Evaluation of fragility curves of Asymmetric-Plan Reinforced Concrete Structures in the Near-fault Earthquakes under the Effect of Torsion Considering Soil-structure Interaction

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ABSTRACT

In this study the life safety and immediate occupancy of asymmetric-plan reinforced concrete dual structures under the simultaneous effect of torsion and soil-structure interaction in the near-fault pulse-like earthquakes were evaluated using a probabilistic framework. An 8-story R/C dual lateral load resistant building consisting of shear walls and moment resisting frames was used. Sub-structure method was used to simulate the SSI effect. The impedance functions were calculated with the Novak semi-analytical method (DYNA5 software). The structure was modelled in the CANNY software considering the nonlinear behavior to perform the nonlinear time history analysis. All of the ground motion records were selected from the near-fault pulse-like records. Incremental Dynamic Analysis was employed to extract and fragility curves. To determine the life safety and immediate occupancy limit states, the strain of steel and concrete (as a micro index) were used rather than the usual macro indexes such as story drifts that lead to increase the accuracy of results. One of the most important of conclusion is that neglecting the SSI effect in the life safety and immediate occupancy limit states for the plan-asymmetric structure is not in the safe side and lead to over estimation in the structure capacity. Also an increase in the mass eccentricity lead to the decrease the base conditions importance and SSI effect. Other considerable observation is that an increase in the shear wave velocity of soil can lead to the decrease in the torsional response and the seismic response of asymmetric structure approaches to the symmetric one.

KEYWORDS

Plan-asymmetric structures, soil-structure interaction (SSI), Life safety, Immediate Occupancy, Near-fault pulse-like earthquakes.

1. Introduction

Real structures are not usually plan-symmetric and fixed base; therefore, the torsion and the soil-structure interaction are two inevitable phenomena that must be considered in the seismic evaluation of structures. In the past studies [1, 2], these two effects were investigated separately, but in this paper, a probabilistic assessment of torsional effects and soil-structure interaction is targeted simultaneously. In this study the the life safety and immediate occupancy of asymmetric-plan reinforced concrete dual structures under the simultaneous effect of torsion and soil-structure interaction (SSI) in the near-fault pulse-like earthquakes were evaluated using a probabilistic framework.

2. Methodology

An 8-story R/C dual lateral load resistant building consisting of shear walls and moment resisting frames was used. The plan of this asymmetric structure is shown in Fig.1.

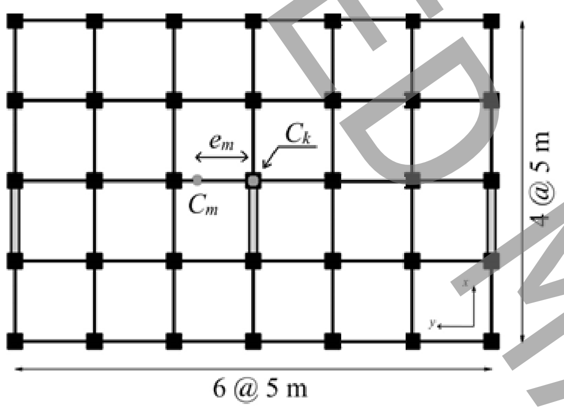

Fig. 1. Plan of the asymmetric structure [1]

Sub-structure method was used to simulate the SSI effect. The impedance functions were calculated with the Novak semi-analytical method (DYNA5 software) [3]. The structure was modelled in the CANNY software [4] considering the Nonlinear behaviour to perform the nonlinear timehistory analysis. For the beams, the moment-curvature model is used at the ends to model the plasticity of beams. For the columns and shear walls because of the presence of axial forces and bi-axial bending moments, the fiber model (multi-spring model) that incoroporate the axial forces and bi-axial bending moments employed.

All of the ground motion records wree selected from the near-fault pulse-like records. Considering the fact (past studies showed) that for T_P/T_1 ratio (T_P is the period of the largest velocity pulse and T_1 is the fundamental natural period of the structure) greater than two, an increase in Tp does not significantly affect the probability of structural collapse and Considering the periods of structures, 10 records have been selected. Other criteria that considered are: (1) the Rrup (the closest distance to co-seismic rupture) is less than 13 km; (2) Moment magnitude (Mw) is greater than 6.5; (3) To simulate the more realistic conditions of the soft soil for SSI effects, the site shear wave velocity ($V_{s,30}$) of the selected ground motions is limited to the 350 m/s (the $V_{s,30}$ is the average shear-wave velocity over a subsurface depth of 30 m).

Incremental Dynamic Analysis (IDA) was employed to extract and fragility curves. To determine the life safety and immediate occupancy limit states, the strain of steel and concrete (as a micro index) were used rather than the usual macro indexes such as story drifts that lead to increase the accuracy of results. In this approach, for the immediate occupancy limit state the steel strain and concrete strain was limited to $\varepsilon_{L \cdot S} = 0.015$ and $\varepsilon_{L \cdot C} = 0.004$ accordingly. Also for the life safety limit state the steel strain and concrete strain was limited to $\varepsilon_{L \cdot S} = 0.6\varepsilon_{su}$ and $\varepsilon_{L \cdot C} = 0.018$ accordingly [5].

