Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 17-18, 2012

Microstructural Analysis on the NPP Concrete under Initial Frost Damage

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1. Introduction

The concrete should secure the quality over certain standard regardless of construction location and period. Especially, because the fly ash (FA) is used in nuclear power plant concrete as a concrete substitute by 20%, the concrete using FA is hugely influenced according to temperature and humidity in terms of constructability, strength and durability due to the material properties. Accordingly, when building the nuclear power plant under various environmental conditions, it's important to secure the concrete quality equally through applying an appropriate curing method to control temperature and humidity.

Although various according to concrete materials and mixture, the concrete-freezing temperature is usually known as about -0.5~-3.0℃. In case the concrete is frozen early under the condition that the strength has not been sufficiently developed yet, because the volume expansion caused by the frozen free moisture inside concrete results in the relaxation and destruction of structure, the strength, watertightness and durability of the concrete get lower drastically even after being hardened.

Accordingly, this study tried to review the quality of nuclear power plant concrete under early freezing through measuring strength, SEM and XRD after making the concrete frozen over certain standard in the early curing with targeting the nuclear power plant (NPP) concrete replaced with FA 20%.

2. Experiment plan and method

2.1 Design of experimental

As for mixture items, the fly ash (FA) being currently used at NPP construction applied the mixture replaced by 20% as seen at Table 1. And, according to the NPP construction specifications, it took the mix design adjusting water reducer and AE agent in order to meet target slump (4.7±1 inch) and air contents (4.5±1.5%).

This study made an early-freezing specimen adding the 30 cycles with regard to freeze thaw through considering the early freeze in curing after curing up to 715 psi at 5℃ for the first standard of NPP showing the design-based strength of 4000 psi. In addition, it compared and reviewed two variables through making a standard curing specimen to consider the general conditions.

Table Ⅰ: Mixture proportion

Str (Psi)	S/a (%)	Gmax (")	WRA (%)	Unit weight (kg/m^3)						
				W	C	FA	Agg	Sand	WRA	AEA
4000	46.7	3/4	0.64	162	260	64.8	938	822	2.08	0.20

It measured the experimental item of pressure strength to the planned age and conducted the X-ray diffraction (XRD) by scanning electron micro-scope (SEM) and X-ray for microstructure analysis.

2.2 Test method

In the test method of this study, the concrete was mixed by using the 1-axis forced pan-type mixer. It tested the compressive strength by ASTM C 39 using the specimen of ∅4×8 inch.

Then, this study planned a test method to reproduce the construction conditions of NPP structure under cold weather environment. First, considering the protective curing for preventing the early freezing, the sealed curing was performed under the temperature of 5℃ until the development of 715 pis, the strength required for early curing, after placing concrete. Thereafter, in order to consider the continuous exposure under cold weather condition after removing the protection devices as Fig 1, this study analyzed the microstructure after exposing it to the freeze thaw condition of 30 cycles under the condition of -18℃~+4℃.

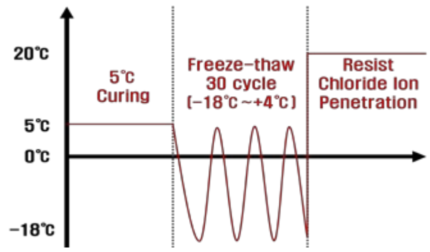


Fig.1 Flow of Curing and tests

3. Result and discussion

3.1 The effect of law temperature on the compressive strength

Fig. 2 shows the compressive strength development results of NPP according to the existence or nonexistence of early freeze thaw. The concrete under early freeze till the age of 35 days showed the lower strength compared to the concrete without early freeze.

