EVALUATING THE EFFECTS OF PERIOD OF STRUCTURES ON SOIL-STRUCTURE INTERACTION

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ABSTRACT

Considering soil structure interaction effect, makes analyzes more complex thus evaluating amount of its effect before analyze can help professionals to judge if it is reasonable to consider it or not. Period of the structure can have a major effect on the amount of soil structure interaction so evaluating this effect can be beneficial. In this text effect of soil structure interaction for 11 structures in three different loading conditions is addressed, and it is derived that stiffer structures with lower periods can express more soil structure interaction effect. In such structures considering this effect can be meaning full.

Keywords: Soil Structure Interaction, Dynamic analyzes, Cone method

1. INTRODUCTION

In routine dynamic analyze of structures it is accepted to consider that the base is not deformable (Clough and Penzien 1993). This means that we consider structure stiffer and less damped than what it is in real, on the other side we neglect the effect of free field on the deformation of ground input motion. In some case of loading and special soils this simplification will lead to over estimation of design effective factors but in some special loadings and some special soils, this simplification can even cause underestimation (Dutta et al 2004; Gazetas and Mylonakis 2001; Mylonakis and Gazetas 2000; Gazetas and Mylonakis 1998; Beilak 1975).

The fact is that this effect is not very compromise as the motion of earthquake is not exactly predictable and the soil domain is very varying. As it is shown in different researches this effect can have a relatively minor influence or in some special cases a considerable influence of up to 40 percent on design of structures (Wolf 1985). So there should be some factor that can help us to predict if considering this effect can have a major effect and we should consider it or not.

Researchers have shown that mass of the structure and the period of it can be good factors to predict how effective soil structure interaction effects can be (Moghaddasi et al 2011; Wolf 1985). These two factors can help professionals to have a rough measure of this effect. In two completely

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equal structures the one with the lower period will observe less soil structure interaction effect, and in two structures with different weights, the heavier one will show more effect.

In this text, further we are going to compare these two factors on soil structure interaction effect. To do this we have analyzed 11 structures beginning with a stiff structure that leads to a low period and at the end a relatively slender structure with a high period. The mass of the structure is constant thus we can evaluate the effect of period and stiffness of structure and the interaction effects.

2. STRUCTURES

As the first mode of structure has a major effect on soil structure interaction and as in this text general behavior of structure is concerned, thus a simple model with general futures of real structure can help us to achieve into a fine accuracy and a proper analyze time. The model that is selected in this paper is a one degree of freedom system with one mass one spring and one damper that is at the top of a solid column with effective height of structure. Figure 1 schematically illustrates this system. This model has been used in (Wolf and Deeks 1985) and some other references.

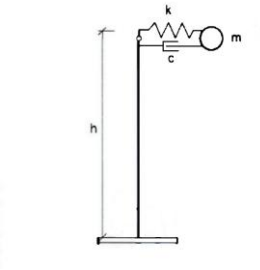

Figure 1: Model of structure with no soil structure interaction effect

In order to cover a proper range of structures in this paper 11 structures are analyzed. First structure is relatively stiff and it has a low period of 0.5 seconds. Last structure is relatively slender and has a high period of 1 second. All structures have a constant mass of 640 ton thus in order to increase their period we should decrease their stiffness in other words from structure 1 to structure 11 structures become more slender. Stiffness of first structure, structure number1 is 101064749 kg/m and stiffness of last structure, structure number 11 is 25266187 kg/m other structures stiffness is between these two

Height of Models, their damping ratio and their foundation's radius are 17 meter, 0.025 and 15.96 meter respectively. Other in formations about these structures can be found in table 1.

