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DISCUSSION ON THE FUNDAMENTAL PERIOD OF SDOF SYSTEMS INCLUDING SOIL-STRUCTURE INTERACTION

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ABSTRACT

The effect of soil-structure interaction on the fundamental period of a structural system is recognized by several modern seismic codes, whereas simple straightforward relationships are provided to estimate the modified period of the building. In the present paper an effort takes place to estimate the fundamental period of structures with surface foundation including soil-structure interaction phenomena, utilizing 2D plane-strain numerical simulations with FE codes. Three characteristic fixed base periods of single degree of freedom systems are considered during the numerical investigation, while the influence of parameters such as the soil category, superstructure mass and height values is highlighted. Comparison with theoretical relationships and seismic code recommendations reveal the accuracy of the employed numerical calculations, whereas a discussion takes place regarding the observed variation of the calculated effective period values, taking into consideration the particular foundation type-subsoil properties of the examined systems.

Keywords: fundamental period, soil-structure interaction (SSI), effective period, code provisions

INTRODUCTION

The mechanisms that soil-structure interaction (SSI) affects the dynamic response of structures during an earthquake event have been highlighted by several studies over the last few decades. Soil deformation under seismic motion is modified by the foundation stiffness at the first stage of interaction (kinematic part), whereas structural oscillation imposes additional horizontal and rotational deformations on the foundation creating outgoing waves (inertial part), constituting together a rather complicated phenomenon. Depending on the foundation shape and formation, the soil stiffness as well as the structural dynamic characteristics, soil-structure interaction may possess a paramount role in the system's seismic performance. Both induced seismic motion and structural dynamic response may be altered during the seismic event, changing dramatically the behaviour especially in the case of structures with stiff foundations on soft soil formations.

FEMA 450 regulations (BSSC, 2003) provide a comprehensive procedure to incorporate interaction phenomena into seismic design of buildings. The employed approach involves modification of the dynamic properties of the structure and evaluation of the response to the prescribed free-field motion (Jennings and Bielak, 1973). The expected consequences of SSI would include an increase in the fundamental natural period of the structure and a change (usually increase) of the effective damping. The effective structural period (including interaction) is calculated using the relationship first proposed by Veletsos and Meek (1974):

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$$T_{SSI} = T\sqrt{1 + \bar{k}/K_y\left(1 + \bar{k}\cdot\bar{h}^2/K_r\right)} \tag{1}$$

where T is the fixed-base period, K_y and K_θ the spring stiffness values to lateral and rocking motions calculated , $\bar{k}$ and $\bar{h}$ the stiffness and effective height of the fixed-base structure. Seismic base shear reduction compared to the fixed-base structure is then calculated, using an appropriate expression that considers also a seismic response coefficient based on the effective period determined above.

Eurocode 8, Part 5 (CEN 2002) instructions refer to the consideration of soil-structure interaction phenomena in the cases that SSI effects could be detrimental, such as:
a) structures where P-δ (2^{nd} order) effects play a significant role
b) structures with massive or deep-seated foundations, such as large bridge piers, offshore caissons, and silos
c) slender tall structures, such as towers and chimneys
d) structures supported on very soft soils, with average shear wave velocity $V_{s,max}$ less than 100m/s
According to EC8, dynamic soil-structure interaction should also take into account the non-linear soil behavior and the radiation damping, resulting in the majority of usual building structures to beneficial seismic response and reduced structural bending moments and shear forces. Nevertheless, specific instructions on the quantitative consideration of SSI effects are not provided in the context of EC8.

The Greek Seismic Code (EAK 2000) on the other hand does not mention directly soil-structure interaction issues, apart from a requirement to take properly into account soil compliancy at the foundation level that may alter the dynamic response of the structure.

The aim of the present paper is to validate 2D plain strain calculations of the effective (SSI) fundamental period of single degree of freedom (sdof) structures, by comparing with corresponding calculations determined from seismic code recommendations or other explicit expressions and theoretical solutions proposed in the bibliography. At the same time a discussion takes place regarding the calculated effective period variation and interesting observations are made in the examined soil-structure cases.

CALCULATION OF EFFECTIVE PERIOD VALUES

The soil-structure system employed during the validation procedure consists of a sdof structure with surface strip foundation (Fig. 1). The rigid foundation is considered bonded with the soil: sliding and foundation uplift have not been taken into consideration during the theoretical and numerical calculations of the SSI period. The crucial parameters that affect significantly the intensity of the soil-structure interaction phenomena, and subsequently the modification of the structural dynamic characteristics compared to the fixed-base case, are properly accounted for during the investigation as presented in the following paragraphs.

