ESTIMATION OF
ACCELERATION RESPONSE SPECTRA OF FLOOR (ARSF)

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ABSTRACT :

The excitations felt by nonstructural component within a building is due to effects such as the location within the building and the relationship between the building frequency of motion and those of the nonstructural component. Several methods have been used to estimate the effect of earthquake excitations on nonstructural components. Building codes and recommended provisions have included approximate formulas for calculating an effective seismic force for both rigid and flexible acceleration sensitive nonstructural components. The design forces for some flexible acceleration sensitive nonstructural components are based on Acceleration Response Spectra of Floor (ARSF) calculated for each floor of the building, however the calculation of the ARSF is a cumbersome task to be used for most buildings. In this study, ARSF are calculated by Nonlinear Time History Dynamic Analyses (NTHDA) for structural models using recorded ground motions. The results of these analyses are compared to NEHRP Provisions (BSSC 2003) procedure for calculating building floor accelerations.

KEYWORDS : Acceleration Response Spectra of Floor, Nonstructural Components

1. INTRODUCTION

The design forces for acceleration sensitive nonstructural components are a function of the seismic demand and the expected ductility and overstrength. The seismic demand depends on the ground motion, the amplification of the ground motion at the location within the building to which the component is attached, and the amplification of the nonstructural motion due to resonance with the building at a certain model period (Kehoe and Hachem 2003).

The companion paper (Akhlaghi and Moghadam 2007) presents a simplified method for the height-wise distribution of Peak Horizontal Floor Acceleration (PHFA) to estimate the input acceleration for rigid acceleration sensitive nonstructural components. The components that can be considered rigid are identified by their fundamental period that should be lower than 0.06 seconds. If the weight of the nonstructural component is small compared to the weight of the structure, and also if the fundamental period of nonstructural component is more than 0.06 seconds, it is considered as a flexible nonstructural component. However, the dynamic interaction between the flexible acceleration sensitive nonstructural components and the input acceleration in this type of nonstructural components will be different and often higher from PHFA so acceleration demands can be estimated using Acceleration Response Spectra of Floor (ARSF). ARSF provide information of the inensity of the floor motion at different frequencies, and hence provide far more information than only the PHFA (Reinoso and Miranda 2004). Since the response of a flexible nonstructural component varies with its fundamental period, this variation in the response characteristics is best represented by the ARSF curves of the floor on which the flexible nonstructural component is supported (Singh et al. 2005).

This paper investigate the acceleration demands for the flexible acceleration sensitive nonstructural components. Since flexible nonstructural components could amplify the motion applied at their base, the 2003 NEHRP Provisions (BSSC 2003), the 2006 International Building Code (ICC 2006), and the SEI/ASCE 7-05 Standard (ASCE 2005) prescribe the use of an amplification factor (a_p) that related to rigidity of nonstructural components to estimate the seismic coefficient.

It reality, this amplification factor depends in a rather complex manner upon several parameters such as the ratio of the component period to the building period, component and building damping ratios, also the location of the component in the building (Singh et al. 2005). However, these complications are simplified and fixed numerical values for the a_p, either 1.0 or 2.5, have been provided in tables in the 2003 NEHRP Provisions (BSSC 2003), the 2006 International Building Code (ICC 2006), and in SEI/ASCE 7-05 Standard (ASCE 2005) for various components. The value of $a_p = 1$ is for rigid components and rigidly attached components and the value of $a_p = 2.5$ is for flexible components and flexibly attached components or the components that are of some safety concerns or higher importance. The values of the amplification factors were based on the simplified amplification curve proposed by Soons et al. (1993).

There are several investigations about floor response spectrum, e.g., Reinoso and Miranda (2004), Singh (2005), and others. To estimate ARSF, information about the fundamental period, damping ratio and also the dominants modes of the building is needed.

In this investigation, the structural models and recorded ground motions introduced in the companion paper (Akhlaghi and Moghadam 2007) are used. The ARSF are calculated by the time history acceleration of floor obtained from NTHDA of structural models. The results of these analyses are compared to the 2003 NEHRP Provisions (BSSC 2003) procedure for calculating building floor accelerations.

2. COMPARISON OF ACCELERATION RESPONSE SPECTRA OF FLOOR (ARSF)

To investigate the Acceleration Response Spectra of Floor (ARSF) in this study, for each structural model and each earthquake time history, acceleration response spectra at four floors were generated. The four floors considered were taken as the roof level, the level at three-quarter of the height, the mid-height level, and the one-quarter height level of the structural model.

Figures 1 to 4 show a comparison of ratio of average of 5% damped acceleration response spectra of floor to acceleration response spectra of ground (relative ARSF) obtained from NTHDA for each one of the four soil types and also for all structural models at the levels of 0.25, 0.5, 0.75 and 1, respectively. In these figures, the relative ARSF obtained from each level for all structural models have approximately the same magnitude. For example the two peaks of relative ARSF at a level of structural model occur at fundamental period of the first and the second modes of structural models.