Table 1: Definition of structures

Number of Structure	Period (second)	Mass (kg)	stiffness (kg/m)	Damping coefficient (kg*s/m)
1	0.5	6.40E+05	1.01E+08	4.02E+05
2	0.55	6.40E+05	83524586	3.66E+05

3	0.6	6.40E+05	70183854	3.35E+05
4	0.65	6.40E+05	59801627	3.09E+05
5	0.7	6.40E+05	51563647	2.87E+05
6	0.75	6.40E+05	44917666	2.68E+05
7	0.8	6.40E+05	39478418	2.51E+05
8	0.85	6.40E+05	34970501	2.37E+05
9	0.9	6.40E+05	31192824	2.23E+05
10	0.95	6.40E+05	27995775	2.12E+05
11	1	6.40E+05	25266187	2.01E+05

3. SOIL

The soil under the structure consists of two layers over a half space of soil. The properties of soil in each layer are constant and vary in different layers. First layer is a relatively soft soil and as depth increases soil become stiffer which can be, as it happens in nature.

Table 2 displays properties of layers and half spaces. In Table 2 from left to right in the first column numbers indicate the layers and H indicates half space and units are mentioned in the top of each column.

Table 2: Definition of soils

Layer	Shearing Modulus (kg/m^2)	Poisson's ratio	Mass per unit volume (kg/m^3)	Depth (meter)
1	12.000E+06	0.25	1800	15.0
2	14.000E+06	0.25	1800	5.0
H	18.000E+06	0.25	1600	infinite

4. CONAN

CONAN is software based on Cone method. Conan is able to analyze the sub structure of soil and this software will finally create unit less coefficients that relate the dynamic and static stiffness's of soil. This finally leads to creating a model with ability of considering soil structure interaction.

5. ANALYZE OF STRUCTURES

After building the models in this paper, they are analyzed. First the structure is analyzed with routine simplification of structure over solid base and then it is analyzed with soil structure interaction.

For the first analyze the base of the structure is connected to the ground rigidly. This condition is schematically shown in Figure 1. In second analyze the structure is connected to the springs and dampers that model the under the structure and models the soil.

This modification will change the period and damping of system. After adding the springs and dampers the period and damping of system will increase. Table 3 shows list of period and compare them with the first assumption of No soil structure interaction.

Table 3: Period of structures with soil structure interaction effect

Number of Structure	Period of fixed structure	Period with Soil Structure Interaction
1	0.5	0.56727
2	0.55	0.61158
3	0.6	0.65655
4	0.65	0.70228
5	0.7	0.74837
6	0.75	0.7949
7	0.8	0.84192
8	0.85	0.88915
9	0.9	0.9367
10	0.95	0.98445
11	1	1.03255

Figure 2 compares these two periods and shows that as the structures become stiffer the simplification will create more mistakes.

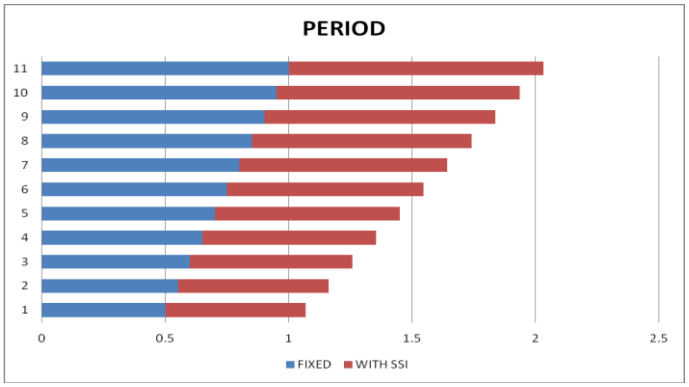

Figure 2: Comparing periods of structures with and without soil structure interaction effect

To have a better understanding of this phenomenon the period elongation versus fixed base period has been shown in Figure 3.

