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Assessment of Reinforced Concrete Building with Soil Structure Interaction Effect under Vertical Earthquake

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Abstract. In past investigation, most of studies on seismic analysis for soil structure interaction effect are small and generally design building were considered to be fixed at their support. In actual condition, flexibility of the bases soil medium were generate some deformation in foundation element and will be shows detrimental effects on the system behavior. This can make a beneficial result on the overall structure response if flexible bases were considered during seismic analysis. The present study attempts to compare the behavior of reinforced concrete medium rise building with soil structure interaction effect and fixed bases under vertical earthquake. The eight-storey irregular 2D frame models were subjected to ground motion from 4 stations with peak ground acceleration ratios vertical to horizontal (V/H) between ranges 0.95 to 1.16. During simulation of simplified model, Impedance Function has been applied to calculate the stiffness of such spring. The structural response quantities were considered displacement histories and axial load variation. The result shows that the consideration of soil structure interaction effect may increase such response behavior.

Introduction

A seismic soil-structure interaction analysis evaluates the collective response of the structure, the foundation, and the geologic media underlying and surrounding the foundation, to a specified free-field ground motion. [1] During numerical model analysis, commonly are assume without considering the flexibility of foundation effects, which overestimates the stiffness of structure. Kim S.J et, al. (2008), performed the effect of vertical ground motion on RC structures studied through a combined analytical-experimental research approach which consider fixed at their support. Analysis results were show that there is no significant change in global horizontal measurements such as lateral displacement or interstorey drift. According to [7], they need to expand their research description to include the effect of soil structure interaction, which may amplify or reduce the effect of vertical motion. Moreover, quantification the effect of vertical motion on the behavior of shallow and deep foundation was needed. Therefore this research was carried out by using computer software to analyze the comparison of structure behavior due to flexibility base (soil structure interaction effect) and fixed base effect with vertical ground motion.

Method Analysis

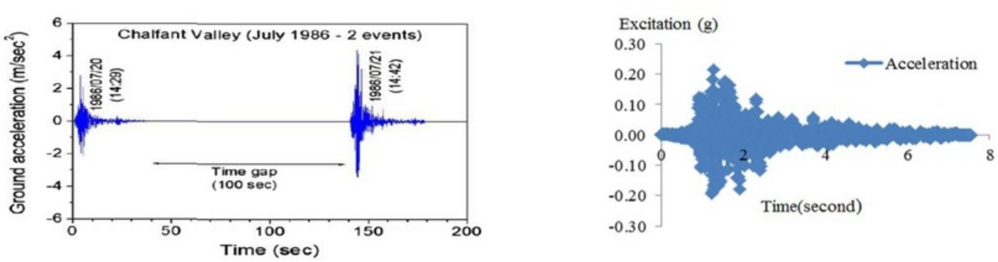
i. Soil Structural Interaction.

Inertial Interaction effects, kinematic interaction effects, and foundation deformation effects were represent the three critical aspects of soil-structure interaction (SSI) effects.[3] Inertia from vibration

of structure was cause base shear and moment which were produce displacements and rotations at the soil-foundation interface. Displacement and rotation due to flexibility of the support was decrease the overall stiffness of structure frame, at the same time will increase the natural periods of the building system. Moreover, these can introduce to energy dissipation via radiation damping and hysteretic soil damping, which affect the system damping. The stiff foundation elements setting at or below the ground surface due to incoherent ground motion will be affect base slab averaging. These ground motion will be reduction with depth of base slab. The phenomena are knows as kinematic interaction

ii. Ground Motion and Structural Idealization

The 8-storey RC frames with as shown in Figure 2 were chosen from the literatures [4] to simulate the behaviour of structure due to SSI effect. These 2D frame model used in this study consists two irregular frame models with different dimension in elevation without considering the soil structure interaction effect and located in a high-seismicity region of Europe. During validation of analytical model, the fixed base condition were considered both gravity and seismic loads where a design peak ground acceleration (PGA) of 0.2g and soil class B according to EC8.[4]. The real seismic sequence database has been used in original frame A4 proposed by [4] is Chalfant Valley (July 1986- 2 events). The databases for seismic input were downloaded from Pacific Earthquake Engineering Research (PEER) Center



Records examined seismic by Hartzigeogiou   Assign in STAAD Pro software

Figure 1 : Design peak ground acceleration (PGA) of 0.28g .(Hartzigeogiou et, al 2010)

