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Seismic response of RC frame building with soft first storey considering Soil Structure Interaction

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Abstract
Earthquakes are one of the most unpredictable and devastating natural hazards causing large economic loss, property and population loss. Nepal is one of the most earthquake prone country. The Bureau of Crisis Prevention and Recovery of the United Nations Development Program ranks Nepal 11th for earthquake risk in the world. With rapid urbanization and increase in the price of land, there has been an increasing tendency in the construction of open ground storey buildings to meet the functional needs of vehicle parking, shopping stores, vehicle showroom etc. The conventional design procedure treats the infill wall as non-structural member and hence is ignored in the modeling. But the recent amendment in IS code has accepted the need to model the infill walls. The conventional design procedure also usually assumes fixity at base of foundation neglecting flexibility nature of soil. But the response of structure resting on flexible medium will be different from the fixed base condition due to interaction between soil and structure commonly referred as soil-structure interaction (SSI). SSI if neglected in analysis and design of structure, may lead to unsafe design.

Keywords
Soil-Structure Interaction – soft storey – infill walls

1. Introduction

Civil engineering structures when subjected to external forces, such as earthquakes, the structural displacements and the ground displacements are dependent on each other. The process in which the response of soil influences the motion of structure and motion of structure influences the response of soil is termed as soil-structure interaction SSI [1]. Conventional structural design methods neglect the SSI effects. Neglecting SSI is reasonable for light structures in relatively stiff soil. However, the effect of SSI, becomes prominent for heavy structures resting on relatively soft soils.

Kathmandu valley falls in one of the most active tectonics zones of the Himalayan belt and has experienced many recurring destructive earthquakes in the past. Due to recent Gorkha earthquake Kathmandu valley suffered major damages of lives and properties and it was observed that some pocket areas within the Kathmandu valley faced major damage. It was also observed that the soft storey failure was the common failure of RC frame structures [2]. The geology of Kathmandu valley makes it very much vulnerable to extensive earthquake damage. Several studies reaffirm the fact that comparatively heavy earthquake damage in the Kathmandu valley is associated with the valley ground structure. Hence, SSI must be considered for the structures being constructed in Kathmandu valley. In this study, the analyses of the structures were done to study the effects of SSI on seismic response of RC frame building with soft first storey using the soil properties of Sankhu site and Balaju site where major soft storey damaged have been observed during the Gorkha earthquake.Equivalent single diagonal strut method based on IS 1893 (Part 1): 2016 was adopted to model the infill walls. In this method, the brick infill is idealized as a pin jointed diagonal strut to RC frame. The masonry infill is modeled as a diagonal strut member whose length is equal to the diagonal length between compression corners of the frame. For the modeling purpose, modulus of elasticity of masonry infill was taken as 2255 N/mm2 and poisson's ratio of 0.15 was considered.

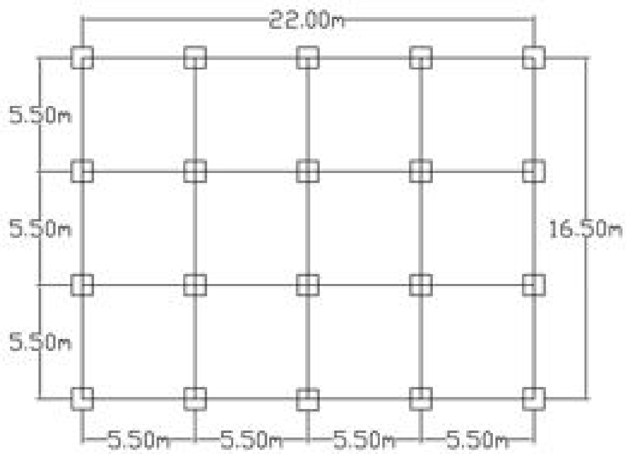

Figure 1: Figure 2: Plan of the building used for the analysis

2. Objective and Methodology

Three models: bare frame model, open ground storey model and fully infilled model with same plan but different elevations (5-storey and 10-storey) were selected and analyzed. To study the linear and non-linear responses of the structures, the models were developed in SAP2000 software. The storey height as well as length of each bay of the building frames was chosen 3.2 m and 5.5 m respectively. Longitudinal Direction consisted of four bays whereas Transverse Direction consisted of three bays as shown in Figure 2. Materials used in modeling was M30 grade of concrete for beam and columns and Fe500 grade of rebar material for longitudinal bars and Fe 415 grade of rebar material for confinement bars and slab. Similarly, the thickness of the floor slab and roof slab was taken as 175 mm. Size of beam was taken as 230*350 mm for 5-storey building and 350*500 mm for 10-storey building. Size of column was taken as 400*400 mm for 5-storey building and 500*500mm for 10-storey building.

