A Study on Soil-Structure Interaction on Seismic Response of Coupled Steel Plate Shear Wall subjected to Near and Far-Field Earthquakes

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Abstract:
Coupled steel plate shear wall (C-SPSW) is a relatively new system that has received less attention from research centers. This system benefits from a high ductility and stiffness, which are the two advantages that make this system superior to the other lateral load-resisting systems. This paper aims to study seismic response of the CSPSWs under near and far-field earthquakes, resting on soil types II and IV considering soil-structure interaction (SSI) effects using the 5, 10 and 15-storey frames in which length of link beams and frame bays is equal to 1.25, 2.5 and 3.75 as well as 2.4, 3.2 and 4.8m, respectively. Based on the analysis results, maximum roof displacement of the 5, 10 and 20-storet frames located on stiff soils (soil type II), does not experience remarkable changes under near and far-field earthquakes but to the contrary, in the case of soil type IV, changes are considerable. Roof acceleration of the structure located on stiff soil, is less than that of the structure on soft soil. In this paper, ratio of base shear to effective weight of the structure was taken into account and it was found that incorporation of SSI effects influences the base shear. Moreover, regarding behavioral modes of the coupling beam and coupling degree of the SPSW, the results indicated that this degree has a meaningful correlation with fundamental period of the structure and the short coupling beams that yield in shear, have a better performance.

Keywords: Coupled Steel Plate Shear Wall (CSPSW), Soil-Structure Interaction (SSI), Near-Filed Earthquake, Far-Field Earthquake, Degree of coupling.

1.Introduction

Steel plate shear walls (SPSWs) have been widely used both in the construction of new buildings and in strengthening of the existing buildings worldwide, especially in earthquake-prone countries, due to their excellent behavior and benefits. This system benefits from an appropriate stiffness to control deformation and has a ductile failure mechanism and high energy dissipation capacity [1]. In the case of tall buildings, huge forces are developed in the columns, which causes the bending lateral displacements to dominate and drift values prevail in the process of structural design. In order to reduce large displacements, various structural systems such as the coupled steel plate shear wall (CSPSW) system have been developed. This system consists of a pair of SPSWs that are connected to each other at the level of each floor by a coupling beam [2]. On the other hand, the near-fault earthquakes are different from the far-fault ground motions. Therefore, it is necessary to study and recognize characteristics and nature of near-fault records and their impact on structures. In addition to earthquakes, underlying soil can also cause changes in structural responses, especially if the structure is built on a soft stratum. Typically, in the codes and standards, the methods used to analyze the structures assume that the soil under the structure is rigid and the effect of the soil-structure interaction (SSI) is neglected. Indeed, the soil is not really rigid and its presence changes dynamic properties and responses of the structure. On the other hand, placement of relatively rigid foundation of the structure in the soil changes the input excitations arriving at the soil-structure system. Hence, the SSI effects should be taken into account while designing the structures.

2. Numerical Modeling Verification

In order to verify the numerical modeling process, specifications of the SPSW model were selected from the experimental study of two three-story structures conducted by Gholhaki and Sabouri in 2008[3]. In this experimental study, two three-story structures equipped with SPSW system with scale of 1/3 were tested under cyclic loading. The mentioned walls had two types of beam-column connection, rigid (SPSW-R) and simple (SPSW-S) and for the plates and columns, mild steel (energy absorbing steel) and high strength steels were used, respectively. Figure (1) shows an overview of the specimen. The modeling process in SAP2000 software is such that first a model with the specifications of Figure 1 and Table 1 is designed according to Figure 2 and then, the diagonal elements that are used instead of steel shear wall are taken into account. According to AISC provisions, the plastic hinges of the SPSW are assigned and finally the load-displacement curve of the model designed in the software is compared with the experimental results. The beam-column connections are rigid and connection of SPSW to the surrounding beams is pinned.

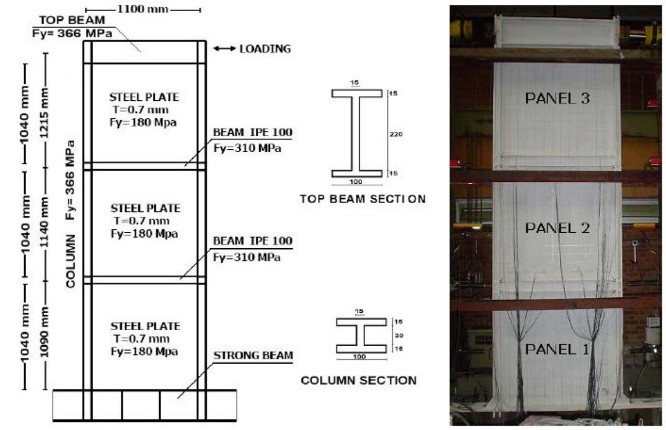

Figure 1: Section Properties and Dimensions of Numerical Model [3]

