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The Service Life Evaluation for Concrete Structure of NPP

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1. Introduction

Concrete has been used as one of the main structural materials for Nuclear Power Plant (NPP) structure because it is easy to obtain this material and it is excellent the workability, durability and economical efficiency in comparison with other structural materials. However, prolonged exposure to the marine environment degrades the durability of concrete and shortens the service life of concrete due to degradation factors such as chloride, carbonation, freezing and thawing, sulfate. Therefore, many country's organizations like the Korea Concrete Institute (KCI), the American Concrete Institute (ACI), the International Federation for Structural Concrete (FIB), the American Society for Testing and Material (ASTM) which recognized the seriousness of this deterioration proposed equation models to evaluate the service life for the concrete structures. As a result, this paper is to especially consider the service life evaluation using these equation models for concrete structure of NPP in Korea compared with 60 years as a design service life.

2. Evaluation of Service Life for NPP

The target and scope of study in this report is in Shin-Hanul NPP units 1&2 including safety-related concrete structures and Essential Service Water intake (ESW) structure permanently exposed to seawater splash and it is difficult to repair these structures during operation.

Fig. 1. Aerial view for Shin-Hanul NPP units 1&2.

2.1 Chloride

Because chloride attack for concrete structure exposed to marine environment is the most dominant factor which determines degradation of concrete's durability, it is important to evaluate the service life by each equation model. Therefore, the assessment of service life for chloride attack in this study is conducted in accordance with KCI standard specification for concrete, ACI 365.1R and FIB TG 5.6. The service life of the concrete foundations of building and reactor containment building is estimated at more than 124 years by using KCI standard specification for concrete, more than 158 years by using ACI regulations and, more than 200 years by using FIB regulations. The service life of ESWs is estimated at more than 76 years by using KCI standard specification for concrete, more than 111 years by using ACI regulations and, more than 200 years by using FIB regulations. These dissimilar results are mostly caused by significantly different time dependent coefficient of diffusion coefficient of chloride ions and threshold concentration of chloride ions (Table I) which each of the equation models has adopted. As shown below Fig. 2, it is showing considerable difference in the service life of the concrete structures by each equation model and KCI standard specification for concrete is the most conservative assessment method.

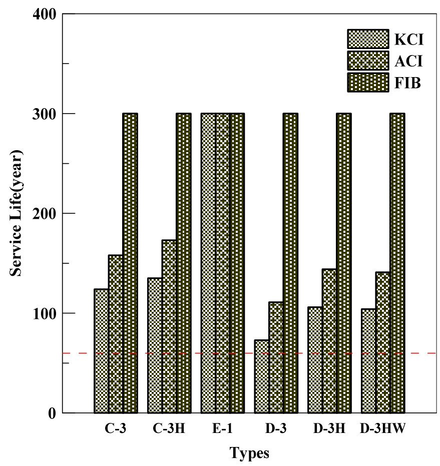

Fig. 2. The service life for chloride in each of the evaluation regulations.

C-3: Foundation (f'_c : 28 MPa)
C-3H: Foundation (f'_c : 28 MPa)
E-1: Reactor containment building (f'_c : 42 MPa)
D-3: ESW (f'_c : 35 MPa)
D-3H: ESW (f'_c : 35 MPa)
D-3HW: ESW (f'_c : 35 MPa)
[*] H: with high water reducing admixture,

W: with water proof admixture

Table I: Threshold concentration of chloride ions

Regulation	$C_{limit}(\times C_{binder})$
KCI	0.4 %
ACI	more than 0.4 %
FIB	0.6 %

2.2 Carbonation

As atmospheric CO_2 by impact of the Industrialization is gradually increased, deterioration of concrete structure in NPP occurs by carbonation and cause performance degradation for concrete. Taking performed result of according to applying accelerated carbonation test of KCI standard specification for concrete (KS F 2584) and ASTM regulation, a velocity coefficient of carbonation is approximately 1.38 ~ 14.76 mm/(week)$^{1/2}$ and the service life by carbonation is identified as more than 500 years at all of concrete structures.

2.3 Freezing-Thawing

As concrete placement in frigid regions and areas of big changes in the temperature is gradually increased by high technology of construction, durability degradation of concrete structures is mostly caused by freezing and thawing. Thus, according to the results of evaluation for concrete durability complying with ASTM C 666, all of the relative dynamic modulus of elasticity in all structures are more than 90 % and this consequence substantially exceed 60 % of minimum threshold value.

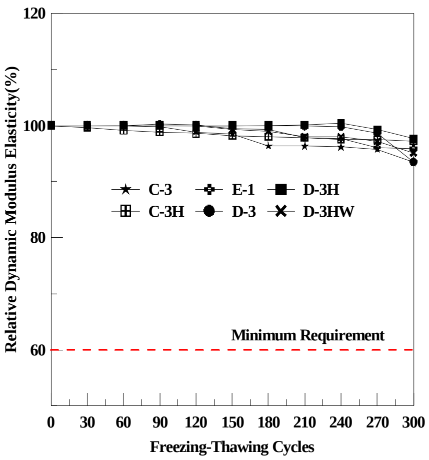

Fig. 3. Relative dynamic modulus of elasticity for each concrete structure.

2.4 Sulfate

NPP exposed to the marine environment is always against sulfate attack. Therefore, as seeing the evaluation result of applying ASM C 1012 and the most commonly used Atkinson and Hearne's evaluation model (1990), the service life by sulfate is more than 98 years at foundation structure, more than 200 years at containment building and ESW.

2.5 Alkali-Aggregate-Reaction (AAR)

According to the result of evaluation pursuant to ASTM C 227, 289 and KCI standard specification for concrete, the change rate in specimen length at the age of 180 days is from 0.017 % up to 0.019 % that is lower than 0.1% as a maximum permissible limit. Additionally, although the reduction amount in concentration of alkali is from 155 mmol/L up to 178.6 mmol/L and the quantity of dissolved silica is from 19.54 mmol/L up to 50.16 mmol/L, this volume is also evaluated to be innocuous on the basis of ASTM C 289.

3. Conclusions

The concrete durability evaluation for Shin-Hanul NPP units 1&2 is carried out by using typically proposed assessment models in domestic and foreign standard. It is confirmed that the service life of concrete durability for each of deterioration factors is significantly higher than 60 years as a design service life. But, in actual practice, the deterioration of concrete structures generally occurs by complex action of combined deterioration factors. As a result, the study of combined deterioration for the concrete structures of NPP in future is positively necessary and maintenance control through regular monitoring should be conducted to secure safety margin basis.

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