In these figures, the relative ARSF obtained from each one of the four soil types at each level of structural model are approximately the same, specially they mach at level of 0.25 of structural model. Also, these figures show how the frequency content of the relative ARSF are varied as height increases. For example the relative ARSF at all levels of structural models, have two peaks that occur at fundamental periods of first and second modes. At level of 0.25, these two peaks have the same magnitude and the peak on the fundamental period of first mode is amplified as level increases. It means that at level of 0.25, the contribution of both the first and the second modes are equal, and at higher levels the contribution of the first mode increases.

In the companion paper (Akhlaghi and Moghadam 2007) the fundamental period of both the first and the second modes of all structural models are mentioned.

3. COMPARISON OF ARSF and NEHRP (2003)

According to the 2003 NEHRP Provisions (BSSC 2003), the amplification factor (a_p) for flexible nonstructural component is equal to 2.5. Also according to it's proposed distribution of acceleration, the values of amplification coefficients of flexible nonstructural component at different levels are as shown in Table 1 :

Table 1. amplification coefficients of flexible nonstructural component at different levels

$(\frac{x}{h})$ Relative Height	$(1+2\frac{x}{h})$	a_P
0	1.0	2.50
0.25	1.5	3.75
0.50	2.0	5.00
0.75	2.5	6.25
1.00	3.0	7.50