Structural mass

The superstructure mass is directly related to the development of soil-structure interaction phenomena. Increased values of structural mass result in enhancement of the foundation rocking motion, due to structural oscillations during the dynamic response of the system. Normalized structural mass m_{norm} is implemented in order to quantify the influence of the superstructure mass to the obtained effective structural period T_{SSI}, according to the expression (Wolf, 1985):

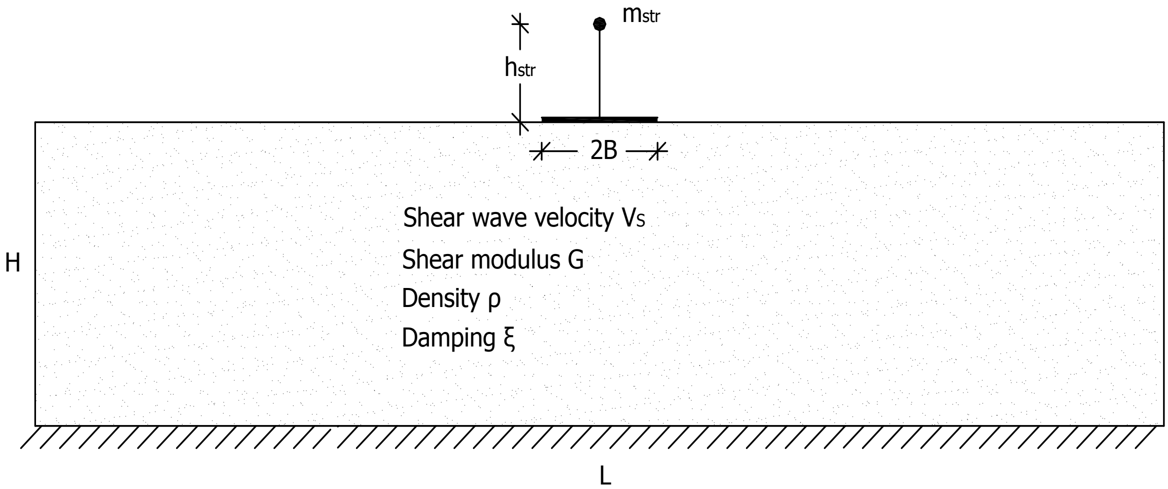

Figure 1. Investigated soil-structure system

$$m_{norm} = \frac{m_{str}}{\rho \cdot \alpha^3} \tag{2}$$

where m_{str} is the superstructure mass, ρ is the soil density and α the characteristic dimension of the foundation, equal to half-width B of the strip foundation employed in this paper.

Structural height

Structural height is also strongly related to the rocking motion of the foundation due to soil-structure interaction, increasing the oscillation of the superstructure and enhancing effective period modification. Normalized structural height is considered herein to study structures of different height, according to the expression (Wolf, 1985):

$$h_{norm} = \frac{h_{str}}{B} \tag{3}$$

Foundation soil compliancy

Depending on the ground type, foundation soil compliancy may differ between different soil categories, affecting significantly the dynamic properties of the SSI system. In this paper three soil types with different properties are examined, each indicative of the soil categories B, C and D as defined by EC8. The considered shear wave velocities Vs are equal to 400m/s, 200m/s and 100m/s for soil types B, C and D respectively. This correlation is useful from the engineering point of view, during the comparative evaluation of the obtained T_{SSI} values with respect to the examined soil categories.

Theoretical calculation of effective period values

Several theoretical relationships have been proposed to estimate the soil stiffness parameters of Equation 1. Static stiffness values are usually first determined, and the dynamic stiffness is then obtained by utilizing a dynamic coefficient that is proposed for each degree of freedom at the soil-foundation interface. This dynamic coefficient depends on the geometry, stiffness and embedment of the foundation body and is usually frequency dependent. Numerous studies in the last few decades have investigated several cases of foundation geometries including strip, circular, square, rectangular or in general arbitrary foundation shapes. Most of the studies concern homogeneous half-space consideration of the foundation subsoil conditions, yet layered soil profiles over bedrock or uniform half-space have also been studied. Analytical expressions for several combinations of footing geometries and soil profiles have been recently discussed in Mylonakis et al. (2006), focusing primarily to bridge foundation cases, whereas dimensionless charts that provide effective periods and damping values of soil-structure systems have been proposed from Aviles and Suarez (2002).

Despite the fact that numerical calculations concern only one specific case of foundation geometry, it is quite interesting to review the variation between different theoretical expressions for foundation dynamic stiffness values. Therefore, during the theoretical calculation of stiffness parameters in the present study, several foundation-soil combinations are examined, as presented in Table 1 and Fig. 2. The provided expressions are adequate to estimate the effective structural period based on Equation 1 that concern SSI behaviour in 2 dimensions considering horizontal and rocking motion. Details of the approach adopted in each specific case are summarized in the following paragraphs.