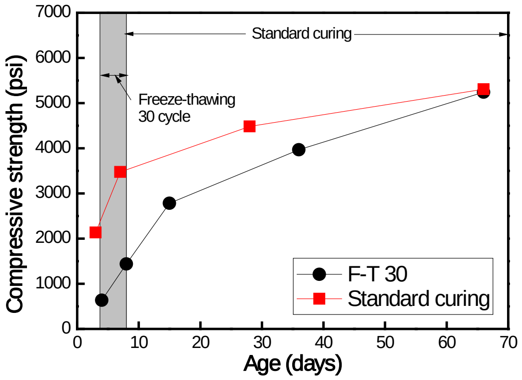


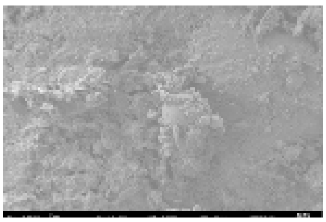
Fig.2 Compressive strength according to curing method

It’s thought that it's because the hydration reaction is delayed in the concrete exposed at the low temperature of 4℃ to -18℃ during the early freeze. Thereafter, because the strength development was improved by the recovery of hydration reaction and the pozzolan reaction, it's found that there was no any difference between the strength in the concrete with early freeze and without early freeze after the age of 68days. In other words, although the minimum compressive strength to block the early freeze regulated under ACI 306R was under early freeze under the condition of repeated 30 cycles at the freeze thaw of -18℃~4℃, it decreased at the early age phase, but it was found that the concrete strength was recovered due to the increased temperature as seen at the study by Powers[1].

3.2 Properties of micros structure

Fig. 3 shows the shapes shot by SEM (x5000) about the NPP concrete with early freeze and the NPP concrete with standard curing. First, a) shows the empty spaces produced due to loose structure in general. In addition, the pozzolan reaction of FA is shown slight due to low temperature. On the other hand, b) shows entirely the tight shape and FA is also covered with hydration structure by the pozzalon reaction.

a) F-T 30



b) Standard curing

Fig.3 SEM of concrete shell

Fig. 4 shows the X-ray diffraction pattern through XRD analysis in terms of early-freezing concrete and standard curing concrete. Generally, the quartz crystal was confirmed regardless of early freeze. It’s because the collection of specimen pieces produced by crushing the concrete specimen had an effect on the fine aggregate. On the other hand, the difference caused by the early freeze, beside quartz, was shown as the existence or non-existence of hydrate (C-S-H), so it was found that the hydrate crystals were shown less in the early freeze specimen compared to the standard curing specimen. According to this result, it's judged that the early freeze specimen proceeded slowly in hydration reaction because it was exposed to low temperature.

In addition, although the protective curing is conducted up to the strength required to early curing of 715 psi, when the concrete would thereafter be exposed to cold weather condition, the hydration reaction proceeds slowly and the tightness gets lower due to the relaxation of inner structure, so it’s found that these results have a harmful effect on the quality of concrete including duration.

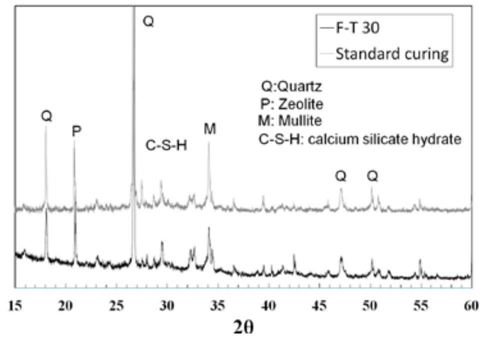


Fig.4 XRD pattern of concrete shell

4. Conclusion

This study, targeting the NPP concrete replaced with FA 20%, analyzed the strength and microstructure through adding the certain standard of freeze in early curing. According to the result, it was found that the concrete under a certain standard of early freeze recovered the similar standard strength as the standard curing concrete in case of sufficient curing in high temperature. As for the characteristic of microstructure, it was found that because the specimen under early freeze proceeded sufficiently in hydration reaction, the structure was not so tight compared to the standard curing.

ACKNOWLEGMENT

This work was supported by the Nuclear Research & Development of the Korea Institute of Energy Technology Evaluation and Planning (KETEP) grant funded by the Korea government Ministry of Knowledge Economy (No.201016010004J).

REFERENCES

[1] Powers, T.C., “Prevention of Frost Damage to Green Concrete”, RILEM, No.14, 1962.