC, the concrete mix used in the existing nuclear power plants, showing a final temperature of 82℃, and the following order of adiabatic temperature rise, from the next highest to the lowest was the HFP, HFM. When the adiabatic temperature rise speed of Fig. 3 was analyzed, the highest to lowest order was the mix used for KNC, HFP and HFM.

Meanwhile, although the temperature rise amount of HFP was shown to be higher than that of HFM, the adiabatic temperature rise speed was the opposite.

When the inside and outside temperature difference is small, only a small amount of cracks form from the heat of hydration, but if the actual construction conditions are taken into consideration, HFP is deemed to be superior to HFM.

3. Conclusions

The summary of the comparative analysis results from the heat of hydration of high fluidity concrete and the concrete currently being used for nuclear power plant structures is as follows:

1) The final temperature rising by hydration reaction is almost similar. However, the curve of temperature rising speed is different from 6 to 42 hours after mixing.
2) The peak temperature rising speed depends on binder type and amount of cement. The more cement is used, the higher the peak temperature rising speed.
3) In HFP and HFM has two peak points in the curve of temperature rising speed. The first peak is occurred by cement hydration and the second peak is occurred by pozzolanic reactions.
4) The second peak temperature rising speed of HFP is less than HPM and the time to the peak is longer than HFM. Therefore, polycarboxylate superplasticizer has delaying effect on cement hydration and pozzolanic reactions.
5) High fluidity concrete, HFM and HFP, containing blast furnace slag was shown to have the effect to relieve crack risk by heat of hydration

REFERENCES

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