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Case Study for Evaluation of Dynamic Characteristics of Adjacent Buildings

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ABSTRACT

In this paper, the influence of soil type and distance between adjacent buildings on structural dynamic properties (natural frequencies and damping ratios) is investigated. For this purpose equations of motion for two adjacent buildings, which affect each other's dynamic responses, are developed. For modeling soil and its effects, springs and dampers in the base level is used. Finally, by studying a real building, its dynamic properties in case of being located adjacent to another same building and individually are calculated and compared. In previous researches, these dynamic properties were calculated by experimental methods. By comparing analytical and experimental results, it is found this proposed model calculate the values of dynamic properties with good precision.

KEYWORDS:

Adjacent Buildings, Natural Frequencies, Damping Ratio, Structure–Soil–Structure Interaction

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1- Introduction

When a structure is located on a rigid base, the energy of vibration must be absorbed within the structure. But if the lower bound can replaced with a flexible foundation, then the vibration energy can be propagated also in the soil and attenuated in the semi infinite soil medium [1–3].

Such a soil structure interaction phenomenon can be taken into account both for single and adjacent buildings [4–7]. In this paper, the main focus is on the effect of soil on the dynamic characteristics of adjacent buildings, so pounding is assumed not to happen and is ignored. The correlation between adjacent foundations during wave propagation is accounted by an approximate model. In this way, frequency independent impedance functions are introduced for each degree of freedom and finally the spring and damper coefficients that couple the degrees of freedom of the foundations are utilized. Therefore, response of a foundation at each time step is a result of two concurrent phenomena, one is soil structure interaction and the other is coupling through the soil between adjacent foundations. In such a system, the equations of motion must be written for the entire system. Taking soil into account changes dimensions of the characteristic matrices of the initial system containing only a single structure. Hence, considering base flexibility causes additional deformations including lateral displacement and rotation of each foundation.

2- System under study

In the studied system, matrices of mass, damping and stiffness have elements related to the structure's and foundation's characteristics. In order to obtain the equations of motion for adjacent structures, two structures with *n* and *m* degrees of freedom are assumed. The equations are written for each part of the system and combined in a matrix form. Fig. (1) shows the system studied.

In order to obtain certain numerical results, the building of the International Institute of Seismology and Earthquake Engineering in Tehran has been studied. This structure was chosen because, first; it has built in two similar adjacent halves, and second; its dynamic characteristics had been extracted experimentally in previous studies and could be compared with the numerical results of this study. Two types of soils are assumed, soil type II with a shear wave velocity of 600 m/sec and soil type III with a velocity of 300 m/sec. First, a half building is considered as a single structure with rigid and flexile bases and the effect of soil-structure interaction on its dynamic characteristics is discussed. In the second part, the structure's dynamic properties in case of being located adjacent to another same building (its real current situation) are calculated and the influence of adjacency on dynamic characteristics is studied.

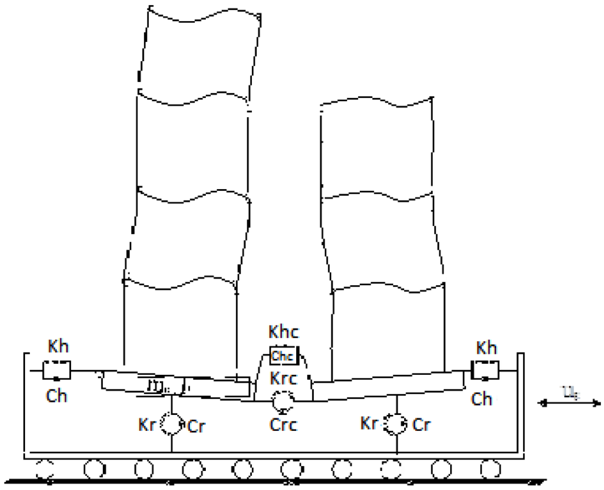

Fig. 1. The system under study

3- Numerical results

Tables (1) and (2) show the calculated periods of the single building in two perpendicular directions using different methods. In addition, Tables (3) and (4) illustrate the calculated damping ratios in the same order.

Tables (5) and (6) exhibit the periods and damping ratios calculated for the system of two adjacent buildings, respectively.