Table 1. Theoretical expressions for dynamic stiffness calculation

Foundation–soil properties	Response Mode	Static Stiffness	Dynamic Coefficient	Reference
(a) Square foundation over uniform half-space	Horizontal	$K_y = \frac{9GB}{2-v}$	$k_y = k_y\left(\frac{L}{B}, \alpha_0\right)$, (proposed diagram)	Gazetas 1991, Gazetas 1997
	Rocking	$K_r = \frac{3.6GB^3}{1-v}$	$k_{rx} \cong 1 - 0.20\alpha_0$	
(b) Arbitrary mat foundation over uniform half-space	effective period $T_{SSI} = T\sqrt{1 + \frac{25 \cdot \alpha \cdot r_\alpha \cdot \bar{h}}{V_s^2 \cdot T^2}\left(1 + \frac{1.12 \cdot r_\alpha \cdot \bar{h}^2}{\alpha_\theta \cdot r_m^3}\right)}$			FEMA 450 (BSSC 2003)
(c) Arbitrary foundation on soil layer over bedrock	Horizontal	$K_y = \left[\frac{8Gr_\alpha}{2-v}\right]\left[1 + \left(\frac{1}{2}\right)\left(\frac{r_\alpha}{H}\right)\right]$	$\alpha_y \approx 1$	FEMA 450 (BSSC 2003), Elsabee et al. (1977), Kausel and Roesset (1975)
	Rocking	$K_r = \left[\frac{8Gr_m^3}{3(1-v)}\right]\left[1 + \left(\frac{1}{6}\right)\left(\frac{r_m}{H}\right)\right]$	α_θ (Commentary FEMA 450)	
(d) Strip foundation on soil layer over bedrock	Horizontal	$\frac{K_y}{2L} \approx \frac{2G}{2-v}\left(1 + 2\frac{B}{H}\right)$	$k_y = k_y\left(\frac{H}{B}, \alpha_0\right)$, (proposed diagram)	Gazetas and Roesset (1976), Gazetas (1983), Mylonakis et al. (2006)
	Rocking	$\frac{K_r}{2L} \approx \frac{\pi GB^2}{2(1-v)}\left(1 + 0.2\frac{B}{H}\right)$	$k_r \cong 1 - 0.20\alpha_0$	

In the expressions of the Table:

(a) $\alpha_0 = \frac{\omega B}{V_s}$, $2B$ is the footing width and G is the soil shear modulus

(b) $\alpha = \frac{\bar{W}}{\gamma \cdot A_0 \cdot \bar{h}}$, A_o is the foundation area, $\bar{h}$ and $\bar{W}$ are the height and weight of the sdof structure, α_θ dynamic rocking coefficient (FEMA 450), $r_\alpha = \sqrt{\frac{A_0}{\pi}}$, $r_m = \sqrt[4]{\frac{4 \cdot I_0}{\pi}}$ and I_o is the footing moment of inertia about axis vertical to the rocking motion

(c) H is the soil layer thickness, whereas stiffness values are valid for $r/H < 0.5$, where for K_y, $r = r_\alpha$ and for K_r, $r = r_m$

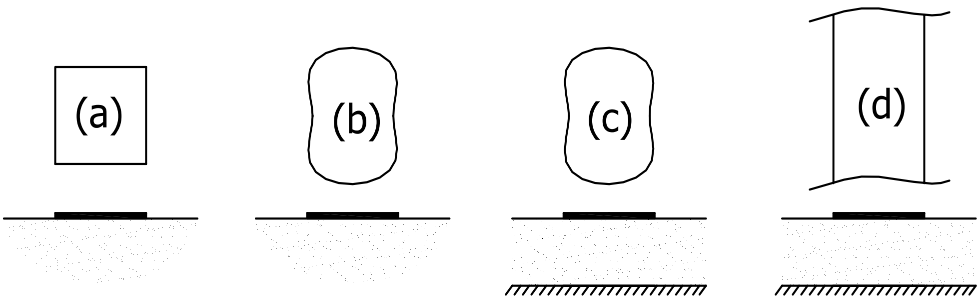

Figure 2. Foundation geometries and soil profiles examined

(a) Square foundation shape over uniform half-space
The expression used for the dynamic stiffness calculation of square foundation geometry over uniform half-space can be found in Gazetas (1991) and Gazetas (1997). The dynamic stiffness coefficient of the horizontal response mode is usually considered equal to 1 for square footings, whereas the coefficient of the rocking response mode is frequency dependent. The dimensions of the square footing are considered equal to the width of the strip foundation of Fig. 1.

(b) Arbitrary mat foundation geometry over uniform half-space
The effective period of arbitrary mat foundation over uniform half-space is calculated directly according to the expression of Table 1, proposed in FEMA 450 Commentary (BSSC, 2003). The effective weight and height of the structure are equal to the total W and h for sdof systems where the whole mass is concentrated in one specific level. The value of the foundation characteristic radius taken into consideration during the stiffness calculations varies, depending on the response mode as presented in Table 1.

(c) Arbitrary foundation geometry lying on soil layer over bedrock
The relationships employed to calculate dynamic stiffness of arbitrary foundation geometry on soil layer over bedrock can be found in FEMA 450 (BSSC, 2003), based on the work of Elsabee et al. (1977) and Kausel and Roesset (1975). The same expressions with the addition of proper coefficients can be also employed for embedded foundations on soil stratum over bedrock.

(d) Strip foundation shape lying on soil layer over bedrock
Dynamic stiffness in the case of strip foundation lying on soil layer over bedrock was calculated using the expressions that can be found in Mylonakis et al. (2006), based on the work of Gazetas and Roesset (1976) and Gazetas (1983). The strip foundation on soil stratum over bedrock that is investigated during the numerical simulation is more closely related to the specific theoretical calculation, presenting therefore a particular interest when reviewing the results. The dynamic coefficient for horizontal movement presents fluctuations with frequency, depending strongly on the H/B ratio and the examined frequency range. In this paper, with the acceptance of a small error, the horizontal dynamic coefficient is assumed equal to 1 for all calculations. Taking into consideration that the examined H/B ratio is quite large (>4), the dynamic coefficient values calculated here are rather overestimated as can be observed in the corresponding diagram in Mylonakis et al. (2006).

