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Investigation of Operation of Link Beam Length in Nonlinear Dynamic Analysis of Steel Plate Shear Walls with Coupling with Rigid Joint

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1. Introduction

Steel Plate Shear Wall (SPSW) has been used as a resisting system against the lateral loads in the construction of new buildings and strengthening the existing buildings (especially in high-rise buildings) within the four recent decades in North America, Canada and Japan. This system has an appropriate stiffness for controlling the structural deformation and because of its ductile failure mechanism, the energy dissipation is high. Due to architectural considerations, the SPSW system is typically located around the core and two SPSW systems get together partly because of the openings in the core. On the other hand, given that the American Regulation has limited the steel shear wall ratios to number 2.5, designers use a simple span beside two SPSWs, similarly, these two walls are connected by a link beam at each floor level.

2. Analysis and modelling of structural assumptions

Nine Coupled Steel Plate Shear Wall frames with a thin plate of rigid connection each with seven spans and different length of link beam, were modeled by using tape model in which the plan geometry used in the present research was based on the plan of the square.

In these samples, the width of the shear panels was 2.5 meters and their length varied from 1.25, 2.5 to 3.75 meters and the width of the side spans was 6 meters on each side. The frames assumed in the three buildings were 3, 10 and 15 floors with the height of 3 meter. Loading of samples was in accordance with the ASCE. The intensity of live and dead loads of floors and roof was considered to be 600, 500, 200 and 150 kg/m^2, respectively, and lateral force distribution of the building was done based on Iranian Earthquake Standard 2800 assuming terrain type 3 and based acceleration scheme of 0.35. in modeling steel ST37 with Poisson's ratio of 0.3 and elasticity modulus of 210 GPa was used.

3. Model verification and calibration

To calibrate finite element models of a thin plate three-story SPSW which has been tested in 2007 by Gholhaki was used. The mentioned wall had rigid connections in the plate of panels and columns, thus soft and high-strength steel has been used in the plates and the columns. The outline and the dimensions of the beam and column of SPSW are shown in Fig. 1 and the mechanical properties of the used components are shown in Table 1. The σ_0 and E are yield stress and modulus of elasticity, respectively.

In this research, a finite element (FE) model for the C-SPSW specimen was constructed using the commercially available ABAQUS finite element software package. The majority of this FE model, including the infill plates and the boundary elements, were constructed using the 4-node, quadrilateral, stress/displacement shell elements with the reduced integration and a large strain formulation (ABAQUS S4R Element). Shell S4R elements were also used in the modeling. For simplicity, two linear plasticity models with kinematic hardening and the Von-Mises function were used. The slope of the hardening part in stress-strain curve was considered to be 3% of the elastic part and we usedthe sensitivity analysis and began the buckling of diagonal tension field by applying a 3 mm initial distortion to the middle of the plate. After conducting sensitivity analysis, a mesh size of 10 cm was used.

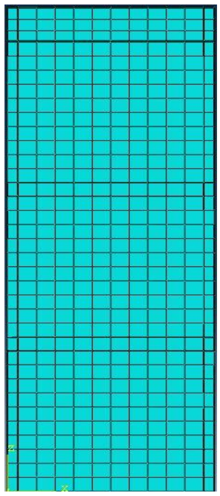

Fig. 1 Overview and details of laboratory sample

Table 1 The mechanical properties of SPSW specimens

Members	$\sigma_0 (N/mm^2)$	$E (kN/mm^2)$
Plate	180	206
Column	366	206
Central beams	310	206
Upper beams	366	206

4. The study of nonlinear dynamic response (Time History)

In nonlinear time history analysis, structural behaviour was observed partialy during earthquakes and this behaviour represents the more realistic behavior of structure during an earthquake than the other analyses. In this analysis, the effect of frequency content, the maximum acceleration and the effective duration of

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earthquake was well observed and it was identified how two different earthquakes with identical maximum acceleration have different destructive effects of on a structure. According to the Iranian 2800 standard, the accelerograms that are used in determining the movement of the earth should represent the actual movement of the ground during an earthquake as much as possible. The duration of strong ground motion in accelerograms is at least 10 seconds or three times the original period of construction, whichever is greater, shall be chosen. In this paper, according to Iranian Earthquake Regulations 2800 and assuming the soil type 3 and reviewing the accelerograms, finally three Northridge earthquake, Tabas (Iran) and Loma Prieta (California, America) were selected and all accelerograms to 0.35g scale and characteristics of these earthquakes can be seen in Table 2.

Iranian 2800 standard was used in order to scale the accelerograms such that after scaling the accelerograms to their maximum value, the acceleration response spectra of each pair of scaled horizontal accelerograms were obtained by considering the 5% damping with SeismoSignal software. After combining the response spectra, each pair of acceleration averaged with square root method, should be compared with the standard design spectrum at interval periods of 0.2T and 1.5T. In order to review the within period intervals, the main period of structure should be obtained. Thus, the main period of structure was obtained using modal analysis which can be seen in Table 3.

5. The nonlinear dynamic analysis

After creating the models in the ABAQUS software, models were analyzed by nonlinear dynamics, then the shears, drift and DC of the models were obtained. Therefore, first of all base shear was calculated and then the drift of floors results were obtained, and at the end DC was studied.

6. Conclusion

In this study the behavior of coupled steel plate shear wall with beam connections to the rigid column was investigated by the use of nonlinear dynamic analysis. Thus, three C-SPSWs with 3, 10 and 15 story, were examined in models at three link beam lengths of 1.25, 2.5 and 3.75 meters. The samples of Northridge, Loma Prieta and Tabas earthquakes were analyzed and their base shear, drift, structure period, the degree of coupling were evaluated. The results showed that increasing the length of the link beam in coupled steel plate shear wall increases the structure's period, drift and reduces the base shear. The results also showed that increasing the length of the link beam has additive and subtractive effects on the degree of coupling. By the increase at the link beam length, at one-third middle height of the buildings, from medium height buildings to the high-rise buildings, the shear decreases and by increasing the height of structures the shear increases. In the Northridge earthquake, in 65% to 80% by changing the height of the strucure of short height to medium height, the height of the drift lowers and in 40% to 50% by changing the height of struvture from medium to high, the drift increases. In the 1.25m link beam, by increasing the number of floors ,the degree of coupling reduces. In the 2.5m and 3.75m cases, with increasing the number of floors, the degree of coupling increases.

Table 2 Characteristics of the selected earthquake

Row	Name of Earthquake	Year	Station	Soil	Distance	PGA (M/S^2)	$\triangle T$	Effective Duration	Selected Interval
1	Northridge	1994	CDMG 13122	3	82.3	0.104	0.02	10	21-11
2	LomaPrieta	1989	CDMG 58223	3	72.2	0.329	0.05	11	20-9
3	Tabas	1978	FERDOWS 71	3	91.1	0.107	0.02	26	36-10

Table 3. The main period of each structure based on modal analysis of 3, 10, and 15-story models

Row	Model - length of link beam	Period	0.2T	1.5T
1	3 story-1.25 m	0.3035	0.0607	0.455
2	3 story-2.5 m	0.3127	0.063	0.469
3	3 story-3.75 m	0.3216	0.065	0.489
4	10 story-1.25 m	0.722	0.144	1.083
5	10 story-2.5 m	0.759	0.152	1.183
6	10 story-3.75 m	0.8378	0.168	1.257
7	15 story-1.25 m	1.167	0.233	1.751
8	15 story-2.5 m	1.27	0.254	1.905
9	15 story-3.75 m	1.38	0.276	2.07