3. Building Description

Static live load of intensity 1.5KN/m2 on roof slab and 3KN/m2 on all other slabs is applied to all models. Floor finish of 1.125 KN/m2 is applied. Wall loads, partition wall loads and staircase loads were converted to uniformly distributed load and assigned to beam members. The dead load of beam, column and slab was calculated by the program itself. Both static and dynamic seismic loading on the structure is considered. To perform pushover analysis, plastic hinges were defined in both beams and columns. The hinge type for both beam and column were selected according to FEMA 356. New analysis case for pushover analysis was created in SAP2000, in which nonlinear pushover analysis was done using nonlinear dead load case. Displacement control multi-step pushover analysis was performed.The underneath soil was modeled by Winkler spring approach using the stiffness and damping coefficients as shown in Table 1.SAP2000 models SSI using a one-parameter Winkler soil model [3]. SSI could be modeled by gap (compression-only) link object which prevents the development of tensile forces enabling foundation uplift. Gap objects exhibit nonlinear behavior, and therefore require a nonlinear load case during analysis.

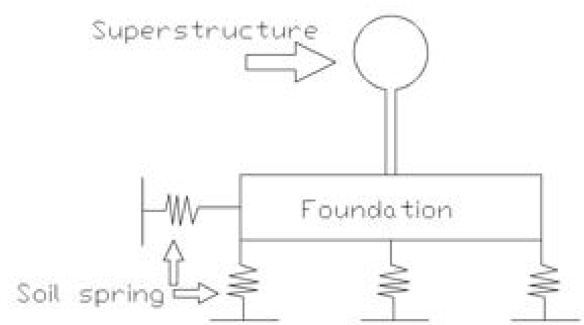

Figure 2: Schematic model of superstructure on a Winkler model foundation

4. Analysis and Result

Pushover Analysis: The capacity curves obtained from pushover analysis along longitudinal direction are shown from Figure 3 to Figure 14 which shows the relationship between structural base shear and top lateral displacement. As the curves show, behavior of fully infilled model is linear under target displacement applied at centre of mass of the building. It is found that capacity curve gets reduced considering the flexibility of soil. This implies capacity is maximum for the structure with fixed base condition. The study reveals that capacity curve of Balaju gets reduced more than Sankhu.

Time History Analysis Ground motion used for time history analysis is synthetic earthquake that consists of a simulated ground motion time history of Lalitpura (developed by Purusottam Karki) whose PGA is 0.4367g. The plot of top storey displacement vs time along longitudinal direction is shown from Figure 15 to Figure 32. The result indicated that top storey displacement is more in bare frame model, intermediate in open ground storey model and less in fully infilled model. It is observed that top storey displacement was more in case of SSI than in fixed base condition. Structure located at Balaju suffered higher displacement compared to corresponding structure located at Sankhu