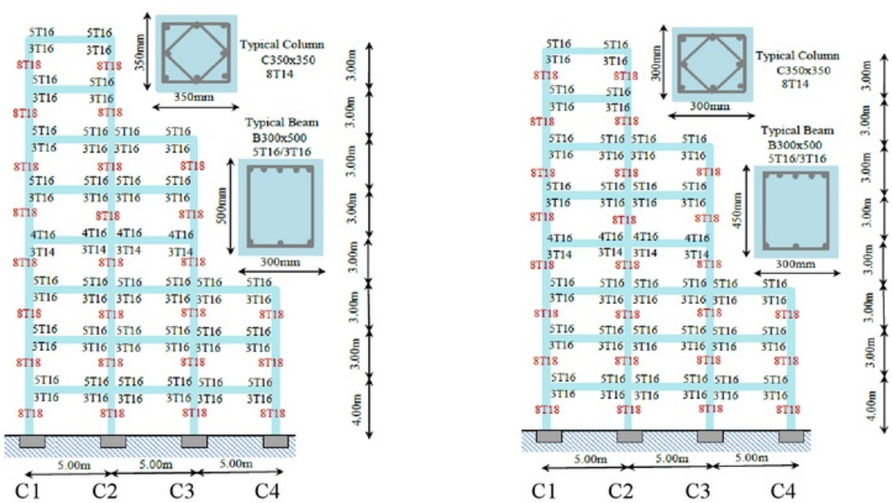


Figure 2: Model Frame A and Frame B

Time History analysis was applied during simulation this model to investigate the structural behavior for horizontal and vertical ground motion. These analyses were applying data over increment time step as a function of acceleration, force, moment or displacement. It provides the response of a structure over time during and after the application of a load. The Time History Response of structure is simply the response (motion or force) of the structure evaluated as a function of time including inertial effect. Two stage were included in these analysis.The buildings model were designed under following combination load as proposed by [4] during in first stage analysis.

i. 1.35G + 1.50Q
ii. 1.00G + 1.00Q + 1.00E
iii. 1.00G+1.00Q-1.00E

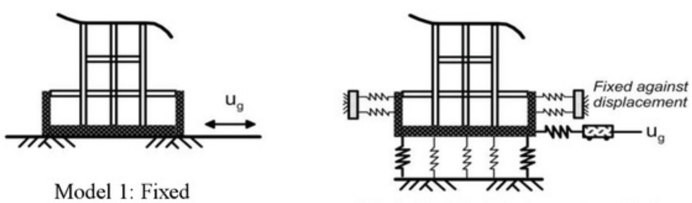
Where G, Q and E correspond to dead, live and earthquake load respectively, and also consider 1.5% characteristic dead weight of the structure as notional design ultimate horizontal load applied at each floor.[8] Meanwhile the second stage analysis were included the stiffness of spring at support. Impedance Function has been applied to calculate the stiffness of such spring.[1]

$$Kx = \frac{2GL}{1-v}\left[2 + 2.50\left(\frac{B}{L}\right)^{0.85}\right] - \left[\left(\frac{0.2}{0.75-v}\right)GL\left(1-\frac{B}{L}\right)\right]$$ is translation along x-axis[1]

$$Ky = \frac{2GL}{1-v}\left[2 + 2.50\left(\frac{B}{L}\right)^{0.85}\right]$$ is translation along y-axis[1]

iii. Spring Application at Support

Modeling approaches are depending on the building formation and the type of supporting element. These researches were compare two difference type of support under vertical ground motion. According to literature [1] one of group frame building will be assign such as model 1. In model 1 assume to be fixed at the base in figure 3. While other buildings were assign horizonta lsprings were used in model 2 for detection the flexibility. Then model frame was subjected to horizontal and combined horizontal and vertical components of earthquake ground motion [6]



Model 1: Fixed

Model 2: Flexible base at vertical and horizontal equation.

Figure 3: Comparison for fixed base and flexible base. [1]

iv. Validation Analytical Modal

Modal analysis and nonlinear time history analysis have been carried by simulation STAAD Pro Software. These validations are to compare the dynamic characteristics of structures frames used in this study (Frame A) with original model (Frame A4). The dynamic characteristic validation will be compare in term Natural Vibration Period, Mass Participation Factor (MPF) and Max Horizontal Displacement. Table 1 is shown the result natural vibration periods and Mass Participation Factor (MPF). The maximum relative deviation of natural vibration period and Mass Participation Factor (MPF) original Frame A4 with Frame A achieve approximately to 15%. These results are very close with the dynamic characteristic of the original model from [3] study

Table 1 Dynamic Characteristics of Structures: Periods and Mass Participation Factor

Dynamic Characteristics of Structure	First Mode		Second Mode		Third Mode	
	Frame A4	Frame A	Frame A4	Frame A	Frame A4	Frame A
Periods (s)	0.9673	0.932	0.447	0.382	0.2746	0.227
MPF	0.731	0.75	0.194	0.112	0.055	0.021

The comparison of maximum horizontal displacement result between frame A and frame A4 from Figure 4 are shown that the model have similar trend along the level of building. This proved that the model can be used in this study for further analysis.

