Development of Containment Liner Plate Corrosion Damage Control Technology in Nuclear Power Plant

Min-Beum Heo[a*], Hyun-Chul Lee[a], Dong-Seok Lim[a], Young-Jin Kim[a],
[a] *FNC Technology Co. Ltd, Heungdeok IT Valley, Heungdeok 1-ro, Giheung-gu, Yongin-si, Gyeonggi-do, 446-908, Korea*
[*] *Corresponding author: hmbnet@fnctech.com*

1. Introduction

Containment Liner Plate (CLP) in nuclear power plant (NPP) is an important material that not only serves to form concrete for construction but also to prevent radiation leakage. In the early 2000s, corrosion between CLP and concrete was found at the US nuclear power plants. In 2010, the NRC initiated the analysis of the CLP corrosion. The cause analysis showed that corrosion of the CLP caused by worker's gloves and other foreign substances. It was predicted that these foreign materials accelerated the corrosion of CLP.

Also, the CLP corrosion can be accelerated by contact with oxygen or water, and the chloride ions. For these reasons, CLP corrosion can be promoted when the airborne chloride present in the air during the construction of the containment building penetrates the concrete / CLP crevice.

One of the NPP in Korea was found CLP corrosion in 2016 and many people concern about the stability of the containment building and structural integrity.

This paper introduces a research project to prevent CLP corrosion and corrosion damage control technology in nuclear power plants.

2. Theoretical Background

(Elemental compounds and chemical reaction)

· Alite, 3CaO·SiO2 (Ca3SiO5), compounds
- pH 12.5 ~ 13.5
- 2Ca3SiO5 + 7H2O →
3CaO·2SiO3·4H2O + 3Ca(OH)2

· Carbonization with CO2 into concrete
- Ca(OH)2 + CO2 → CaCO2 + H2O
- pH decrease to pH 8 ~ 9

(The Stability of formed oxide film on CLP)

The thin oxide film on CLP surface has an unstable in low pH condition.

There is a possibility that the oxide film is destroyed due to the interaction with the chloride.

(Embedded wood)

The CLP corrosion can be accelerated by moisture including wood.

The organic materials of wood are released into the form of organic acid such as acetic acid and formic acid. These organic acids can reduce local pH and corrosion acceleration.

(Concrete porosity)

When pumping concrete into the containment structure, some voids are easy to form inside the structure. The voids decrease the binding energy of concrete to CLP. Moisture and chloride trapped in the voids accelerate localized corrosion.

Figure 1 shows the schematic diagram of CLP Corrosion phenomena at various conditions

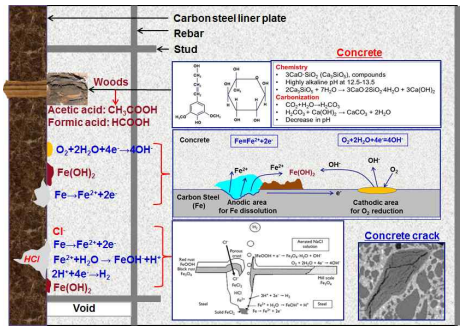

Fig. 1. 3D Schematic Diagram of CLP Corrosion phenomena

Figure 2[3] is an E-pH diagram shows the stability of iron oxide film and unstable region. The iron oxide film on carbon steel surface has a lower stability as the pH is lowered or the corrosion potential of iron is lower, thus accelerating the corrosion rate of carbon steel

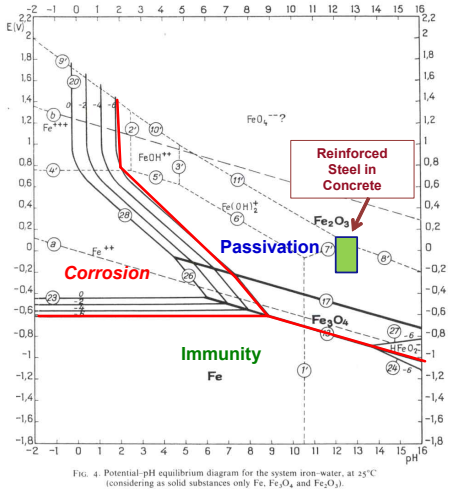

Fig. 2. Fe oxide Stability Diagram on Carbon steel surface in aqueous solution

3. Experimental Design for Corrosion Prediction Model

The cause of CLP corrosion phenomenon in the containment building is not clear. This study will be conducted to determine the causes of CLP corrosion and a corrosion prediction model by CLP corrosion database at various conditions will be collected.

