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Seismic Performance of Rehabilitated Moment Frame with Steel Shear Wall by considering Structural Uncertainties

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1. Introduction

In the seismic design of structures, uncertainties in the designed structures have been considered. In seismic regulations, structural uncertainties and changes in seismic stimulation are considered separately. In these regulations, uncertainties are considered based on qualitative data in existing structures. In seismic rehabilitation of structures, the secondary system which is added to the existing structure has also uncertainties. These uncertainties may increase the uncertainties of rehabilitated structure. In this study, a steel shear wall has been used for the rehabilitation of the steel moment frame. Then, uncertainties of the steel shear wall and quantification of them have been investigated. Assuming probabilistic variables, an effective number of the structural models were generated. The quantification of uncertainties of the steel shear wall were investigated to evaluate the uncertainties in seismic rehabilitation. The design and evaluation of seismic performance of structures should be performed using reliability-based methods. In this study, the effect of uncertainties on the seismic performance of the rehabilitated structure was studied using the reliability methods.

2. Rehabilitated Structure and Considered Uncertainties

In this study, a 9-story steel moment frame was selected which was designed based on UBC1994 regulations. The structure, located in center of Los Angeles and on stiff soil, was designed as an office building and as a steel moment frame. In this structure, perimeter Moment Resisting Steel Frames (MRSFs) were used as structural system. The beams and columns have yield strength of 50kip and modulus of elasticity of 29,000ksi. In the two-dimensional modeling, the effect of the interior frames and orthogonal steel moment frames is not considered. In order to consider the effect of interior frames, a gravity equivalent column (p-delta column) was used.

In this study, the structure was evaluated in order to investigate the need for rehabilitation. For seismic evaluation, nonlinear static analysis was used, while bilinear moment-rotation relationship was employed for modeling the nonlinear behavior of members in the nonlinear static analysis. The steel shear wall was considered for rehabilitation of the existing structure. Figure 1 displays the rehabilitated structure with steel shear wall.

In this study, IDA analysis was used to calculate the uncertainties caused by random parameters of the structural system. Initially, the structure with basic parameters underwent IDA analysis with selected seismic records. The selected records involved extensive variations in ground motion characteristics. The results of this stage were associated with uncertainty caused by various seismic records. In the next step, assuming Rayleigh's damping, steel yield strength, and strain hardening of force-deformation relationship of steel shear wall as probabilistic variables, an effective number of structural models were generated. Then, each structural model was subject to IDA analysis for the selected records. The results of this stage included aleatory and epistemic uncertainties. Table 1 shows statistical characteristics of selected probability variables.

3. Results

The sensitivity of structural response to each of the selected probability parameters was investigated under sensitivity analysis.

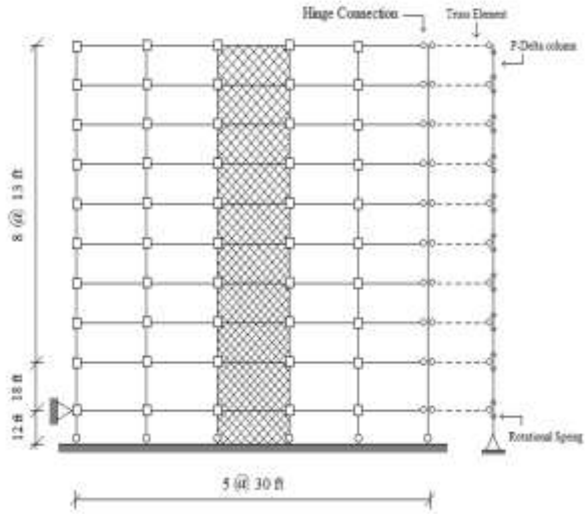

Figure 1. Rehabilitated structure with steel shear wall

Table 1. Statistical characteristics of input random variables

Name		Mean	C.O.V	Dis.
Strain Hardening Ratio	A	0.025	0.4	Normal
Damping	Z	0.02	0.4	Normal
Steel Strength	F_y	35kip	0.07	Lognormal

The results of sensitivity analysis revealed that the response of the structure has least sensitive to strain hardening parameter of force-deformation relationship of

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steel shear wall, and has the greatest sensitivity to steel yield strength parameter of the steel shear wall. In this study, incremental dynamic analysis was done on the structure before and after the rehabilitation. The obtained IDA curves revealed that rehabilitation of steel moment frame with steel shear wall significantly reduced the maximum inter-story drift of the structure in the considered limit states. Comparison of curves of the rehabilitated structure with and without uncertainties demonstrated that consideration of uncertainties has increased the maximum inter-story drift. This suggests that consideration of uncertainties reduces the existing conservatism (Figure 2-3).

The annual exceedance probability of the selected limit states was calculated for the base building and rehabilitated building with and without uncertainties. The annual exceedance probability of the selected limit states diminished with rehabilitation of the structure under far-field and near-field records, suggesting that the seismic performance of the structure improves with rehabilitation of the structure. Eventually, the results revealed that the annual exceedance probability of the selected limit states was increased with consideration of uncertainties in the rehabilitated structure under far-field and near-field records (Table 2 and Table 3).

4. Conclusion

According to the results obtained from this paper, with rehabilitation of the studied structure, the probability of failure in the limit states decreased. The comparison of fragility curves of rehabilitated structure indicates that consideration of uncertainties of rehabilitated structure has increased probability of failure. This suggests that the consideration of uncertainties reduces the conservatism. The results revealed that the annual exceedance probability of limit states increased with consideration of uncertainties in the rehabilitated structure under far-field and near-field records. The comparison of results showed that the reduction or growth in annual exceedance probability under far-field records is greater than near-field records. Based on the response spectrum of selected far-field records, this may be due to the greater impact of these records in the main period of rehabilitated structure.

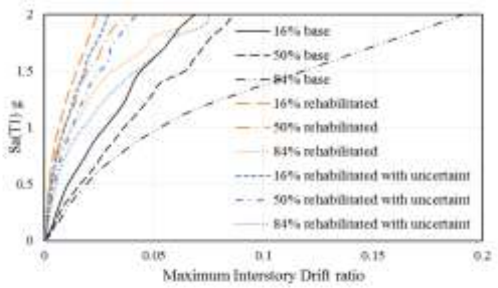

Figure 2. IDA curve of the structure under far-field records

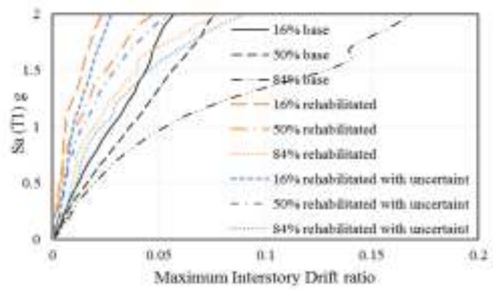

Figure 3. IDA curve of the structure under near-field records

Table 2. Annual exceedance probability of three selected limit states under far-field records

Case	Annual exceedance probability (P_{LS})		
	IO	LS	CP
Base building	0.02704	0.00107	0.000203
Rehabilitated building	0.00050	0.00010	0.000046
Rehabilitated building with uncertain	0.00089	0.00012	0.000056

Table 3. Annual exceedance probability of three selected limit states under near-field records

Case	Annual exceedance probability (P_{LS})		
	IO	LS	CP
Base building	0.01969	0.0011	0.000209
Rehabilitated building	0.00042	0.00008	0.000048
Rehabilitated building with uncertain	0.00044	0.00009	0.000053