Effect of soil-structure interaction on the seismic performance of structures designed by ASCE7-16

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INTRODUCTION

In classical methods of design and analysis of structures, the motion at the foundation level of the structure is assumed to be equal to the free field motion (FFM). This assumption is correct only for the structures resting on rock or very stiff soils because the motion will transmit from the source to the structure without any significant variation. In contrast, for other field characterization or ground conditions, soil structure interaction (SSI) could have a significant effect on the FFM.

OBJECTIVE

Investigate the importance of considering fully non linear SSI effect on the seismic response of moment resisting frames (MRF) designed according to ASCE 7–16.

METHODOLOGY

1) STRUCTURE

The buildings were assumed to be located in a high seismicity area and designed in accordance with ASCE 7-16 by using the Visual Analysis 18 software. The structures have ten levels with a story height of 3.5 m for all the stories. ASCE 7 uses a risk-targeted design philosophy for seismic hazards. The site soil condition is Class D, and the seismic hazard building risk category is D based on the spectral response acceleration parameters using S_S=1.026 and S_1=0.357. The permissible drift was limited in the designs to the story height, h_{sx}, divided by 50

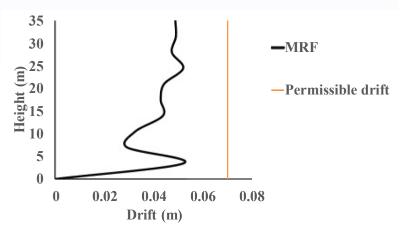

Fig 1. Allowable drift check

2) SOIL PROFILE

A clayey soil profile was adopted in this study. The shear wave velocity V_{S30}, was 250 m/s, which classifies as Site class D according to ASCE7-16. The properties are adopted from Faris and Alba (2000) based on an actual site in order to make the analysis more representative of reality as shown in Table 1.

Table 1. Soil properties adopted for the investigation.

Site class	(V_{S30}) (m/sec)	G_{max} (kPa)	Plasticity Index PI (%)	Liquid Limit LL (%)	Friction angle Φ' (deg)	Cohesion, c' (Kpa)
D	250	124063	18	40	24	65

3) GROUND MOTIONS

For dynamic analysis of the structures, ground motion records must be selected to represent the possible earthquake at the site. To obtain these motions, a best fit between the ground motion spectra to the code-specified design spectrum should be accrued. The numerical measure of the best fit between the ground motions to the design spectra is the Mean Squared Error (MSE) (NIST 2011) or the mean-square-difference parameter, DRMS, (Katsanos et al. 2010). Four ground motion records are chosen with small values of DRMS for use in this study. The table shows the basic properties of the applied motions.

Table 2. Properties of the ground motions

Event	Year	Station	Mag. (M_W)	R (km)	S.F
Chi-Chi, Taiwan	1999	ILA067	7.6	33.27	1.697
Irpinia, Italy-01	1980	Rionero In Vulture	6..9	27.49	3.175
Chuetsu-oki, Japan	2007	Nadachiku Joetsu City	6.8	35.79	2.165
Chuetsu-oki, Japan	2007	Kawaguchi	6.8	23.63	2.094

