Determination of Response Modification Factor for Reinforced Concrete Frames equipped with Steel Plate Shear Wall using Incremental Dynamic Analysis

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1. Introduction

As the reinforced concrete (RC) frames equipped with steel plate shear walls (SPSW) are a novel type of structural system, the respective codes have not incorporated sufficient information about their design procedure. Thus, it is required to determine the seismic parameters of such frames as response modification factor that plays an important role in seismic design.

One of the significant uncertainties for the assessment of seismic performance of the structures is the intrinsic nature of earthquake and for the sake of quantifying this uncertainty, the effect of change in earthquake characteristics needs to be evaluated using a number of dynamic analyses. Therefore, to account for the effect of such uncertainties, incremental dynamic analysis (IDA) was applied.

2. Incremental Dynamic Analysis (IDA)

In this paper, to take the building's characteristics into account, the spectral acceleration of 1st mode of vibration with damping of 5% ($Sa(T_1,\zeta=5\%)$) was used as the seismic intensity. The incremental dynamic analysis (IDA) was used as one of the most powerful methods which has turned out comprehensive to study seismic performance of structures. To further generalize the analyses, in addition to the site soil effects (soil type III), both far and near-field ground motion records have been applied.

3. Numerical Modeling Process and Verification

To carry out the nonlinear static and dynamic analyses, OpenSees 2.4.0 was employed.

To verify the numerical modeling, the experimental model of the RC frame equipped with steel plate infill wall (SPIW1) tested by Choi and Park, was adopted.

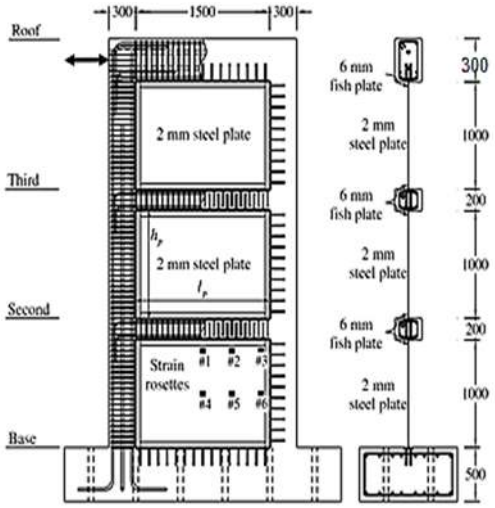

Figure 1. Experimental Model of Choi and Park

The comparison between the numerical and experimental results are presented in Figure 2.

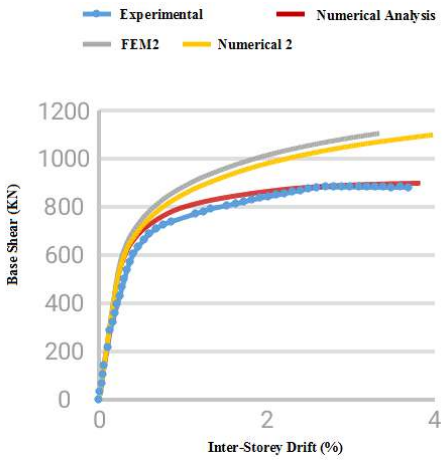

Figure 2. Comparison of Numerical and Experimental Results

The results indicate that the numerical analysis using the strip-based model, has managed to properly analyze behavior of the models.

4. Studied Models and Analysis of Results

Three RC frames including 7, 15, and 30 stories whose structural system is special RC frame equipped with thin steel plate shear wall were analyzed.

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5. Calculation of Response Modification Factor (R)

Based on the results obtained from the nonlinear static and dynamic analyses, the overstrength, ductility and response modification factors were calculated. The results indicate that because of severe decline in ductility, increasing trend of overstrength has not managed to grow the response modification factor and, thus, decreasing trend of ductility factor has been dominant leading to a decrease in the response modification factor (R).

To compute the response modification factor, at first, the average values of this factor for each structure was determined as presented in Table 1. Then, these values were averaged to obtain one response modification factor. The results show that as the height increases, the response modification factor is reduced and consequently, it would be unreasonable to devote a single response modification factor to a broad range of structures with different heights.

Based on the results, the values of response modification factor for an RC frame equipped with SPSW using the ultimate state design method, is equal to 9.

It is noteworthy that according to ASCE07, the response modification factors for dual special moment frame plus shear wall as well as special dual steel frame equipped with SPSW, is equal to 8. Hence, further studies are required to scrutinize this factor.

Table 1. Values of Seismic Parameters

Model	Rs	Rμ	R_{LRFD}	R_{ASD}
7 Storey	1.96	5.73	10.84	15.6
15 Storey	2.29	4.69	9.19	13.24
30 Storey	3.19	2.3	6.98	10.05
Ultimate Value	2.48	4.24	9	12.96

6. Conclusion

Application of SPSW as a lateral load-resisting system entails the recognition of seismic parameters derived from rigorous analyses. In this study, three RC buildings equipped with SPSW comprised of 7, 15, and 30 stories were analyzed and designed and, then, their seismic parameters were obtained using nonlinear static and dynamic as well as Ida analyses under 10 near and far-field earthquakes.

The results indicated that response modification factor of 9 for the RC frame equipped with SPSW is adequate. Moreover, the values of ductility and overstrength factors are equal to 4.24 and 2.48. It is notable that further analyses are required to scrutinize these values to be applied in design procedures.