The above tables show that effect of a flexible soil is reducing the natural frequencies of the system. This effect is more considerable only in the fundamental mode of vibration. In addition, the adjacency of buildings increases the vibration mode corresponding to the translation of foundation. Damping of soil is only affecting the damping ratio of the fundamental mode of the structure and of the case when the foundation displaces horizontally. Finally, by comparing the analytical and experimental results, it is found that the proposed model can estimate the values of dynamic properties with a good accuracy.

4- References

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Table 1. Natural frequencies of the single building in East-West direction using different methods (rad/sec)

Mode Number	Experimental Methods	3^D Analysis	Rigid Base	Flexible Foundation	
				Soil Type II	Soil Type III
1	14.01	14.51	14.27	14.04	15.57
2	42.03	33.87	43.64	43.75	43.71
3	65.47	48.51	68.23	68.23	68.23
4	–	65.66	89.00	89.90	89.90
5	–	–	111	111.24	111.24
6	–	–	130	130.75	130.75
Base Translation	–	–	–	25.51	11.73
Base Rotation	–	–	–	1.73	0.87

Table 2. Natural frequencies of the single building in North-South direction using different methods (rad/sec)

Mode Number	Experimental Methods	3^D Analysis	Rigid Base	Flexible Foundation	
				Soil Type II	Soil Type III
1	20.36	12.38	13.72	13.53	15.10
2	55.86	31.86	37.66	37.84	37.76
3	57.43	42.66	59.15	59.17	59.16
4	–	68.78	80.77	80.72	80.72
5	–	–	101	101.09	101.09
6	–	–	115	115.73	115.73
Base Translation	–	–	–	25.41	11.62
Base Rotation	–	–	–	1.73	0.87

Table 3. Damping ratios of the single building in East-West direction sing different methods (%)

Mode Number	Experimental Methods	3^D Analysis	Rigid Base	Flexible Foundation	
				Soil Type II	Soil Type III
1	4.1	5	5	4.9	5.1
2	4.9	5	3.2	3.2	3.2
3	5.1	5	3.6	3.6	3.6
4	–	5	4.3	4.3	4.3
5	–	5	5	5	5
6	–	5	5.7	5.7	5.7
Base Translation	–	–	–	6.1	5.9
Base Rotation	–	–	–	1.5	1.5

Table 4. Damping ratios of the single building in North–South direction using different methods (%)

Mode Number	Experimental Methods	3^D Analysis	Rigid Base	Flexible Foundation	
				Soil Type II	Soil Type III
1	3	5	5	4.9	5.1
2	3.1	5	3.2	3.3	3.3
3	3.1	5	3.6	3.6	3.6
4	–	5	4.3	4.3	4.3
5	–	5	5	5	5
6	–	5	5.6	5.6	5.6
Base Translation	–	–	–	6.1	6
Base Rotation	–	–	–	1.5	1.5

Table 5. Natural frequencies for the system of two adjacent buildings and single building in East-West direction (rad/sec)

Mode Number	Single Building (Rigid Base)	Single Building (Flexible Foundation)	Adjacent Building (Structure–Soil–Structure Interaction)		
			d/a=0.25	*d/a*=2	*d/a*=5
1	14.27	14.04	14.13	14.13	14.13
2	43.64	43.75	43.69	43.69	43.69
3	68.23	68.23	68.22	68.22	68.22
4	89	89.90	89.89	89.90	89.90
5	111	111.24	111.23	111.24	111.24
6	130	130.75	130.75	130.75	130.75
Base Translation	–	25.51	25.51	20.11	21.53
Base Rotation	–	1.73	1.73	1.73	1.73

Table 6. Damping ratios for the system of two adjacent buildings and single Building in East-West direction (%)

Mode Number	Single Building (Rigid Base)	Single Building (Flexible Foundation)	Adjacent Building (Structure Soil Structure Interaction)		
			d/a=0.25	*d/a*=2	*d/a*=5
1	5	4.9	5	4.8	5
2	3.2	3.2	3.3	3.2	3.2
3	3.6	3.6	3.7	3.7	3.7
4	4.3	4.3	4.3	4.3	4.3
5	5	5	5	5	5
6	5.7	5.7	5.7	5.7	5.7
Base Translation	–	6.1	5.9	6.7	6.5
Base Rotation	–	1.5	1.5	1.8	2

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