Sensitivity of Variables with Time for Degraded RC Shear Wall with Low Steel Ratio under Seismic Load

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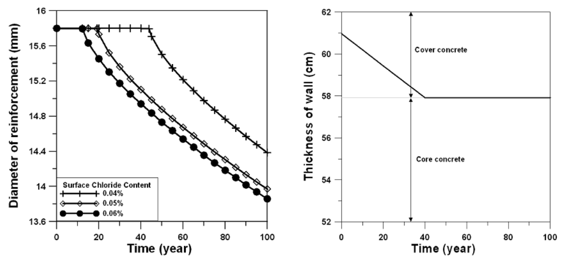
1. Introduction

Various factors lead to the degradation of reinforced concrete (RC) shear wall over time. The steel section loss, concrete spalling and strength of material have been considered for the structural analysis of degraded shear wall [1]. When all variables with respect to degradation are considered for probabilistic evaluation of degraded shear wall, many of time and effort were demanded. Therefore, it is required to define important variables related to structural behavior for effectively conducting probabilistic seismic analysis of structures with age-related degradation.

In this study, variables were defined by applying the function of time to consider degradation with time. Importance of variables with time on the seismic response was investigated by conducting sensitivity analysis.

2. Degradation of shear wall with time

A previous research on shear wall with age-related degradation was only focused on degradation variables but concrete hardening occurs usually with time in RC shear wall. In this study, a material database of structural aging program (SAG) [2] was used in considering concrete hardening with time. While the steel corrosion and concrete spalling due to chloride penetration were considered as degradation effect of shear wall as shown in figure 1.



a) Reinforcing steel b) Concrete

Fig. 1. Rebar and wall section loss with time [3]

3. Analytical model

Analytical model is an H-shaped RC shear wall with two flange walls and one center wall as shown in figure 2. The steel ratio of shear wall is 0.3%. The layered shell element is used to model concrete and steel. Concrete compressive strength (f'_c), elastic modulus of concrete (E_c), yield strength of steel (f_y), elastic modulus of steel (E_s), steel section (A) and thickness of wall (T) were defined as variables.

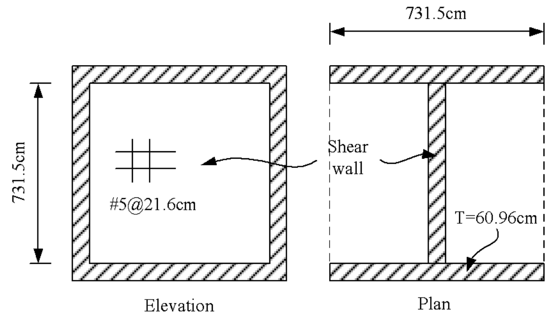


Fig. 2. Shear wall model

3. Sensitivity analysis

The difference of structural responses, referred to as swing, is considered as a measure of sensitivity [4]. In the first order second moment (FOSM) method, means and standard deviations (SD) of random variables are assumed and the mean and SD of structural responses are obtained using FOSM where SD can be used as a measure of sensitivity. Variability of the shear force of shear wall due to the random variables is represented in the form of a tornado diagram. In this diagram, the swings (mean ± 2SD) are displayed in the descending order of the swing size from top to bottom.

4. Analysis results and discussion

4.1 Seismic behavior of shear wall with time

The natural frequency of degraded RC shear wall is dominated by concrete hardening and degradation. The natural frequency increases with time because the increase ratio of concrete elastic modulus is higher than the decrease ratio of the steel section loss and the thickness of wall (table1).

Figure 3 presents the force-displacement curves of analytical model. The stiffness and yield strength of shear wall with time increased due to concrete hardening. The cross of figure 4 presents the limit state of shear wall with time based on displacement criteria.

In this study, the limit state of initial model was defined to be 4 times yield displacement. The limit state of degraded shear wall was decreased with time by the ductility reduction due to steel corrosion.

Table 1. The natural frequency of analytical model

Time (year)	Natural frequency (Hz)
0	10.67
20	12.49
40	12.63
60	12.76
100	12.92

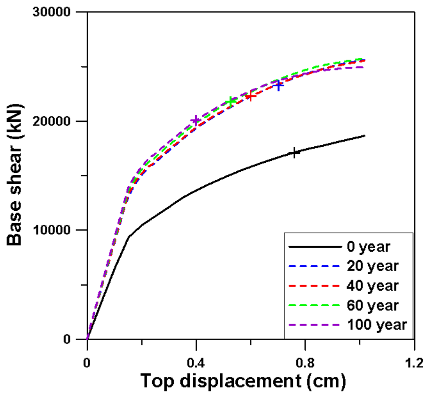
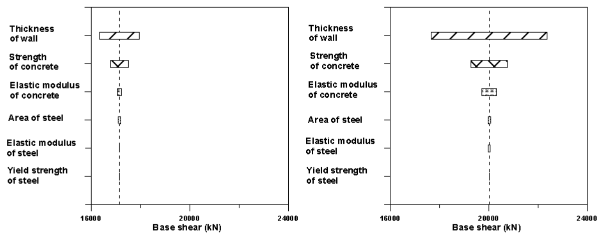


Fig. 3. Pushover curves of analytical model with time

4.2 Sensitivity of degraded shear wall with time

The pushover analysis was performed at 0 year, 20 year, 40 year, 60 year and 100 year to calculate the seismic response of shear wall with time.

It was observed that the thickness of wall was the most sensitivity variable and the swing of the compressive strength of concrete and the elastic modulus of concrete was higher than that of variables (i.e. the steel section, the elastic modulus of steel and the yield strength of steel) with related to steel corrosion as shown in figure 4 because of the low steel ratio of shear wall.



a) 0yr b) 100yr

Fig. 4. Important variables of analytical model with time

Figure 5 presents the variation of swings between a measured year and initial year to investigate the important of variables with time for degraded shear wall. The compressive strength and elastic modulus of concrete is sensitive at early year because of concrete hardening and then the sensitive of thickness of wall is increased with time. Consequently, degraded shear wall has affected by concrete hardening effect at early year and then by degradation effect.

Although the section of steel over time is reduced by corrosion, the variation of swing with related to both the area and the elastic modulus of steel does not increased continually with time. This result was caused by the difference of the degradation level of variables.

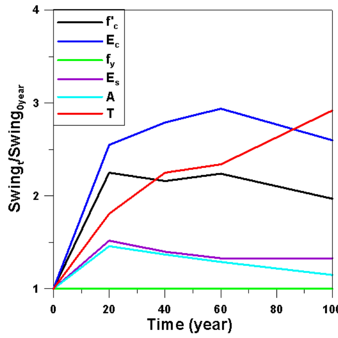


Fig. 5. The change of swings with time

5. Conclusion

In this study, the sensitivity analysis was performed for identifying important variables with time on seismic behavior of shear wall. It was observed that the compressive strength and the elastic modulus of concrete were important variables at early year because of concrete hardening. Therefore concrete hardening as well as degradation should be considered to evaluate seismic capacity of degraded shear wall.

When the shear wall has low steel ratio, the variables on steel corrosion should not be considered in evaluating the seismic capacity.

Acknowledgement

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