Numerical calculation of effective period values
Numerical plain strain calculation of the effective period for the structure with the strip footing is based on the model schematically depicted in Fig. 1. The value of L/H ratio is selected equal to 4, to avoid any undesired reflected waves emanating from the side boundaries, whereas H/B ratio is equal to 4.6. Soil behaviour is considered linear elastic, characterized by the shear modulus G and density ρ that determine the shear wave velocity within the soil deposit from the expression:

$$V_S = \sqrt{\frac{G}{\rho}} \tag{4}$$

General purposed FE codes ADINA (2005) and ANSYS (2000) are employed for the numerical determination of the effective structural period. Simulation efficiency of the aforementioned codes has been previously verified in the case of wave propagation and site effects investigation, as well as in selected physical centrifuge experiments of soil-structure interaction systems (Pitilakis et al. 2005, Kirtas et al. 2006a).

In order to identify the effective structural period T_{SSI}, the results of numerical time-history analysis are employed. An earthquake recording is imposed at the base of the model (bedrock level) and seismic waves propagate throughout the soil deposit to the surface and the structural base, triggering therefore soil-structure interaction phenomena. The response period of the structure in each soil-structure combination is then identified, using the Fourier transform of the corresponding response time-histories at the base and the top of the structural model. Indeed the top-to-base ratio of the response histories depicted in the frequency domain (transfer function), can be utilized for the determination of the resonance period at the point of maximum motion amplification. This effective period value varies for different soil categories, given the same structural fixed-base period, subject to different soil compliances that affect the extent of the developing interaction phenomena.

Using the Fourier ratio instead of plain modal analysis to identify the dynamic characteristics of the soil-structure system can provide additional information apart from the effective period value. An indicative example in the case of the structure with fixed-base period equal to 0.2s is presented in Fig. 3. The resulting effective period of the structure can be identified quite easily from the diagram in the case of soil categories B and C. On the other hand, an effective period value is also determined when soil type D is examined, by selecting the period value at the peak of the Fourier ratio. Nevertheless, the frequency content of the response in this particular combination is not very clear, since the ratio has almost uniform value for a significant frequency range. Additional information is therefore provided from the Fourier ratio, highlighting the enhanced interaction phenomena in the case of the soft soil deposit and questioning the use of a single effective period value to characterize uniquely the overall structural response. This phenomenon is also reviewed in Aviles and Suarez (2002) for systems involving short structures.

