# The Effect of Correlation on Seismic Capacity of Degraded RC Shear Wall

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## 1. Introduction

The steel corrosion and concrete spalling lead to the degradation of reinforced concrete (RC) concrete shear wall. There is a correlation among the variables considering the degradation mechanism. Especially it is required to investigate the effect of correlation with time because the seismic response of degraded shear wall over time can be changed by the correlation.

In this study, a RC shear wall with time-dependent material property was used as an analytical model to consider degradation. The correlation of variables was defined by considering previous research and a degradation mechanism of RC structures. A correlated case was compared with uncorrelated case to investigate the effect of correlation on seismic capacity with time.

## 2. Variables on degradation

### *2.1 Time-dependent variables and correlation*

Various variables (i.e. strength, elastic modulus, steel corrosion, etc.) can be used in conducting structure analysis of degraded shear wall. According to the previous result [1], such variables are changed with increasing time.

In this study, the compressive strength of concrete ($f'_c$), elastic modulus of concrete ($E_c$) were considered as variables on hardening. And the area of steel (A), and thickness of wall (T) were considered as variables on degradation. While the elastic modulus of steel and the yield strength of steel can be omitted in conducting seismic fragility analysis because of its low sensitivity.

It is difficult to predict the correlation of variables for degraded shear wall. In this study, the correlation of variables was assumed by the previous research and degradation mechanism. It was reported by Pilar etc. that the compressive strength and elastic modulus of concrete have high correlation as shown in figure 1 [2]. Also Bhanja etc. showed the relationship between split tensile and compressive strength by performing regression analysis on 32 concrete mixes [3]. According to the degradation mechanism, the steel corrosion is correlated with the cracking strength of concrete and the concrete spalling.

Based on this relation, the correlation coefficients of variables were summarized as shown in table 1.

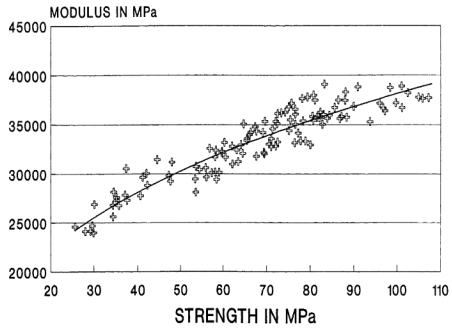


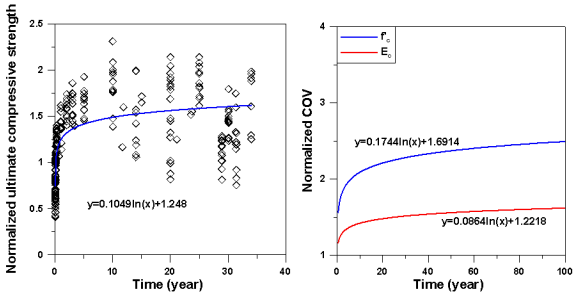

Fig. 1. Relationship of between $E_c$ and $f'_c$ [2]

Table. 1. Correlation coefficient on degradation

| | $f'_c$ | $E_c$ | A | T |
|---|---|---|---|---|
| $f'_c$ | 1 | | | |
| $E_c$ | 0.9 | 1 | Symmetric | |
| A | -0.5 | -0.4 | 1 | |
| T | -0.5 | -0.4 | 0.5 | 1 |

### *2.2 Uncertainty of variables*

If the number of data on degradation is constant with time, epistemic uncertainty will be constant. While an environment condition and a level of degradation lead to increase of aleatory uncertainty (i.e. randomness in probabilistic seismic analysis) with time as shown in figure 2 b). The normalized coefficient of variation (COV) related to both compressive strength and elastic modulus of concrete was defined by regression analysis as shown in figure 2 a). It was assumed that the COV of other variables was linearly increased by 5% / 20year.




a) Compressive strength [1] b) Normalized COV with time

Fig. 2. Statistical properties of variables with time

## 3. Analytical model

Degraded RC shear wall with time-dependent material properties was used for investigate the effect of correlation on the seismic capacity with increasing time. Analytical model is RC shear wall with two flange walls and one center wall [1]. A pushover analysis with increasing time was performed to evaluate seismic capacity of degraded shear wall.

## 4. Seismic fragility of shear wall with correlation

### *4.1 Calculation of seismic fragility*

The fragility of a structure commonly is modeled by a lognormal cumulative distribution function. In this study, the equation (1) was applied to evaluate seismic fragility of degraded shear wall with time.

$$P_f(t) = \Phi\left(\frac{\ln(a/\hat{a}_t)}{\beta_t}\right) \quad (1)$$

where $\Phi[\ ]$ and $a$ represent standard normal probability integral, demand parameter. And $\hat{a}_t$ and $\beta_t$ represent median capacity parameter and logarithmic standard deviation at time "$t$". In this study, the first order second moment method was applied in calculating mean and standard deviation of seismic response. The COV of seismic response is higher for correlated case than for uncorrelated case as shown in table 2. Besides, it is observed that the COV ratio on seismic response of correlated case to uncorrelated case is increased with time. It leads to the difference on seismic capacity between two cases.

Table. 2. The COV of response with time

| Time (year) | 0 | 20 | 40 | 60 | 100 |
|---|---|---|---|---|---|
| $COV_{uncorrelate.}$ | 0.11 | 0.25 | 0.26 | 0.26 | 0.27 |
| $COV_{correlate}$ | 0.13 | 0.30 | 0.32 | 0.32 | 0.35 |
| $\frac{COV_{cor.}}{COV_{uncor.}}$ | 1.18 | 1.20 | 1.23 | 1.23 | 1.30 |

### *4.2 The effect of correlation on seismic capacity*

To investigate seismic capacity with time by correlation, the seismic fragility analysis was conducted at early year, 20 year, 40 year, 60 year and 100 year. The fragility curves of correlated case are more flat than that of uncorrelated model as shown in figure 3 because the uncertainty of seismic response is increased by correlation as noted above.

The difference of seismic capacity between two cases increased with time as shown in figure 4 because the increase ratio of uncertainty over time was changed by degradation.

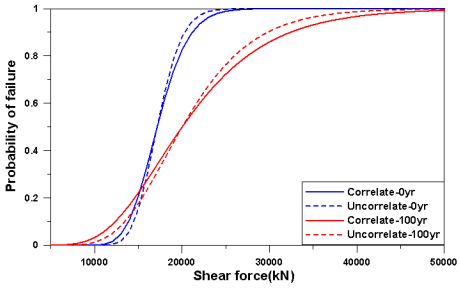



Fig. 3. The change of seismic fragility curve by correlation

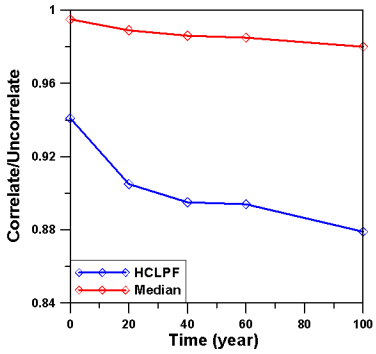



Fig. 4. The effect of correlation on seismic capacity

## 5. Conclusion

In this study, the effect of correlation on the seismic capacity of degraded shear wall was investigated by using seismic fragility analysis.

It was observed that the seismic capacity was lower for correlated case than for uncorrelated case and the difference of seismic capacity of two cases increased with time. Consequently, the correlation of variables on degradation should be considered for conservatively evaluating shear wall with age-related degradation.

## Acknowledgement

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