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Effects of SSI on Dynamic Properties of R.C.C. Building Frame

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Abstract : *An analyst or a designer is mainly concerned with the analysis and design of a variety of structures. All these structures are exclusively supported by soil and hence, the subject of soil-structure interaction has come into existence and has attracted the attention of the analysts for last four-decades. This research intends to investigate the effect of soil-structure interaction on the dynamic properties of three dimensional R.C.C. buildings. This objective is achieved through the analyses of multi-story 3D frames using OpenSees. The results are presented for cohesionless soils with wide range of shear wave velocities and variable-height buildings (3, 7, 10, 14, and 18 floors). The investigated effects are: fundamental time period. Parametric analyses show that SSI alters the buildings performance essentially for stiffer ones (low-raised).*

1. INTRODUCTION

Various researches demonstrated the important effects that SSI has on the seismic response of buildings (Ramadan, Al-Anany and Sanad 2012) and on other large structures such as bridges (Tongaonkar and Jangid 2003) and dams (Burman, Nayak, Agarwal and Maity 2011). These studies included two-dimensional and three-dimensional soil-structure models using either the substructure method or the direct approach. A prevailing common conclusion of all studies is that SSI could produce significant effects on the seismic response of structures: both beneficial and detrimental effects were reported. Nevertheless, utilization of the findings of these research efforts in national and international design codes and in routine design calculations is still very rare if not absent.

In this paper, a common asymmetric 3D R.C.C. frame is investigated to quantitatively assess the effects of soil-structure interaction on the system's dynamic properties and seismic response. To this end, many frames are analyzed via the direct approach of solving SSI problems using SAP2000. The analyzed frames represent buildings with variable heights (3, 7, 10, 14 and 18 floors) built on soils varying from soft to stiff and subject to earthquakes ground motions with different frequency contents and peak ground accelerations. First, the structural model and the applied seismic ground motions are briefly described. Then, the effects of SSI on the fundamental time period of the building is discussed. The paper then ends with the major findings of the study.

2. MODEL DESCRIPTION

Several three storeyed, seven storeyed, ten storeyed, fourteen storeyed, eighteen storeyed space frames resting on pile foundation embedded in different types of soil were analyzed and subsequently, a parametric study was carried out. Based upon the finite element formulation presented below and the features thereof, the program OpenSees was used for the purpose of parametric study and analysis.

The model consists of 3 bays in X-Direction and 2 bays in Y-Direction of 6m each. The storey height is 3m. The frame is an open space frame with beam dimensions 0.3m×0.5m and column dimensions 0.45m×0.7m. All elements in the structure use M30 concrete and HYSD Fe415 steel.

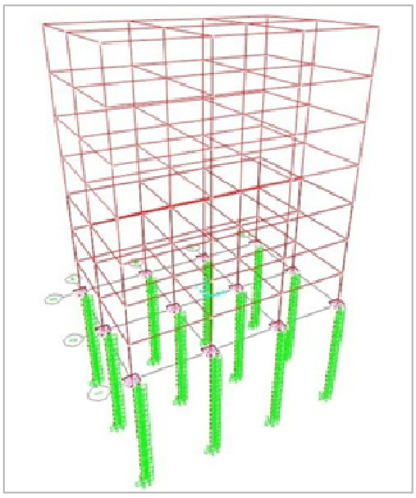

Figure 1: Mathematical Model

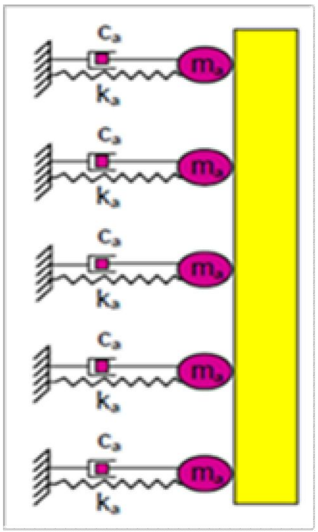

Figure 2: Soil Model

The pile has a circular cross section with 0.5m diameter and has a length of 10m. The pile cap has dimensions 1m×1m×0.5m and is made of concrete. A 7-storeyed building with flexible base is shown in Fig. 1.

Beams, columns and piles were modelled using frame element. Soil model proposed by Gustavo Pacheco, Luis E. Suárez, and Miguel Pando was used for modelling soil. (Pacheco, Suárez, & Pando, 2008).

Soil was modelled as linear compression-tension link element. Soils with shear wave velocity varying from 50m/s to 300m/s with an interval of 25m/s were considered for each multi-storeyed building. A typical soil model is shown in Fig 2.

3. RESULTS

Variation of Shear Wave Velocity: 3-Storeyed, 7-Storeyed, 10-Storeyed, 14-Storeyed and 18-Storeyed models were analyzed with fixed bases and varying shear wave velocities for various pile configurations. The pile configurations considered were Single Pile (SP), Two Piles in Series (2PS) and Two Piles Perpendicular (2PP). The Time Period obtained was graphed against the shear wave velocities considered.