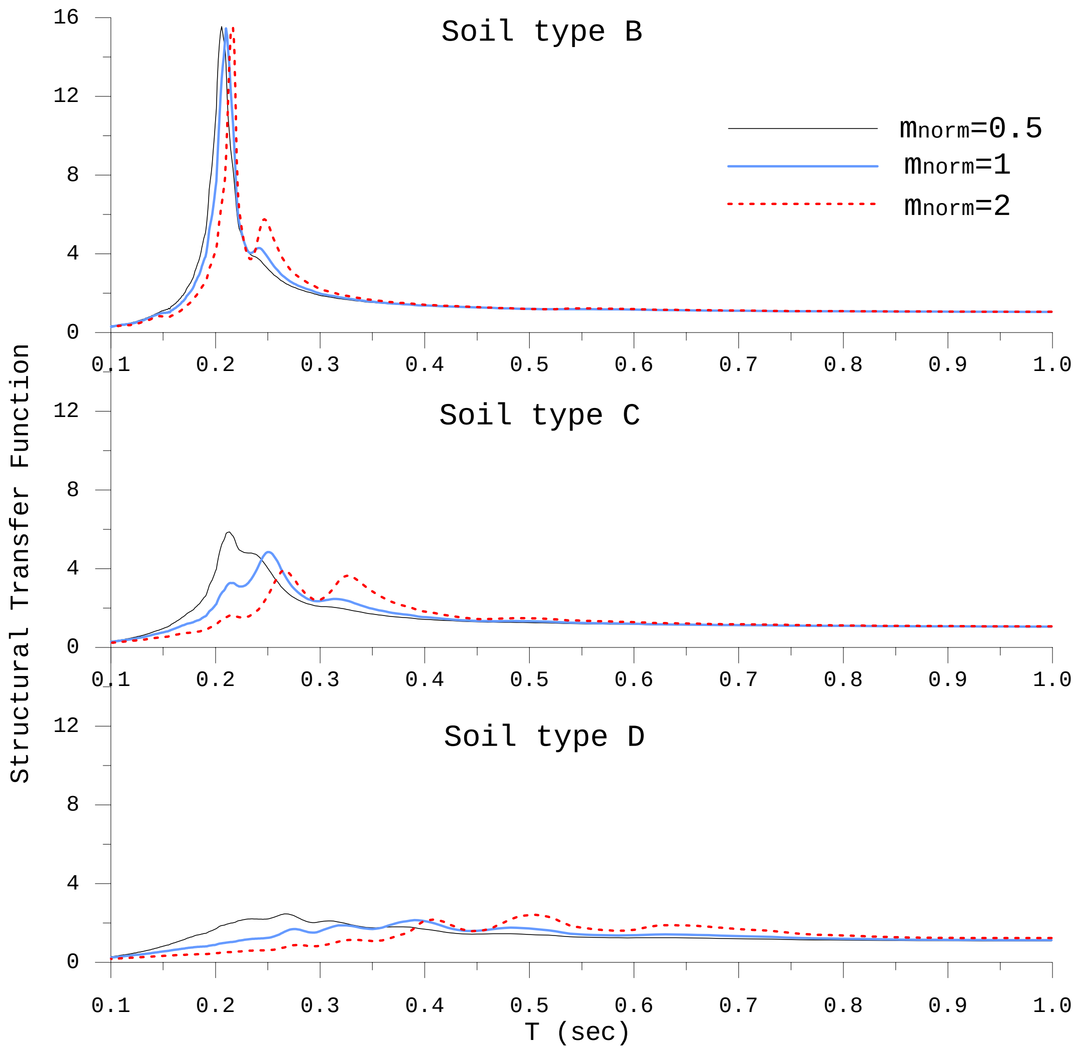

Figure 3. Top-to-base Fourier ratios (transfer functions) for structure with T=0.2s (fixed base)

EVALUATION OF THE RESULTS AND VALIDATION OF NUMERICAL SIMULATIONS

Validation of effective period numerical calculations is presented in the next few paragraphs, based on the comparison of numerical analyses using sdof structures on rigid strip foundations, towards calculations that consider theoretical expressions given in the bibliography. The examination of the several "soil type"–"structural mass" combinations for each structural fixed-base period provides the results of Table 2. In Fig. 4 a comprehensive diagram of the various investigated cases is illustrated, presenting the variation of the effective period for each combination. In the same diagram both theoretical and numerical results are presented, allowing for a comparative evaluation of the corresponding calculations. It is important to mention here that increased values of structural mass or lower soil categories are directly related to increasing interaction effects and larger effective period values. Nevertheless, when combinations of the parameters "soil type"-"structural mass" are examined (X axis in the diagram of Fig. 4), it is not possible to predict in advance the case that presents more significant period modifications. The sequence of the soil-structure combinations examined in the X axis of the specific diagram is therefore indicative, since for example C-2 case (soil type-normalized mass) could result in larger effective period than D-0.5 combination that follows.

Table 2. Theoretical and numerical analysis results of effective period (h_{norm}=1)

Soil-m_{norm}	Theoretical				Numerical	
	(a)	(b)	(c)	(d)	ADINA	ANSYS
Fixed base structure T=0.2s						
B-0.5	0.210	0.208	0.208	0.213	0.206	0.217
B-1.0	0.219	0.216	0.216	0.225	0.210	0.226
B-2.0	0.236	0.231	0.230	0.247	0.217	0.245
C-0.5	0.239	0.232	0.231	0.249	0.213	0.240
C-1.0	0.271	0.259	0.259	0.289	0.251	0.253
C-2.0	0.325	0.306	0.305	0.354	0.266	0.281
D-0.5	0.338	0.311	0.311	0.366	0.268	0.336
D-1.0	0.425	0.389	0.388	0.469	0.390	0.347
D-2.0	0.555	0.507	0.505	0.622	0.506	0.488
Fixed base structure T=0.4s						
B-0.5	0.405	0.404	0.404	0.406	0.402	0.406
B-1.0	0.410	0.408	0.408	0.413	0.406	0.410
B-2.0	0.419	0.416	0.416	0.425	0.410	0.422
C-0.5	0.420	0.416	0.416	0.426	0.410	0.422
C-1.0	0.438	0.432	0.431	0.449	0.418	0.440
C-2.0	0.473	0.461	0.461	0.494	0.431	0.471
D-0.5	0.478	0.463	0.463	0.499	0.422	0.482
D-1.0	0.543	0.518	0.517	0.578	0.506	0.506
D-2.0	0.650	0.612	0.611	0.709	0.532	0.546
Fixed base structure T=0.6s						
B-0.5	0.603	0.603	0.603	0.604	0.602	0.611
B-1.0	0.606	0.605	0.605	0.608	0.602	0.611
B-2.0	0.613	0.611	0.611	0.617	0.611	0.611
C-0.5	0.613	0.611	0.611	0.617	0.611	0.611
C-1.0	0.625	0.622	0.621	0.633	0.611	0.621
C-2.0	0.650	0.643	0.642	0.665	0.621	0.630
D-0.5	0.652	0.643	0.643	0.668	0.630	0.621
D-1.0	0.700	0.683	0.683	0.729	0.661	0.630
D-2.0	0.786	0.757	0.755	0.835	0.719	0.640