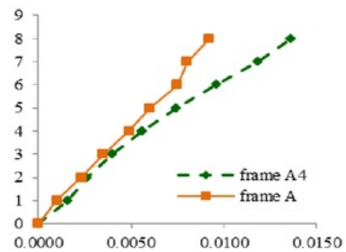


Figure 4: Maximum horizontal displacement frame A and frame A4

Result and Discussion

Figure 5 are provides the comparison variations of axial load with respect to the statistic (gravity) load HGMs and HVGMs consider fixed support and Soil Structure Interaction effect for Frame A and Frame B

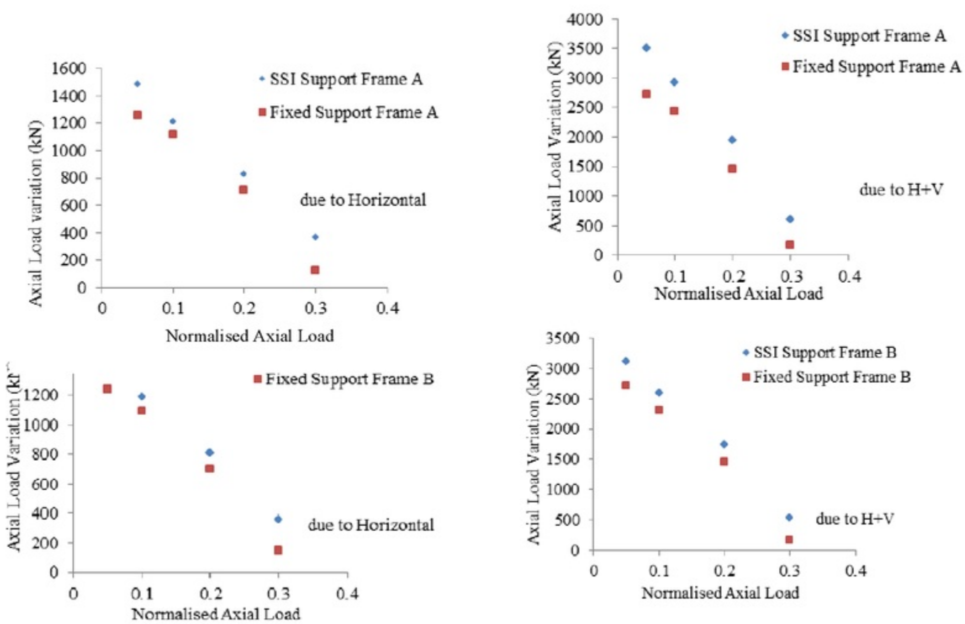


Figure 5: Variation Axial Load in the column subjected to Horizontal and combination Horizontal and vertical earthquake ground motion

Table 2 are provide average values for variation of axial load from figure 4. The variation of axial load is significant in columns under HVGMs, especially in compression. For values of v corresponding to actual RC columns in framed building structures, normalized axial load v >0.10, the average increase the ranges between 4.0% (v = 0.1) and 4.9% (v = 0.3)

Table 2: Comparison between Variation Axial Load considering SSI effect and fixed base under Horizontal and Horizontal + vertical earthquake ground motion

Column No	C1			C2			C3			C4		
Normalised axial load	v = 0.05			v = 0.1			v = 0.2			v = 0.3		
Type of Support	SSI	Fixed	%	SSI	Fixed	%	SSI	Fixed	%	SSI	Fixed	%
H	1468.6	1248.4	2.2	1199.7	1103.8	1.0	819.9	705.1	1.1	361.2	136.5	2.2
H+V	3309.6	2718.1	5.9	2763.1	2366.2	4.0	1846.2	1457.9	3.9	657.8	166.6	4.9
(H+V)/H	2.3	2.2		2.3	2.1		2.3	2.1		1.8	1.2	

The results in figure 5 also prove that for both Frame A and Frame B show the SSI condition was significant larger than that in the fixed base condition. It it becoming widely accepted that SSI effect into consideration.

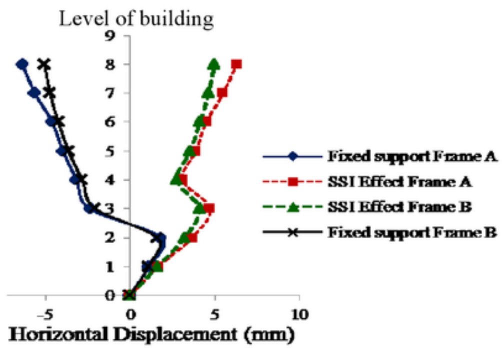


Figure 6: Comparison between Horizontal Displacement for Frame A and Frame B under considering SSI effect and fixed support.

Figure 6 show the distribution of the horizontal displacement along the height of model Frame A and Frame B at the critical collapse state in the x direction. The deformation mode of building is similar to that in the third translation vibration mode and the mass participation factor show that the SSI condition are higher than fixed support condition.

Conclusion

The results of study are shows that the effect of SSI may give a significant role to increase the overall time vibration period of building. The SSI effect could extend the periods of vibration mode, and the smaller stiffness of the soil foundation system leads to longer vibration period. However, the SSI effect has a minor influence on the translational vibration of building.

Acknowledgements

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