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Salt Damage Impact to Silo Dry Storage System for Spent Nuclear Fuel

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1. Introduction

The dry storage facility for spent nuclear fuel at the Wolsong Nuclear Power Plant (Fig. 1) is located near the coast and is affected by salty seawater. To examine this effect, the salt damage impact to the concrete structure of silo dry storage system was analytically assessed using a computer analysis program.

Generally, a major factor affecting the integrity of concrete structure exposed to the marine environment is the corrosion of internal steel reinforcement due to the chloride penetration. Concrete structure does not corrode due to the passive film formed on the surface of internal reinforcement. However, when the chloride concentration inside the concrete increases, the passive film is partially destroyed, leading to corrosion in the reinforcement. When the corrosion occurs, the cross-sectional area of reinforcement decreases, causing expansion pressure, which results in cracks in the concrete structure. When such cracks appear, the strength of concrete decreases, and the structure is damaged. In other words, salt damage is a phenomenon in which corrosion occurs due to chloride inside the structure, affecting its integrity.

The chloride concentration was predicted when the concrete structure of silo dry storage system was exposed to the chloride for a long period. Additionally, the corrosion of steel reinforcement was assessed to determine whether the silo structure could maintain its integrity throughout its design life.

Fig. 1 Silo dry storage facility

2. Analysis and Assessment

The method of predicting the chloride penetration into the concrete structure involves calculating the chloride concentration in the steel reinforcement based on the diffusion theory. The design chloride concentration in the steel reinforcement is obtained using the Fick's Second Law (the change in concentration over time). This value is then compared with the chloride concentration limit at which the corrosion occurs to determine the likelihood of corrosion during the design life.

A three-dimensional analysis of chloride diffusion over time in the silo concrete structure was performed using ABAQUS, a general purpose computer analysis program. The analysis model (Fig. 2) utilized the mass diffusion function provided by the program, and the surface chloride concentration was set as a boundary condition.

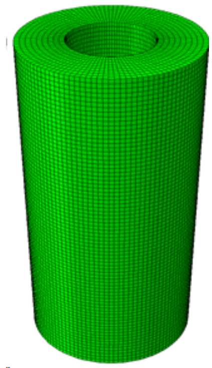

Fig.2 Analysis model

To verify the adequacy of analysis model, the chloride diffusion coefficient and the surface chloride content were applied to the analysis to calculate the chloride concentration inside the structure by comparing it with the experimental results from reference [1]. The surface chloride concentration of the concrete structure was set according to the environmental conditions of the structure, following the values suggested in the "Commentary on Concrete Standard Specifications"[2] for the coastal concrete structures. The chloride diffusion coefficient is affected by the internal conditions and external environment of concrete. Among several models, the ratio of water to cement was applied. The chloride concentration limit for reinforcement corrosion was set at 0.03% by weight of concrete, based on the ACI-222R code[3], which serves as the chloride management standard for concrete. The input data used for the analysis were the surface chloride concentration of 1.5kg/m^3, the chloride diffusion coefficient of 3.096x10^{-6}mm^2/s, the chloride concentration limit for reinforcement corrosion of 0.69kg/m^3 for the concrete weight ratio of 0.03%, and the concrete cover thickness of 76mm.

The depth of chloride penetration into the surface of silo structure and the chloride concentration over time in the steel reinforcement, obtained through computer analysis over a 300-year period, are shown in Fig. 3 and Fig. 4, respectively. In Fig. 4, the chloride concentration exceeded the limit of 0.69kg/cm^3 after approximately 50 years. This indicates that steel reinforcement corrosion occurs in the silo structure after approximately 50 years, affecting the integrity of the structure.

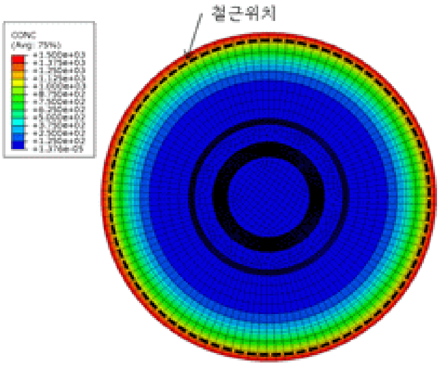

Fig. 3 Chloride penetration depth after 300 years

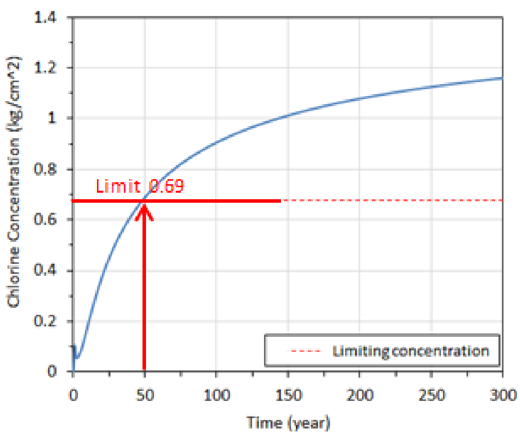

Fig. 4 Chloride concentration over time in the steel reinforcement

3. Conclusions

The design life of silo dry storage system at the Wolsong site was approved for 50 years, meaning it can be operated until 2041. The chloride concentration in the steel reinforcement of concrete structure, as obtained from computer analysis, indicates that corrosion of the silo structure would occur after approximately 50 years. Therefore, it is expected that the silo dry storage system for spent nuclear fuel will be able to maintain its integrity against salt damage throughout its 50-year design life.

REFERENCES

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