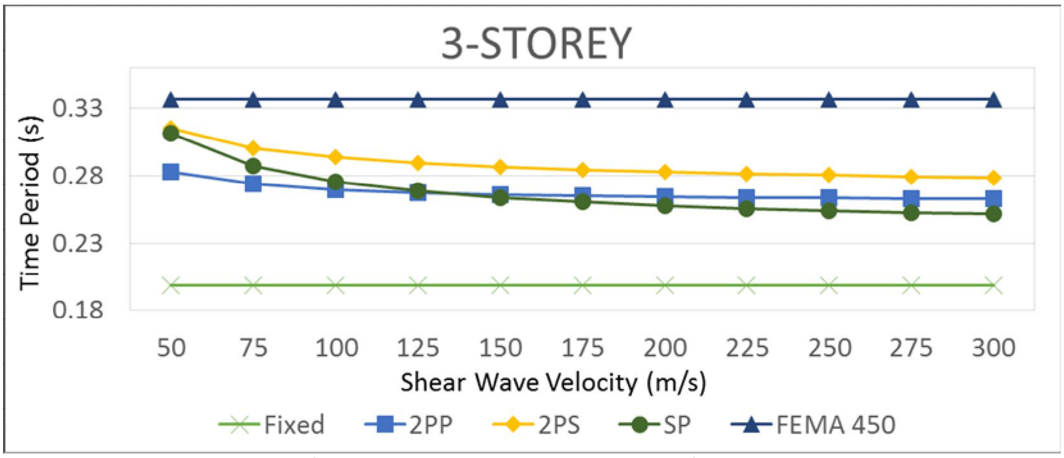

Fig. 3 Variation of T with Shear Wave Velocity (m/s) for 3-Storeyed Structure

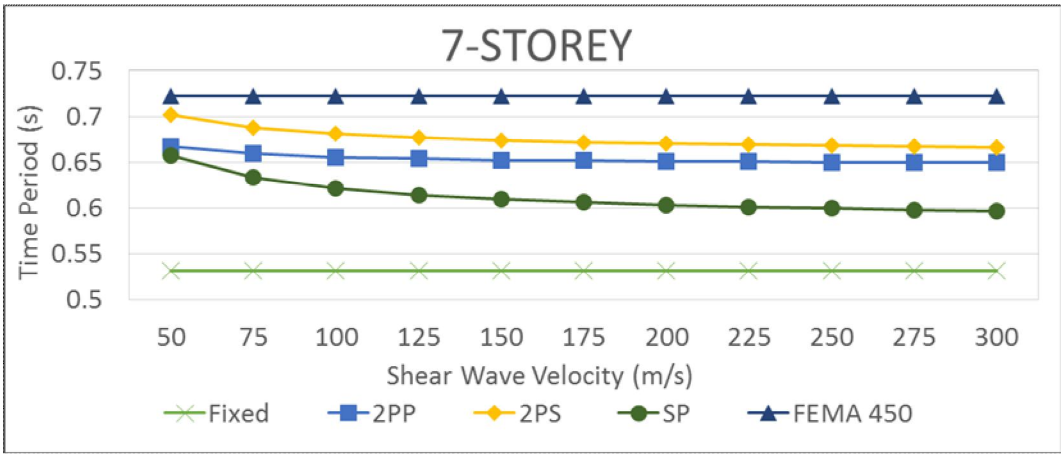

Fig. 4 Variation of T with Shear Wave Velocity (m/s) for 7-Storeyed Structure

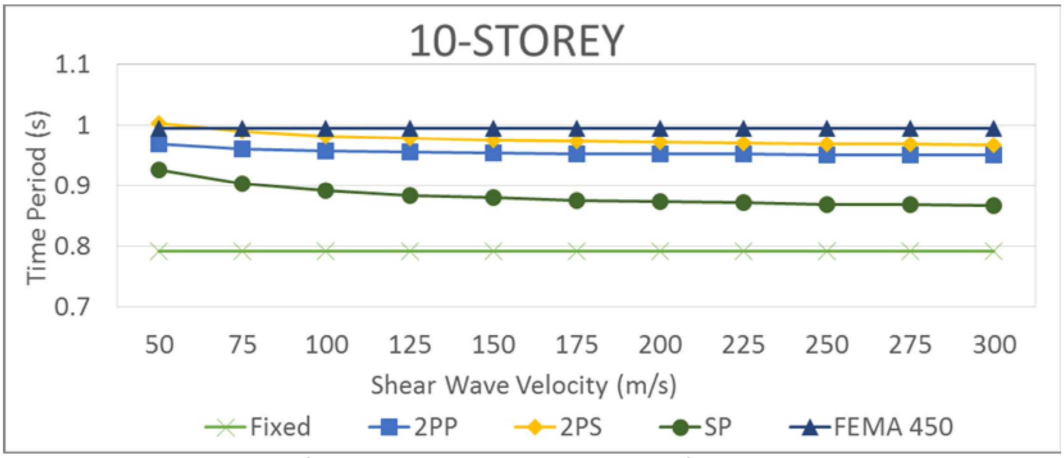

Fig. 5 Variation of T with Shear Wave Velocity (m/s) for 10-Storeyed Structure

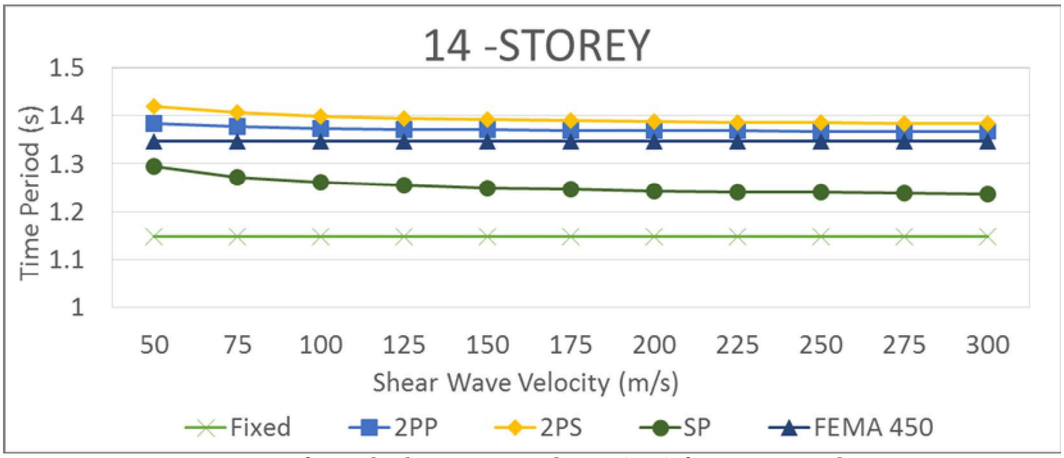

Fig. 6 Variation of T with Shear Wave Velocity (m/s) for 14-Storeyed Structure

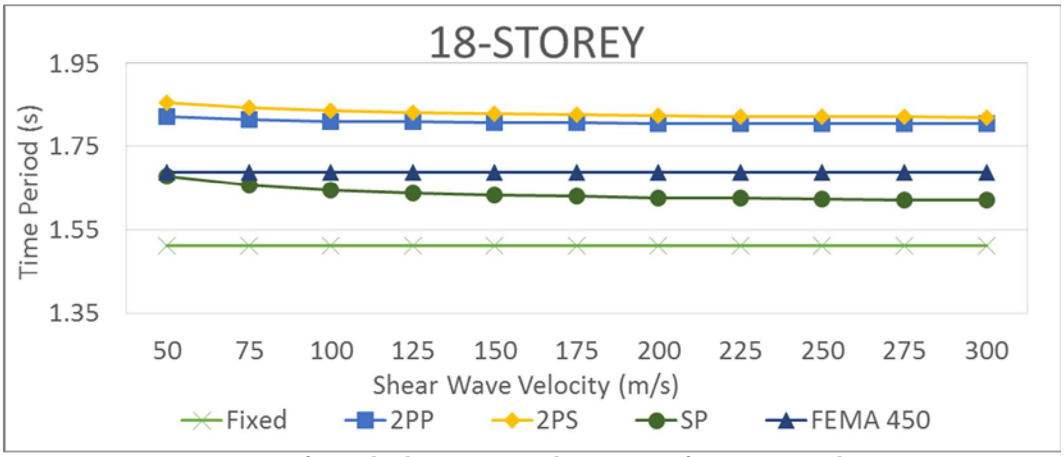

Fig. 7 Variation of T with Shear Wave Velocity (m/s) for 18-Storeyed Structure

The fundamental time period decreased with increase in the shear wave velocity of soil. The variation remained constant for soils with shear wave velocities exceeding 100m/s for a particular configuration.

4. CONCLUSION

i. Single Pile Structures: The increase in Time Period for structures with flexible bases was found to vary from 57% to 27% for 3 storey structures, 24% to 13% for 7 storey structures, 17% to 10% for 10 storey structures, 13% to 8% for 14 storey structures and 11% to 7% for 18 storey structures as compared to fixed base structures for shear wave velocities varying from 50m/s to 300m/s.

ii. *Two Piles (X-Direction) Structures:* The increase in Time Period for structures with flexible bases was found to vary from 59% to 41% for 3 storey structures, 32% to 25% for 7 storey structures, 27% to 22% for 10 storey structures, 24% to 21% for 14 storey structures and 23% to 21% for 18 storey structures as compared to fixed base structures for shear wave velocities varying from 50m/s to 300m/s.

iii. *Two Piles (Y-Direction) Structures:* The increase in Time Period for structures with flexible bases was found to vary from 43% to 33% for 3 storey structures, 26% to 22% for 7 storey structures, 22% to 20% for 10 storey structures, 21% to 19% for 14 storey structures and 20% to 19% for 18 storey structures as compared to fixed base structures for shear wave velocities varying from 50m/s to 300m/s.

iv. The variation in Fundamental Time Period was found to be negligible for shear wave velocities exceeding 100m/s which is consistent with Eurocode 8 (CEN, 2004).

v. For all configurations the variation in time period goes on decreasing with increase in storey height.

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