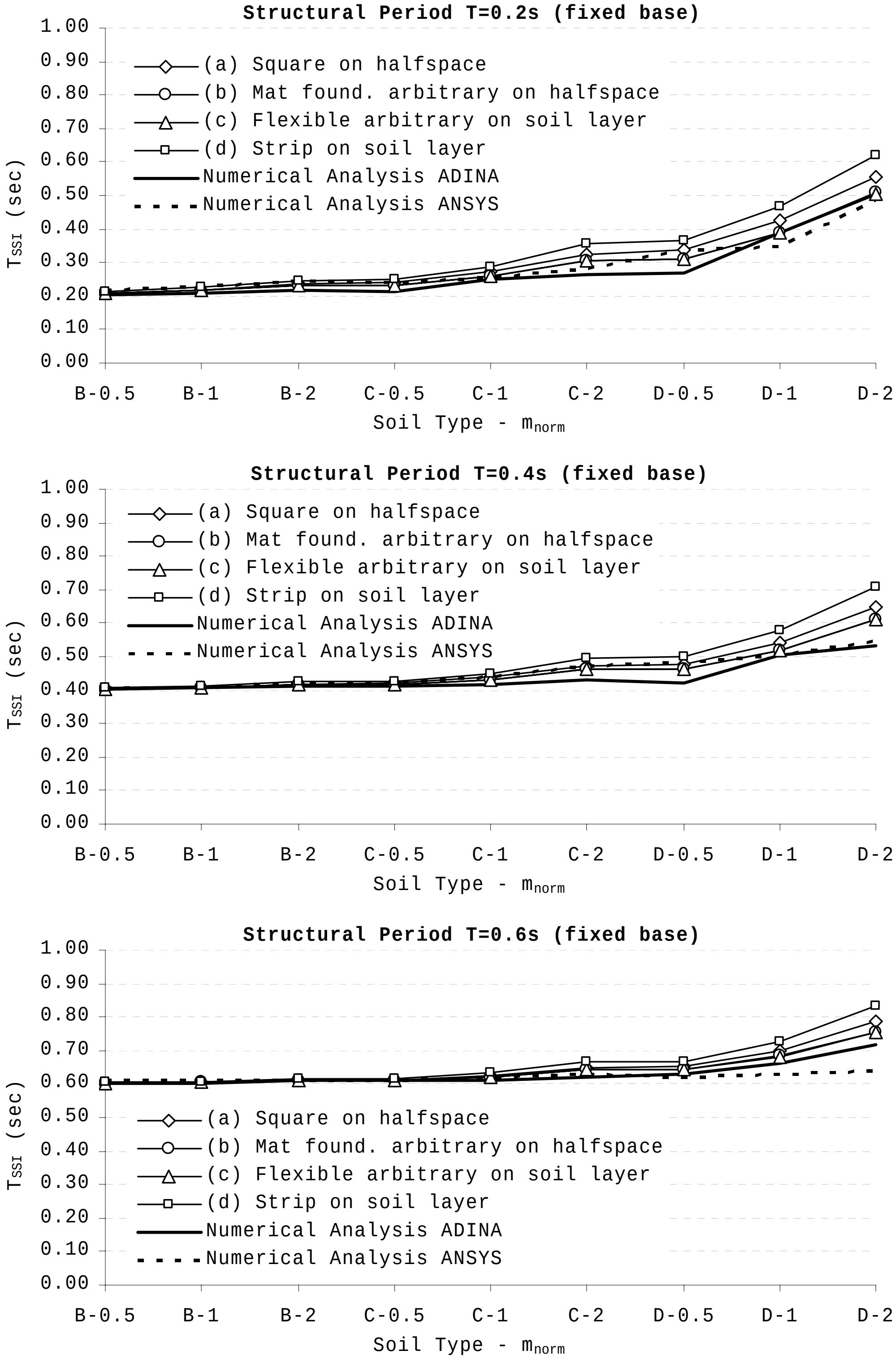

Figure 4. Effective period variation with soil type-normalized mass combinations (h_{norm}=1)

Natural period modification due to soil-structure interaction effects is more pronounced in the case of lower period (stiffer) structures with increased normalized mass. Indeed, the structure of fixed base period equal to 0.2s approaches effective period values of the order of 0.5s to 0.6s, in the extreme case of very soft subsoil conditions and large superstructure mass that result in the development of significant interaction effects. The modification of the natural period in the specific structure is equal to 150-200% compared to the fixed base value. On the other hand, maximum effective period alteration is reduced when more flexible structures are examined, presenting increase of 40-75% and 17-40% in the cases of 0.4s and 0.6s structures respectively.

It is quite interesting to comment on the calculated effective periods of cases (b) and (c) that refer to "arbitrary mat foundation over uniform half-space" and "arbitrary foundation lying on soil layer over bedrock" respectively. Both expressions, proposed by FEMA 450 (2003), produce almost identical results, indicating that the examined H/B ratio is rather large to interfere to the calculation of the effective period value. On the other hand, the observed difference between (a) and (b) is quite large considering that they refer to the same subsoil conditions and equivalent foundation properties (i.e. square and arbitrary footing shape). Furthermore, it is evident from Table 1 that when the thickness of the soil layer underneath the foundation is small compared to the characteristic footing dimension, the impedance factor is increased compared to the case of uniform halfspace (which occurs when H/B approaches infinity). This is not depicted in Fig 4 where the foundation case (d) constantly presents larger values of effective period (i.e. smaller overall stiffness) compared to any other case, even though the corresponding stiffness parameters where already overestimated during the calculations since the horizontal dynamic coefficient was assumed equal to 1 as mentioned previously.

It is therefore deduced from all the above observations, that in order to make an accurate estimation of the effective period it is not compulsory to consider in great detail the particular characteristics of the involved subsoil conditions and foundation properties, at least for cases similar to the ones examined here. A rough description of the soil-structure system in terms of subsoil geometry and foundation shape, along with the proper determination of the soil type and structural mass, height and fixed base period, seem to provide a satisfactory effective period value. The variation in the case of the utilized theoretical relationships lies in relatively small values, not exceeding 15-20% between the different calculations, verifying the coherence amongst the aforementioned expressions. Taking into consideration the inherent difficulties in the prediction of the dynamic characteristics due to soil-structure interaction, a more detailed description of the system's dynamic response than simply the estimation of T_{SSI} may require the thorough procedures proposed in the corresponding references.

