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Effect of chemical attack on elastic stiffness of reinforced concrete wall and floor response spectrum

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1. Introduction

Nuclear power plants in South Korea are constructed along the coastline to secure a supply of cooling water. As a result, the nuclear power plant buildings are exposed to the high concentration of chlorides in seawater. While the reinforced concrete, a critical structural element of NPP, is known to have a durable lifespan, prolonged exposure to chloride can lead to various forms of degradation, including reinforcing bar corrosion, carbonation, and expansion. Especially, the corrosion of reinforcing bar significantly impacts the durability of concrete, not only by reducing the cross-sectional area that resists the external forces but also by decreasing bond stress, increasing internal stress, and causing microcracks. Figure 1 shows the process of damage due to reinforcing bar corrosion [1].

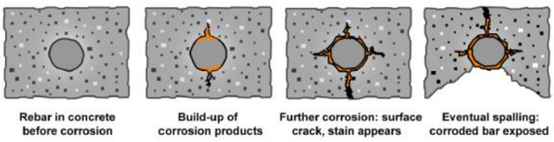

Fig. 1. Process of reinforced concrete damage due to reinforcing bar corrosion [1].

In this research, the finite element analysis was conducted to assess the impact of degradation on the performance of concrete walls, and structural analysis will be performed based on the FEA results.

2. FEA Model

2.1 Analysis model

To investigate the effect of reinforcing bar corrosion and delamination at cover concrete, finite element analysis was conducted. The non-deterioration model was developed based on the actual experimental results [2]. The test specimen was designed to be representative of the walls of auxiliary buildings in nuclear power plants. The vertical and horizontal reinforcing bar ratio was closed to 2.0 % and 1.0 %, respectively. The final failure mode of specimen was concrete crushing failure at the web area due to shear deformation. Figure 2 shows the comparison results of FEA model and test results.

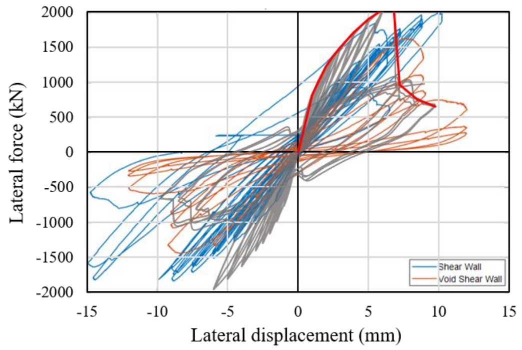

Fig. 2. Comparison results of FEA model (black line) and experimental (blue line).

The maximum strength of FEA model and experimental results was same. On the other hand, the stiffness of FEA model was 10 % greater than experimental results. The reason why greater stiffness was occurred is that the slip of basement, zig and actuators can not apply in FEA model. Therefore, the relative stiffness comparison between analysis results, rather than absolute stiffness was performed accordingly.

2.2 Reinforcing bar corrosion and delamination

When corrosion occurs in the reinforcing bar, not only does the resistant cross-sectional area decrease, but the bond strength also decreases. In this study, the effect of cross-sectional area decrease was not considered. The degradation of bond strength due to corrosion was developed according to Lin et al [3]. To investigate the effect of reinforcing bar corrosion at different locations, models were developed for cases where reinforcing bar corrosion occurred at various positions.

The model with delamination was developed by artificially creating slight cracks at the depth where the reinforcing bar is located. The slight cracks were implemented with compressive-only contact conditions. In addition, for comparison, the model was compared with the model in which the concrete element of the part where the delamination was removed.

Figure 3 shows the summary of analysis results. The maximum strengths of analysis model were decreased as 24% and 38 % in slip and delamination model, respectively. On the other hand, the initial stiffnesses of bond slip and delamination model were 5 % and 8 % less than the non-deterioration model (fig 3 (a)), respectively.

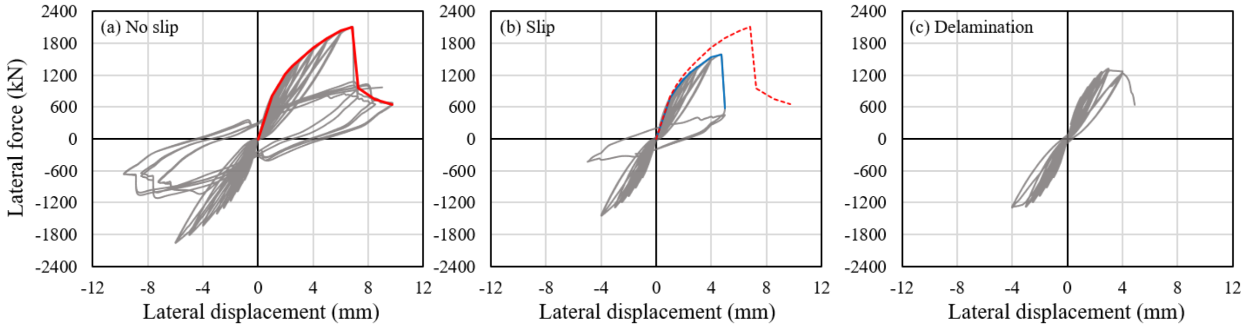

Fig. 3. Analysis results of Non-degradation, bond slip, and delamination.

The reduction in bond strength of the horizontal reinforcing bar did not affect the maximum strength or the initial stiffness. However, in the case of vertical reinforcing bars at the wall flanges, it had a significant impact on the initial stiffness.

3. Effect on floor response spectrum

The target building selected for analyzing the effects of degradation is the auxiliary building of the OPR1000. Because the containment building has a smaller surface area directly exposed to the external environment due to being surrounded by the auxiliary building itself, the auxiliary building was selected. The analysis will be performed using the ABAQUS software.

Chemical deterioration of concrete is expected to progress from the lower floor. Therefore, an analysis plan was established by assuming the condition according to the aging deterioration time and Table 1 shows the plan of analysis procedure. Due to the reduction in stiffness of reinforced concrete wall caused by deterioration, a change in the natural frequency of the entire structure is predicted, and it is anticipated that the maximum value of the floor response spectrum will decrease.

Table I: Problem Description

	Deterioration	Location
Step 1	Non-Deterioration	-
Step 2	Low-bond	1^{st} floor
Step 3	Low-bond	All floor
Step 4	Delamination	1^{st} floor
	Low-bond	All floor except 1^{st} floor
Step 5	Delamination	1^{st} and 2^{nd} floor
	Low-bond	All floor except 1^{st} and 2^{nd} floor
Step 7	Delamination	All floor

4. Conclusions

The performance reduction of reinforced concrete walls due to chloride diffusion was analyzed using finite element analysis. The primary performance reductions assumed were the bond strength of reinforcing bar and spalling due to internal cracks. The analysis model was based on the experiment and theories from previous researchers. The analysis results confirmed that both maximum strength and initial stiffness are reduced due to deterioration. Based on the analysis results, future research will be conducted to study the changes in the floor response spectrum in cases where stiffness decreased due to deterioration, through modeling of the auxiliary building in nuclear power plants.

ACKNOWLEDGMENTS

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