The Effect of Earlry Frost Damage on the Penetration Resistance of Chloride Ion of NPP Cocrete

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1. Introduction

The specification for the nuclear power plant (NPP) structure construction specifies the conformity of the regulation ACI-306R in constructing the cold-weather concrete. According to the regulation with regard to the curing condition for cold weather concrete, the insulation curing of cold weather concrete should be appropriately performed under the environment of 5℃ or more until the strength of 500 psi is developed. In addition, according to the regulations regarding the cold weather concrete in the domestic concrete specifications, the insulation curing should be performed until the strength development of 715 psi considering the safety factor indicated to the ACI regulation under the temperature of 5℃ or more[1].

According to the above-mentioned regulations, the NPP structure is required to develop the minimum strength of 715 psi or more and to maintain the important quality including strength development, early anti-freezing and duality under the cold weather condition. However, even though the early strength of 715 psi or more is secured under cold weather condition, if the structure is exposed to the continuous cold weather condition after the protection equipments including curing coat are removed, the structure's durability can go down compared to the concrete cured under the standard curing temperature condition in spring and fall, but the studies on this status still remain poor.

Accordingly, this study tried to verify the adequacy of the insulation curing management standard, which is currently presented, in time of constructing the cold weather concrete, through reviewing the penetration resistance of chloride ion with considering the local characteristics of domestic NPP located at coastal areas after curing until the point of 715 psi, then exposing it to a certain cycle of freeze-thaw environment under the continuous cold weather condition.

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%).

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

This study made an early-freezing specimen (F-T 30) 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.

It measured the experimental item of compressive strength to the planned age and as for the duration performance evaluation, it measured the penetration resistance of chloride ion through considering the characteristics of NPP structure located at coastal areas

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 psi, 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 measured the penetration resistance of chloride ion to the method of ASTM C 1202 after exposing it to the freeze thaw condition of 30 cycles under the condition of -18℃~+4℃ and then conducting the standard curing.

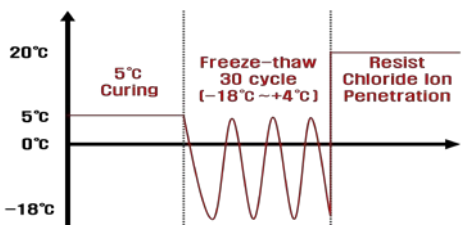

Fig.1 Flow of Curing and tests

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 process of maturity. This study cured the concrete with considering the winter season, so because the NPP concrete was replaced with FA 20%, it was influenced more by low temperature condition compared to the general concrete. Accordingly, it analyzed quantitatively the effect which the low-temperature curing had on the NPP concrete strength development through introducing the concept of maturity.

In general, as the maturity increased regardless of the curing temperature, the compressive strength also showed the tendency to increase and the point to reach 715 psi at 5℃ was about 40 °DD. This result meets significantly the experiment and interpretation outcomes produced from the previous researchers [2]. Given the results of the experiments targeting the general concrete without using FA in the past, however, it's thought that it's necessary to consider additionally the temperature sensitivity in time of using the NPP concrete mixture in this study.

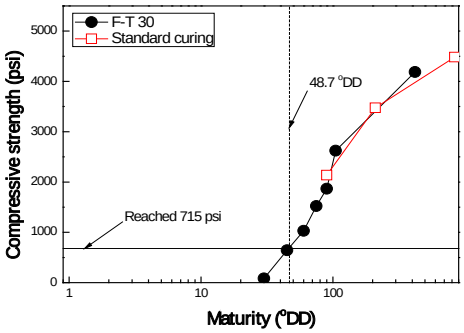

Fig.2 Compressive strength with maturity

3.2 Resist chloride ion penetration

Fig. 5 and 6 shows the passage current and charge amount according to time process of the curing condition-specific concrete.

In general, it was found that the passage current amount in cold-weather condition increased sharply according to time process compared to the standard curing condition. Accordingly, the cold-weather curing was measured as 348 mA and the standard curing as 125 mA in the 360th minute, or the final test-completing time. It's thought that the concrete didn't proceed the sufficient hydration reaction although the strength developed up to 715 psi at 5℃ and because the concrete was exposed to the freeze thaw of 30 cycles at that condition and the quality deterioration including fine cracking occurred in the process of the freeze and expansion of moisture inside the concrete and then it was not relatively tight compared to the standard curing specimen, the passage current amount was shown more.

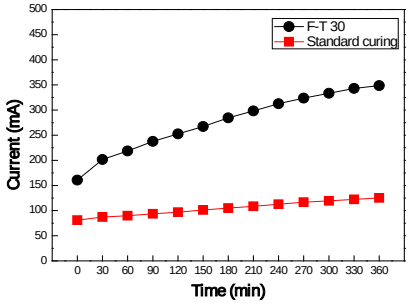

Fig.3 Current of concrete according to initial frost damage

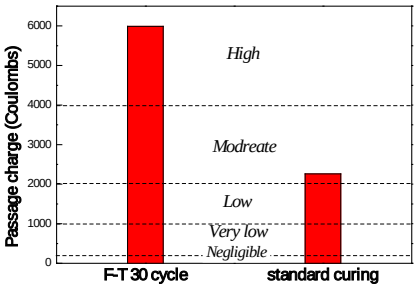

Fig.4 Charge passed according to initial frost damage

In addition, the passage current amount, or the accumulated statistic of passage current amount, was shown 5991 coulombs in the cold-weather curing and 2262 coulombs in the standard curing, so the penetration of chloride ion regulated at ASTM C 1202 as seen at Table 8 was shown very high as over 4000 coulombs in the cold-weather curing and normal as 2000~4000 coulombs in the standard curing.

As a result, even though the strength of 715 psi or more is secured in the cold weather environment, when it was continuously exposed to the cold weather condition, it's thought that the durability gets lower hugely. Accordingly, it's thought that it's necessary to take the additional actions such as increasing the curing period with considering the safety rate rather than curing to the regulation conditions in the cold-weather concrete construction for the structure requiring the high durability as the NPP structure.

4. Conclusion

This study analyzed the effect which the early freeze had on the penetration resistance of chloride ion in the NPP concrete. According to the results, it was found that the penetration resistance of chloride ion in the NPP concrete under a certain standard of early freeze fell down.

ACKNOWLEGMENT

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[2] Carino N. J., Maturity method, Teory and application, Journal of Cement and Concrete, ASTM, 1984