Seismic Capacity of RC Shear Wall after Design Life

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1. Introduction

The problem regarding durability of nuclear power plants (NPPs) has lately become a subject of special interest according to increase of aged NPPs. A chemical and physical attack on age-related degradation can result in distress of RC shear wall. The seismic capacity of RC shear wall with age-related degradation may be changed because the ductility and strength of aged RC shear wall is reduced. The seismic fragility analysis with time will be a great help in predicting seismic capacity after design life.

In this study, the comparisons of degraded and undegraded fragility are used to evaluate the effect of degradation on shear wall. The seismic capacity of RC shear wall after design life was performed considering degradation and hardening effect.

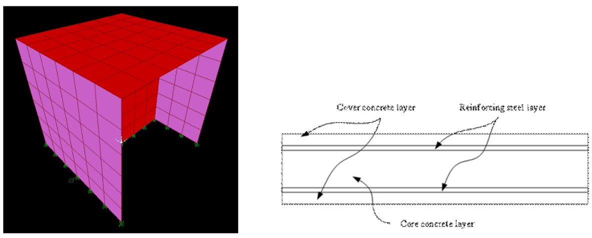
2. Analytical model

2.1 Modeling of RC shear wall

RC shear wall is an H-shaped wall with two flange walls and one center wall. Figure 1a) is shown that FE model was used to analysis. The layered shell element is used to model concrete and steel.

The thickness of the wall is 2' throughout. The length of the center wall is 20', the length of the flange wall is 20', and the height of the wall is 24'.

The reinforcement consist of #5(15.9mm) bars spaced at 8.5' (21.6cm) at each face in each direction resulting in a horizontal and vertical reinforcing ratio equal to 0.003. A vertical load equal to 300psi applied in the wall.

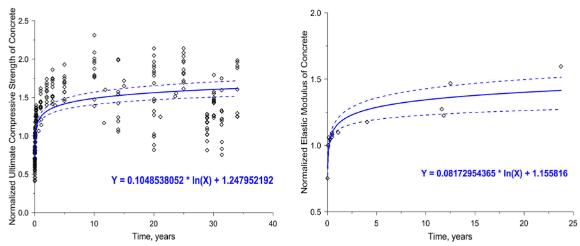


a) Finite element model   b) Multi-layered shell element
Fig. 1. Shear wall model

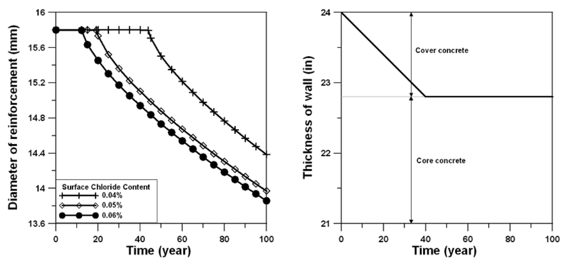
2.2 Material property with time

When properly designed and constructed, the compressive strength of concrete over time was usually increased. According to the SAG material DB [1], the compressive strength of concrete after 10 year is higher about 50% than initial strength.

On the other hand, the relationship between time and steel section loss due to chloride content can be presented as shown in fig. 2 using equation proposed by Choun et.al.[2]. Because of confined effect of core concrete, the core concrete spalling doesn't occur easily. For this reason, it was assumed that the thickness of RC shear wall was reduced by 0.03in/yr (fig.3).



a) Compressive strength   b) Elastic modulus
Fig. 2. Concrete hardening with time



a) Reinforcing steel   b) Concrete
Fig. 3. Rebar and wall section loss with time

3. Seismic fragility of RC shear wall

3.1 Input motion

20 ground motions used in SAC-steel project [3] were selected for seismic analysis of shear wall. Figure 4 shows the spectral acceleration of the near fault ground motion normalized at 0.2g.