Table 1: Mechanical Properties of Structural Elements in SAP2000[3]

Section	$F_y(N/mm^2)$	$E(KN/mm^2)$
Plate	180	206
Column	366	206
Beam	310	206
Top Beam	366	206

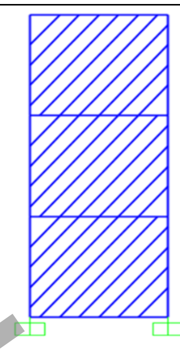

Figure 2: The model designed in SAP2000

To validate the models, the rigid connection of the beam to column has been used and also, nonlinear static analysis (Pushover) has been performed through a displacement control loading protocol using a triangular force distribution pattern. In this method, the applied load is gradually increased until the displacement of the specified point reaches the intended value. After analysis, since in the experimental results, displacement of the first story was used as a basis, displacement of this story along with the base shear was extracted from the software and plotted as a load-displacement curve, and then, this curve was compared with the experimental load-displacement curve extracted from the hysteresis curves. Figure 3 illustrates a comparison between the numerical and experimental load-displacement curves.

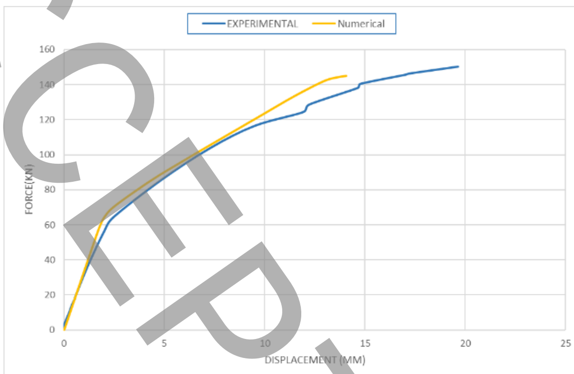

Figure 3: Comparison between Numerical and Experimental Load-Displacement Curves

3. Results

in stiff soils, the roof displacements in the case of fixed base and flexible bases are not different and the SSI can be ignored during design but for design of structure resting on soft soils, SSI effects have to be taken into account. Soil-structure interaction is faced a decrease in structural acceleration subjected to the average near and far-fault records, compared to a fixed base. In addition, as per increase in length of the coupling beam (length of SPSW is constant), acceleration of structures increases under the average near and far-fault earthquakes. changes in the ratio of base shear to effective weight of the structure of all structures have increased in comparison between the fixed and flexible bases under the earthquakes near the stiff soil sites. As the length of the span length increases, the base shear of the structures decreases. Respectively. most of the coupling beams are in a shear mode (which is a suitable behavior) indicating the fact that as aimed in design process, the steel plate has entered into its plastic range of behavior and the other elements remain elastic. Due to presence of coupling beams, a greater share of the story shear is undergone by the frame surrounding the steel plate. Thus, the steel plate has withstood less share of the lateral load and will require a smaller thickness. As thickness of the steel plates decreases, story beams need to be sufficiently strong to resist the tension field. Moreover, when span length of the shear walls increases (length of coupling beam is constant), energy absorption capacity of the structure increases and drifts are reduced.

4. conclusion

This paper deals with the SSI effects on seismic behavior of the CSPSW systems in 5, 10 and 20-storey structures with coupling beam lengths of 1.25, 2.5 and 3.75m and span lengths of 2.4, 3.2 and 4.8m. accordingly, the structures were subjected to seven near and far-fault earthquakes and are assumed to be located on soil types II and IV.

As per increase in length of the coupling beam when length of the SPSW is constant, drift and fundamental period of the structures increase, base shear and degree of coupling are reduced. Moreover, length of the coupling beam majorly affects ductility of the structure.

Use of the CSPSW illustrated that this system compared to the SPSW, is of greater stiffness and even following increase in span length of the SPSW while coupling beam is constant, base shear increases and drift are reduced.

Determination of the degree of coupling of the CSPSW considerably affects design process of the structures. Energy absorption of the coupling beams that are yielded in shear, is more appropriate because in shear mode, whole of their capacity is exploited. Moreover, stiffness of the coupling beam markedly affects fundamental period of structures and degree of coupling.

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