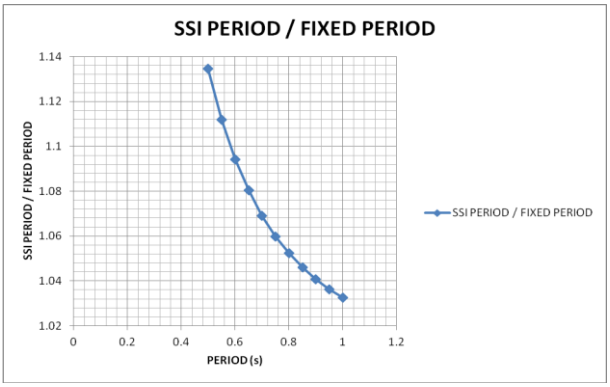

Figure 3: Period vs. rate of period change

6. RESPONSE SPECTRUM ANALYZE OF STRUCTURES

The period of structure with considering the effect of soil is enhanced and thus the behavior of structure to dynamic loads will be different. To study this modification in this text tree response spectrums are use to analyzed the structures. The first one is a spectrum prepared for the site of Azadi hotel and the second one is the response spectrum of Parkfield earthquake and the third one is Tabas earthquakes response spectrum. Figure 4 thought 6 shows these response spectrums respectively.

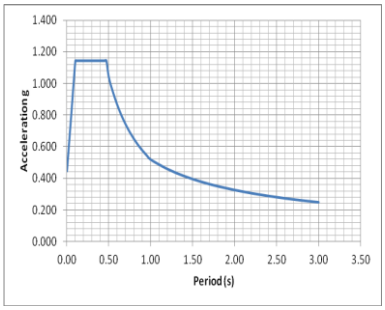

Figure 4: Azadi response spectrum

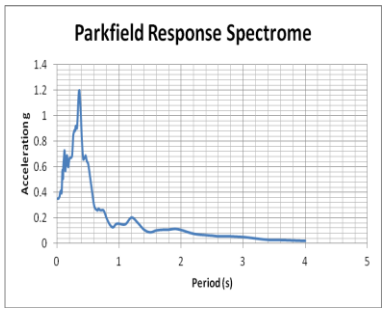

Figure 5: Parkfield response spectrum

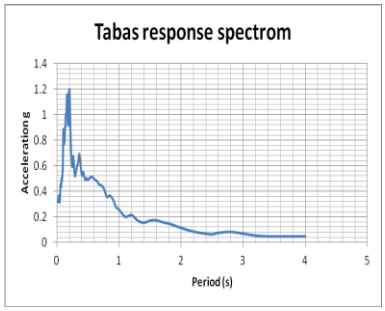

Figure 6: Tabas response spectrum

The structures are analyzed with considering the effect of soil structure interaction and without considering it. The results of analyzing the structures by responses are compared in Table 4.

Table 4: Reduction of distortion in different loadings

Number of Structure	Reduction Percent (Azadi)	Reduction Percent (Parkfield)	Reduction Percent (Tabas)	Average
1	36.70%	54%	26%	39%
2	31.90%	53%	28%	38%
3	27.60%	27%	25%	27%
4	23.90%	18%	22%	21%
5	20.60%	16%	20%	19%
6	17.70%	32%	25%	25%
7	15.20%	29%	9%	18%
8	13.10%	19%	15%	16%
9	11.40%	-6%	20%	8%
10	9.80%	6%	12%	9%
11	7.50%	7%	12%	9%

In these loading cases and soil condition, and these structures, reduction of stiffness of structures which will in a constant mass lead to increasing of their period, will reduce the effect of soil structure interaction Table 4 shows a list of the amount of these reductions had occurred in the deformation of structure.

It is obvious that the stiffer structure have shown more soil structure interaction effects. In order to study this effect better figure 7 shows a comparison of reduction percent and the period of structure.

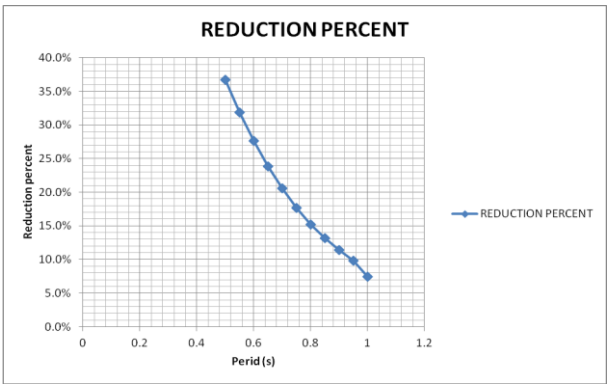

Figure 7: Period vs. reduction of distortion in Azadi loading

In Figure 8 and 9 reductions of structures against their periods is studied in two charts for Parkfield and Tabs earthquakes. Charts of Figures 8 and 9 have a trended line which can help to illustrate the general behavior of structures. Trended lines of Figure 9 and 8 are written in their Figure. It is obvious that the reduction percent of distortion against period of structure in general have a trended line with negative slope.