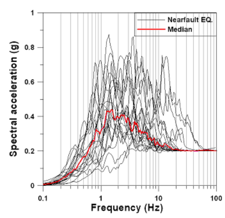


Fig. 4. Spectral acceleration of input ground motion

3.2 Seismic fragility of aged RC shear wall

Among seismic fragility parameter, the median capacity and uncertainties (e.g. aleatory, epistemic) will change as age. In this study the seismic fragility of analytical model was calculated using the equation (1). The lognormal standard deviation on randomness and uncertainty was assumed to be 0.15.

$$f'(t) = \Phi\left[\frac{\ln(a/A_m(t)) + \beta_U(t)\cdot\Phi^{-1}(Q)}{\beta_R(t)}\right] \qquad (1)$$

where $A_m(t)$, $\beta_R(t)$, and $\beta_U(t)$, represent median capacity, randomness and uncertainty at time "t".

In seismic probabilistic risk assessments, structural failure of RC shear wall is generally defined to occur when deformation of are sufficient impair the functionality of attached equipment. In this study limit state was defined to be 4 times yield displacement. The limit state was changed by ductility reduction in degradation model.

4. Results and Discussions

4.1 Responses of RC shear wall

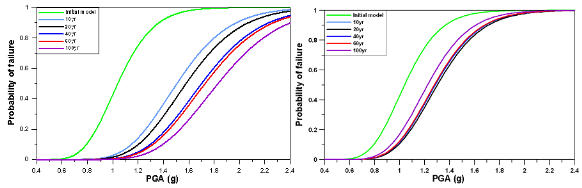
To investigate the response of shear wall under seismic load, nonlinear time history analyses were performed. By gradually increasing peak ground acceleration (PGA) from 0.2g to 2.0g, the fragility analysis of shear wall was performed.

In this study, undegraded model were compared with degraded model to identify capacity reduction of degraded model. According to the result, displacement of initial model is higher than other model because concrete hardening occurs over time.

4.2 Fragility curves

To identify seismic capacity of RC shear wall after design life, fragility curves was presented at 40year, 60 year and 100 year. As shown in figure 5a), the mean fragility curves of undegraded model considering only concrete hardening were shifted to the right as shear wall age. In case of degraded model, fragility curves until 10 year were shifted to the right due to concrete hardening and fragility curves after 20 year were shifted to the left since ductility of RC shear wall was reduced by steel corrosion (fig. 5b)).

Seismic capacity of undegraded model with time depends on concrete hardening. For this reason, high confidence low probability failure (HCLPF) of undegraded model was increased dramatically until 10 year because concrete strength and elastic modulus were sharply increased. After design life (40 year), HCLPF of undegraded model was smoothly increased. On the other hand HCLPF of degraded model after design life was continually reduced because the capacity of RC shear wall was reduced by ductility reduction. After design life (40 year), the HCLPF of degraded model reduced over 25% than undegraded model as shown in figure 7. When RC shear wall reaches design life (40year), HCLPF of undegraded and degraded model represent 1.04g and 0.78g, respectively. When the age of RC shear wall reached 100year, HCLPF of undegraded and degraded model represented 1.12g and 0.75g, respectively.



a) Undegraded model b) Degraded model
Fig. 5. Fragility curve of RC shear wall

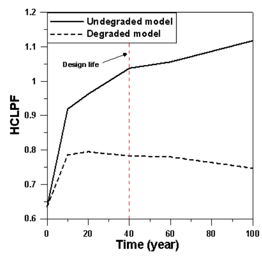


Fig. 6. HCLPF with time

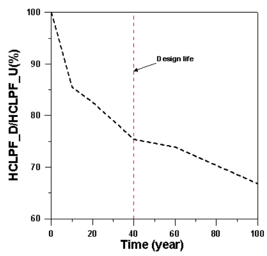


Fig. 7. HCLPF ratio with time

5. Conclusion

This study presented the seismic capacity of RC shear wall with time. The seismic capacity of degraded model after design life was lower than undegraded model. The seismic capacity of degraded model after 40 year was higher than that of initial degraded model. To ensure seismic capacity of RC shear wall after design life, unexpected degradation such as pitting corrosion of steel was prohibited.

Acknowledgement

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