3. Results and Discussion

The fragility curves were extracted using Intensity Measure (IM) directly (IM-based) with the Log-Normal distribution assumption. The Spectral Pseudo-Acceleration of the first mode of the structure with 5% modal damping ($S_a(T_1, 5\%)$) is selected as Intensity Measure (IM). For example, two cases of fragility curves are shown in Figure 2 and 3.

4. Conclusions

One of the most important of conclusion is that neglecting the SSI effect in the life safety and immediate occupancy limit states for the plan-asymmetric structure is not in the safe side and lead to over estimation in the structure capacity. Also an increase in the mass eccentricity lead to the decrease the base conditions importance and SSI effect. Other considerable observation is that an increase in the shear wave velocity of soil can lead to the decrease in the torsional response and the seismic response of asymmetric structure approaches to the symmetric one.

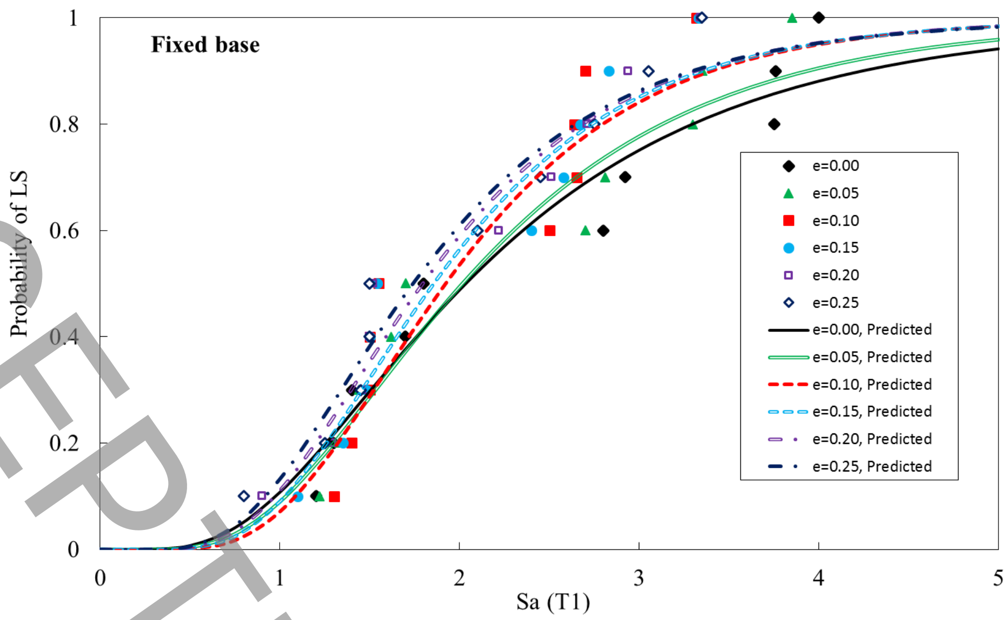

Figure 2. An example of a figure Fragility curves of the fixed base structure for the LS limit state

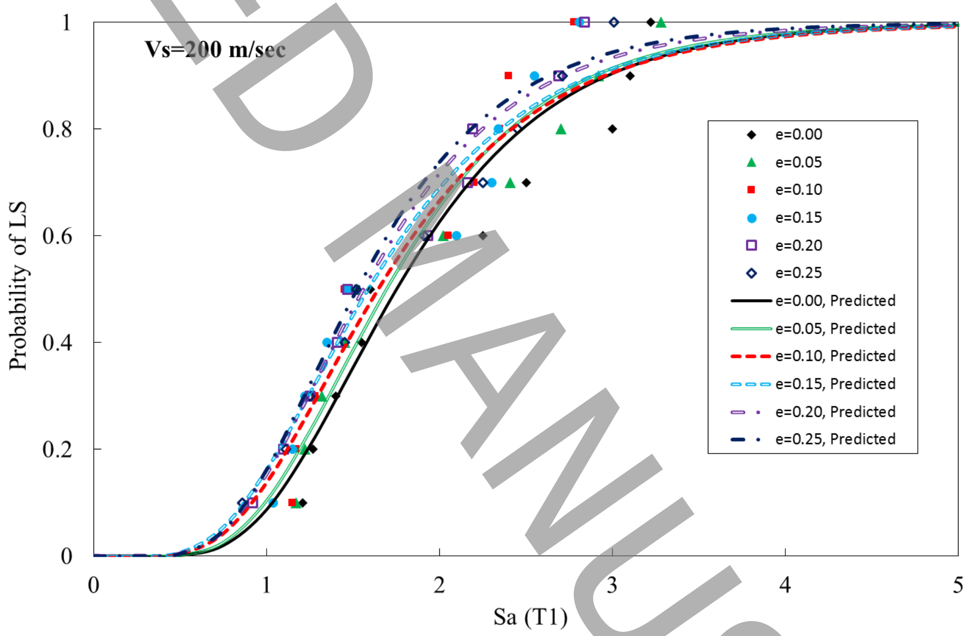

Figure 3. Fragility curves of the flexible base structure (Vs=200 m/s) for the LS limit state

5. References

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