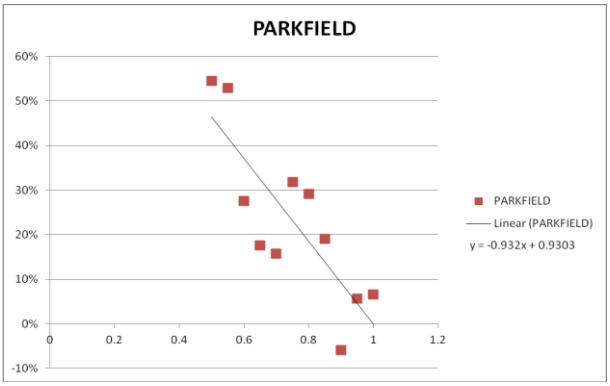

Figure 8: Period vs. reduction of distortion in Parkfield loading

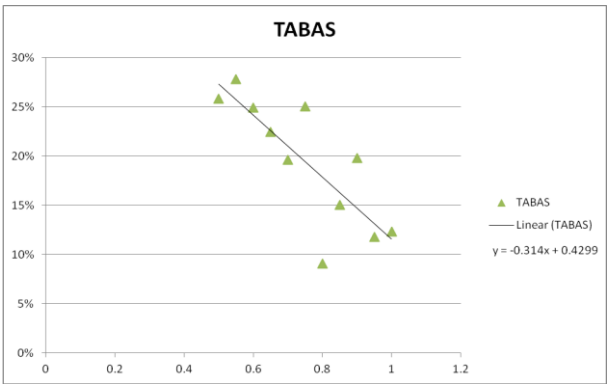

Figure 9: Period vs. reduction of distortion in Tabas loading

In figure 10 behaviors of structures in scaled spectrum of Azadi and in spectrums of Parkfield and Tabas earthquakes are compared. It is obvious that the general behavior of structures in scaled spectrums is near their behavior in earthquakes.

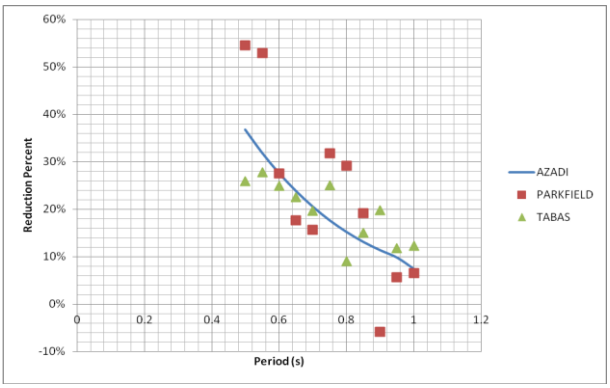

Figure 10: Comparing reduction percent in different loadings

7. CONCLUSION

In analyzing structures placed over firm soils effect of soil structure interaction is neglect able, but in structures placed over soft soil this affects can have a major effect on the dynamic behavior of the

structures. The dynamic characteristics of the structure such as the first period, mass and stiffness of structure can have great effects on soil structure interaction.

Finding a proper factor that can give professionals an estimation of how important this effect can be, will help them to decide when to omit it. Thus in this paper we have evaluated factors of structures mass and period to find this effect.

The result is obtained from 33 analyzes for 11 structure. Structures are relatively becoming more slender from structure 1 to structure 11. The general result obtained from these loading and structures illustrate that those structures which are stiffer will obtain more effect of soil structure interaction and more slender structures will be less sensitive to soil structure interaction effect.

This is a very rudiment search trying to focus on general behavior of structure so the result of this text obtains structures within period of 0.5 second to 1 second. Extending the result of this research can help to compare if more slender or stiff structures can show the same general results or they act in a different way.

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