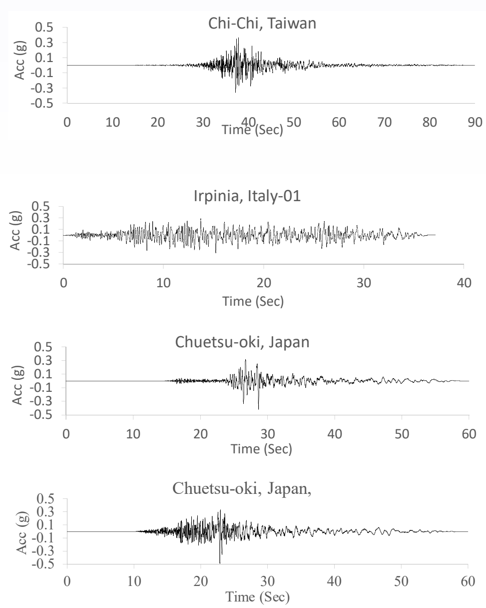

Fig 2. Acceleration time histories for the four selected ground motions

CHARACTERISTICS OF THE SSI MODELS

In this study, the direct method of 2D soil structure interaction analysis is applied to study the elastic response of the structure using FLAC2D software. The dynamic response of both fixed and flexible base structures are investigated, the elastic model of the soil was considered. Figure 3-a. In the fixed base case, the ground motion is applied directly at the base of the structure. The second case considers a flexible base, and the system is modeled by the combination of the two-dimensional structure represented by beam elements and connected by interface elements to the two-dimensional plane strain grid elements that represent the soil domain, homogeneous medium of 30 m over the bed rock (Figure 3-b). the foundation is discretized for the 2D system with a 12.5 m width, 25 m length, 1 m depth.

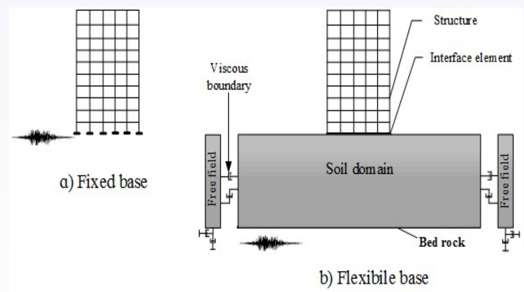

Fig 3. The models of the structures a) fixed base and b) flexible base considering the soil beneath the structure

RESULTS AND DISCUSSION

Results in terms of drift from the analyses are performed for the right edge of each structural frame. inter-story drift have been calculated using the following equation:

$$\mathbf{drift} = (\mathbf{d_{i+1}} - \mathbf{d_i})$$

Figures 4 and 5 show the results under all motions.

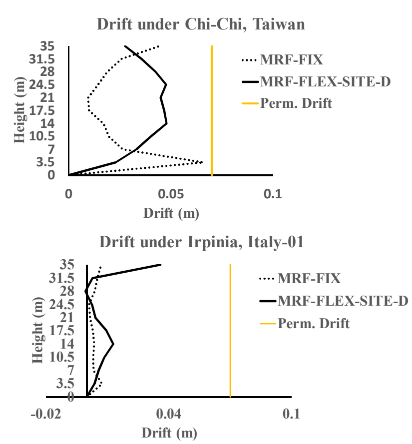

Fig 4. Drift of the structures under Chi-Chi, Taiwan and Irpinia, Italy

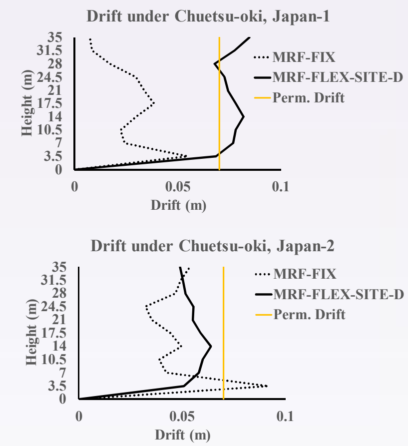

Fig 5. Drift of the structures under Chuetsu-oki, Japan-1 and 2

The average ratio of the drift was calculated as shown in Figure 6.

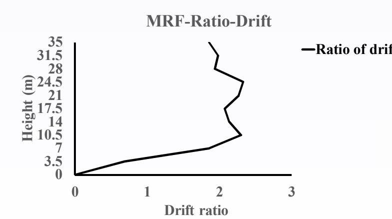

Fig 6. The ratio of the drift

CONCLUSION

1. The inter-story drift increases under the effect of SSI compared to the fixed base case, indicated by an average drift ratio of almost two when flexible and fixed base are compared.
2. The seismic performance of the models designed with site class D have been effected considering SSI with site class D, the performance exceed the acceptable drift depends on the kind of the motion(i. e. Chuetsu-oki, Japan-1) .

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ACKNOWLEDGEMENTS

The authors gratefully acknowledge the HCED in Iraq