It is evident in all examined structural periods that the numerical results tend to slightly underestimate compared to the existing analytical expressions, the effective structural period when soil-structure interaction is considered. Yet, from a preliminary evaluation of the obtained results, both employed numerical codes seem to follow closely the trend of the T_{SSI} variation with different soil-structure combinations. Effective periods calculated with ANSYS are closer to the theoretical solutions in the case of 0.2s and 0.4s structures, whereas in the case of the 0.6s structure it is ADINA calculations that fit better the theoretical results. In general, effective period values calculated with ADINA appear to form a lower bound to the examined approaches, presenting a constant deviation compared to theoretically calculated values. On the other hand, ANSYS results do not present a uniform pattern. In certain cases it coincides with the analytical results whereas it is failing to follow the trend observed by the various analytical approaches in the specific case of 0.6s structure.

When higher structures are investigated, the interaction effects become more significant resulting in increased effective period with structural height as presented in Fig. 5 for the specific structure of 0.4s fixed base period and normalized structural mass equal to 1. Numerical investigation with ADINA code revealed an even better agreement between theoretical predictions and numerical simulations. Indeed numerical results lie within the range of the theoretical calculations, indicating an efficient modelling of the interaction phenomena in terms of structural period modification.

APPLICATION OF SUBSOIL STIFFENING INTERVENTION

An interesting question within the context of the present paper concerns the effective period modification due to subsoil interventions of limited scale in the foundation area. Indeed several interventions result in subsoil stiffness increase in order to enhance soil strength and reduce settlements. The indirect consequence of similar mitigation methods would be the modification of the soil-structure system's dynamic properties, altering simultaneously the seismic response in the case of an earthquake event (Kirtas et al., 2006b).

The specific intervention case examined here, refers to a soil shear modulus increase by a factor of 10, resulting in a much stiffer soil formation compared to the initial conditions at a specific area below foundation (Fig. 6). Therefore, soil category D with a reference shear modulus value equal to 18 GPa, after the intervention is assumed to obtain a G value equal to 180 GPa, corresponding to shear wave velocity of 316 m/s. Such an increase implemented in soil type B would result in a mixture that can no longer be characterized as soil, since the modified shear wave velocity is larger than 1000 m/s resembling properties of soft rock formations. Thus, the theoretical predictions in the diagrams of Fig. 7 referring to soil type B (marked as B* to denote enhanced soil stiffness), should not be taken into consideration since the modified soil properties are outside the valid range of the corresponding relationships. Moreover, during the evaluation of the effective period, an inherent deviation is expected between the theoretical predictions and the numerical simulations due to the partial application of the soil stiffness enhancement. Indeed, theoretical predictions utilizing the modified soil stiffness would actually concern a general mitigation in the surface layer over the whole area beneath the foundation, providing therefore erroneously smaller effective period estimates in the present case that only a limited area is modified.

Observation of the effective period variation in Fig. 7 verifies the above prediction. Theoretical relationships result systematically in smaller effective period values compared to the numerically obtained results. The inadequacy of the analytical relationships to predict the T_{SSI} value without the proper consideration of the limited intervention extent is therefore evident, especially when soft soil conditions and large superstructure mass characterize the initial soil-structure case. The relative deviation between ADINA and ANSYS is similar to the one observed in the reference soil-structure systems, yet this time forming the upper bound of the illustrated values. Comparison of numerical results between Fig.4 and Fig. 7 is indicative of the significant intervention effect, leading the structural response to frequencies closer to the fundamental frequency of the fixed base structure.

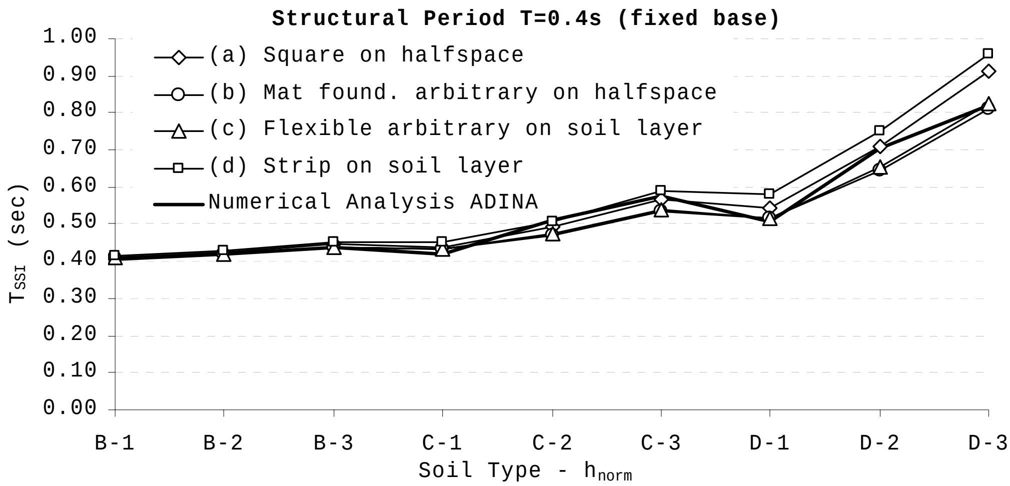

Figure 5. Effective period variation with soil type-normalized height combinations