3.1 Measurement of chloride concentration from sea breeze

Chloride ions have high mobility and increase the corrosion rate of the steel. Since the domestic nuclear power plants are currently being built and operated near the sea, there is a lot of exposure to chloride ions by salt from the sea.

Therefore, it is plan to measure the chloride ion concentration in the NPP area for 2 years and make a database with background data of the corrosion prediction model.

3.2 Measurement of Concrete Conductivity

The CLP is combined with concrete as a structure. Generally, concrete is known as electronical insulated material. But, the electrical conductivity of concrete can be changed by external environment condition as chloride ion penetration, water absorb, and porosity of the concrete

Various types of concrete will be made including chloride ion concentration, water contents, and void fraction of concrete. These concrete samples are measured face resistance and calculate the conductivities. The obtained conductivities are very important input data in corrosion prediction model.

.

3.3 Design of Corrosion Experiment Facility

The Corrosion test facility is to measure pH, chloride ions concentration and electrical conductivity. Figure 3 shows the schematic diagram of test facility. Then, test the corrosion proof of CLP with the following variables to analyze the corrosion rate, the corrosion products (Oxide layer at the surface), and the corrosion trend to establish the DB for the corrosion factor.

- Crevice : The clearance between concrete and CLP shall be variable as 0.0mm, 0.1mm, 2.0mm, 5.0mm, and 10.00mm.
- pH : pH 3, pH 5, pH 7, pH 9, and pH 11 variables.
- Foreign Materials : The gloves used by workers and wood containing moisture are used as variables.

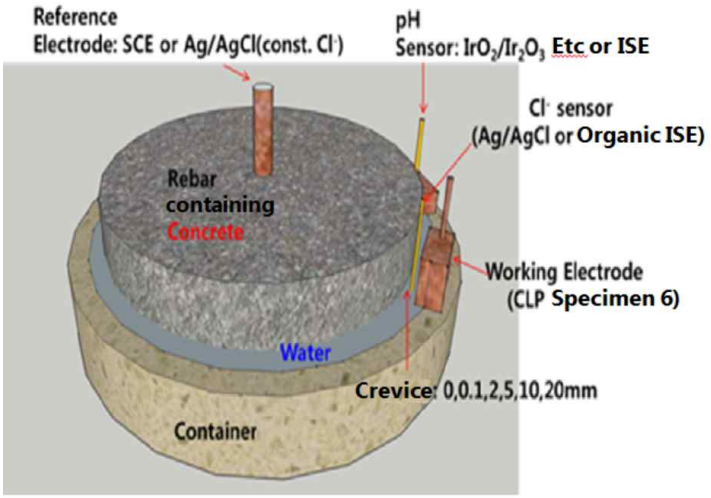

Fig. 3. Schematic diagram of Corrosion Experiment Facility

4. Conclusions

CLP corrosion phenomenon in NPP has many expected variables such as foreign material, void, chloride ion concentration. But the cause of CLP corrosion is not clear. The CLP corrosion will find its major cause and make a lot of CLP corrosion databases. Develop a corrosion prediction model and calculation program based on the database. The program is helpful to manage containment building and the other structure in NPP site.

ACKNOWLEDGMENTS

This work was supported by Development of Containment Liner Plate Corrosion Damage Control Technology in Nuclear Power Plant of the Korea Institute of Energy Technology Evaluation and Planning (KETEP) grant funded by the Korea government Ministry of Knowledge Economy
(No. 20181510102310)

REFERENCES

[1] Darrell S. Dunn, April L. Pulvirenti, and Matthew A. Hiser, “Containment Liner Corrosion Operating Experience Summary”, US-NRC report, August 2011

[2] 격납건물 라이너플레이트(CLP) 배면부식 관련 중간점검결과 및 향후 계획”, 2017.7.27., 원자력안전위원회