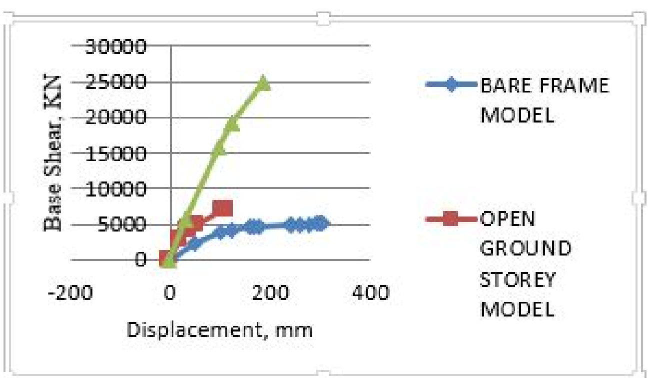

Figure 3: Capacity Curve for five storey building for Fixed Base Condition

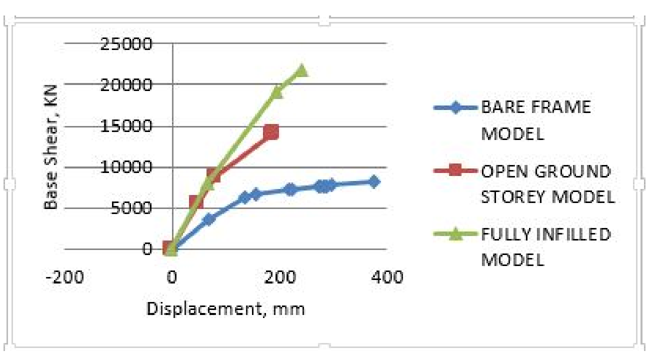

Figure 4: Capacity Curve for ten storey building for Fixed Base Condition

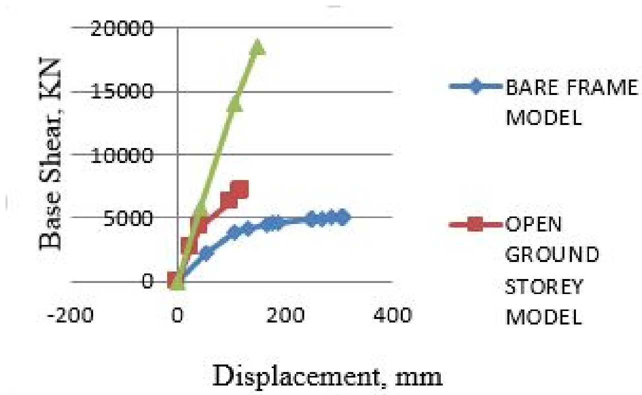

Figure 5: Capacity Curve for five storey building considering SSI at Sankhu

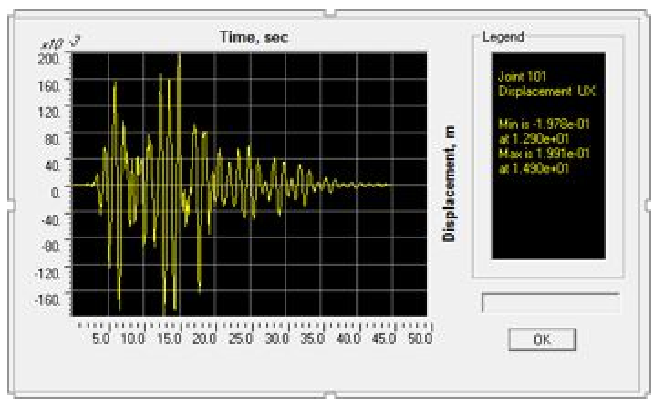

Figure 6: Displacement of top storey for five storey Bare Frame Model due to Lalitpura Earthquake for Fixed Base Condition

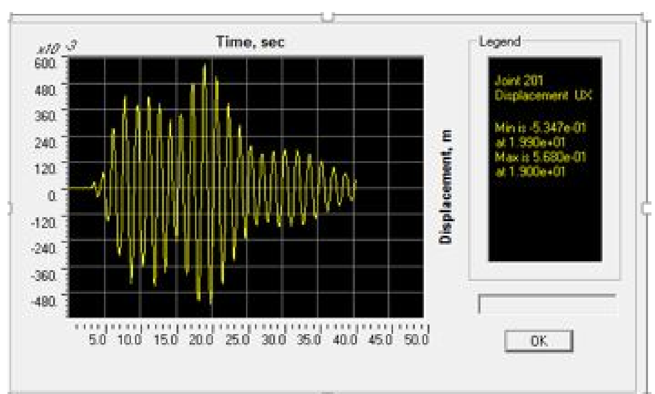

Figure 7: Displacement of top storey for ten storey Bare Frame Model due to Lalitpura Earthquake for Fixed Base Condition

5. Conclusions

The present study is based on the three different models of building: bare frame model, open ground storey model and fully infilled model comprising of five storey and ten storey with and without considering SSI. For this purpose, soil properties adopted were of Sankhu site and Balaju site. The soil properties of Sankhu site consisted of higher shear wave velocity, higher mass density and lower poisson's ratio indicating comparatively stronger soil whereas the soil properties of Balaju site consisted of lower shear wave velocity, lower mass density and higher poisson's ratio indicating comparatively weaker soil. The study shows that the presence of infill walls and SSI affects the time period and base shear of the structure. Presence of infill walls decreases the time-period of the structure whereas SSI increases the time period of the structure. It is observed that time period of bare frame model is maximum whereas the time period is minimum for fully infilled model. It is also observed that the time period of structure located at weaker soil is greater than the corresponding structure located at stronger soil. Base shear of the structure increases due to the presence of infill walls and decreases due to consideration of SSI. Capacity of the structure gets enhanced due to the presence of infill walls. Fully infilled model has the highest capacity whereas bare frame model has the lowest capacity. It is observed that capacity curve gets reduced considering the flexibility of soil. Structure located at stronger soil has higher capacity compared to the corresponding structure located at weaker soil. Time history analysis shows displacement is maximum in bare frame model and minimum in fully infilled model. It is also observed that top storey displacement was more in case of SSI than in fixed base condition. Structure located at weaker soil suffered higher displacement compared to corresponding structure located at stronger soil. It can be concluded that modeling of the infill walls and SSI should be considered to understand the actual response of the structure under seismic loads

References

[1] Massumi A. and Tabatabaiefar H.R. A criterion for considering soil-structure interaction effects in seismic design. *The 14th World Conference on Earthquake Engineering*, 2008.

[2] Khalil et al. Influence of the soil-structure interaction (ssi) on the fundamental frequency of structures. *4th International Conference on Earthquake Geotechnical Engineering, June*, 2007.

[3] Dutta et al. Response of low-rise buildings under seismic ground excitation incorporating soil-structure interaction. Master's thesis, 2016.

[4] Massumi A. *A Criterion for considering soil-structure interaction effects in seismic design*. PhD thesis, 2008.

[5] *Influence of the soil-structure interaction (SSI) on the fundamental frequency of structures*. PhD thesis, 2007.