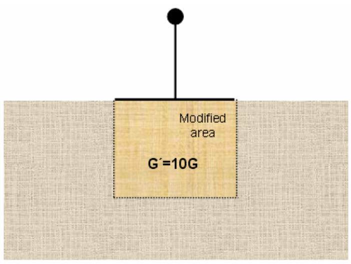

Figure 6. Application of soil stiffness enhancement below foundation

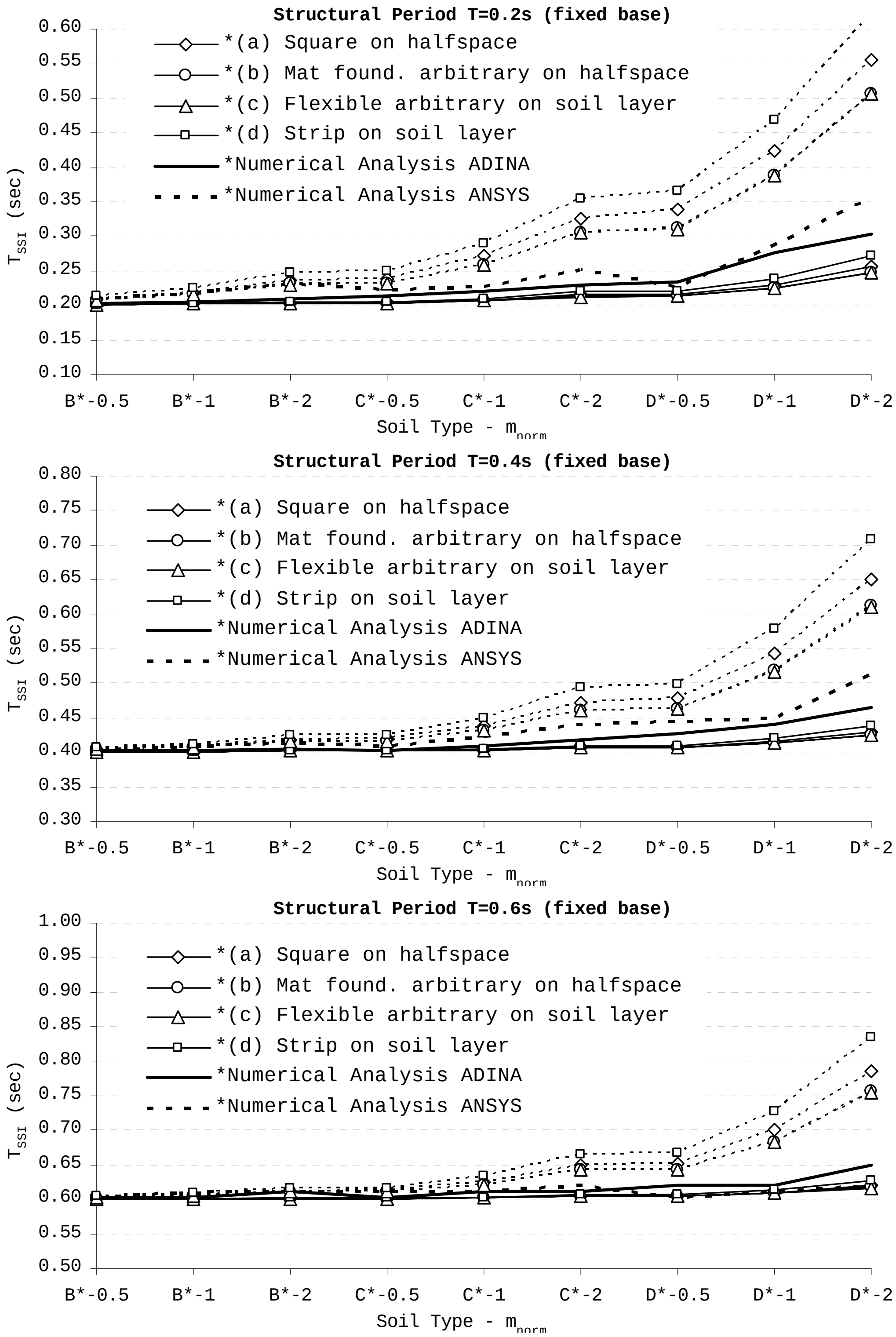

Figure 7. Effective period variation with soil type-normalized mass combinations (stiffened soil) (Theoretical calculations of the unmodified soil case are depicted in discontinuous lines)

CONCLUSIONS

The effective structural period in several soil-structure cases has been estimated using popular theoretical expressions and numerical simulations with FE codes ADINA and ANSYS. Subsoil conditions refer to soil categories B, C and D whereas three structural fixed base periods as well as three different superstructure masses have been implemented during the investigation to include a wide range of representative soil-structure cases. Validation of the effective period calculations from the numerical simulations that was based on theoretical solutions, revealed a satisfactory approximation of the structural period modification due to soil-structure interaction. Application of the same comparison in soil-structure cases of locally mitigated subsoil area beneath the foundation, indicates the induced reduction of the effective period due to similar interventions of enhanced soil stiffness. Yet the inadequacy of the analytical relationships to predict the T_{SSI} value without the proper consideration of the limited intervention extent is evident.

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