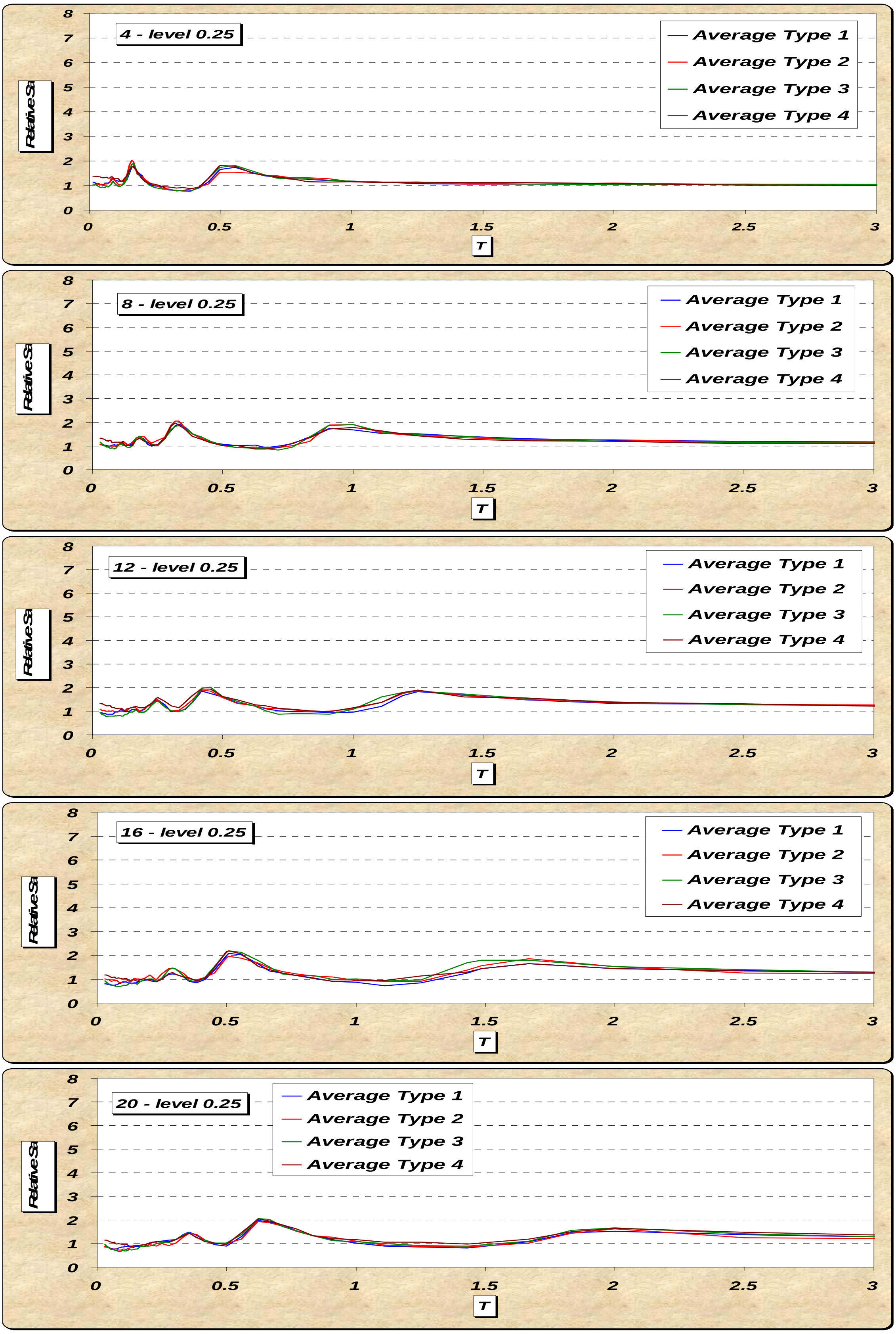

Figure 1. Comparison of average of relative ARSF for each one of the soil types and at the level of 0.25 of 4, 8, 12, 16 and 20 story models

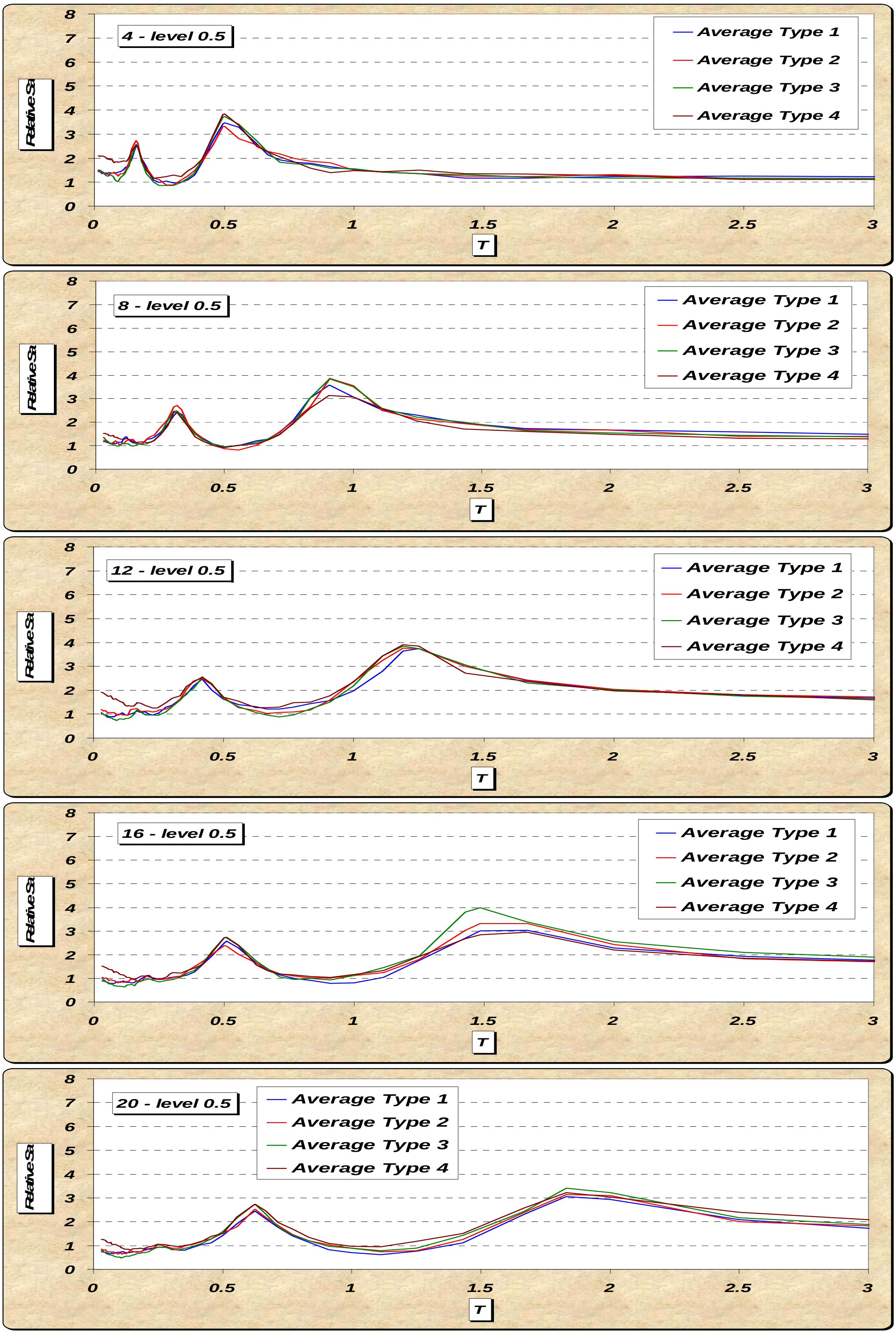

Figure 2. Comparison of average of relative ARSF for each one of the soil types and at the level of 0.5 of 4, 8, 12, 16 and 20 story models

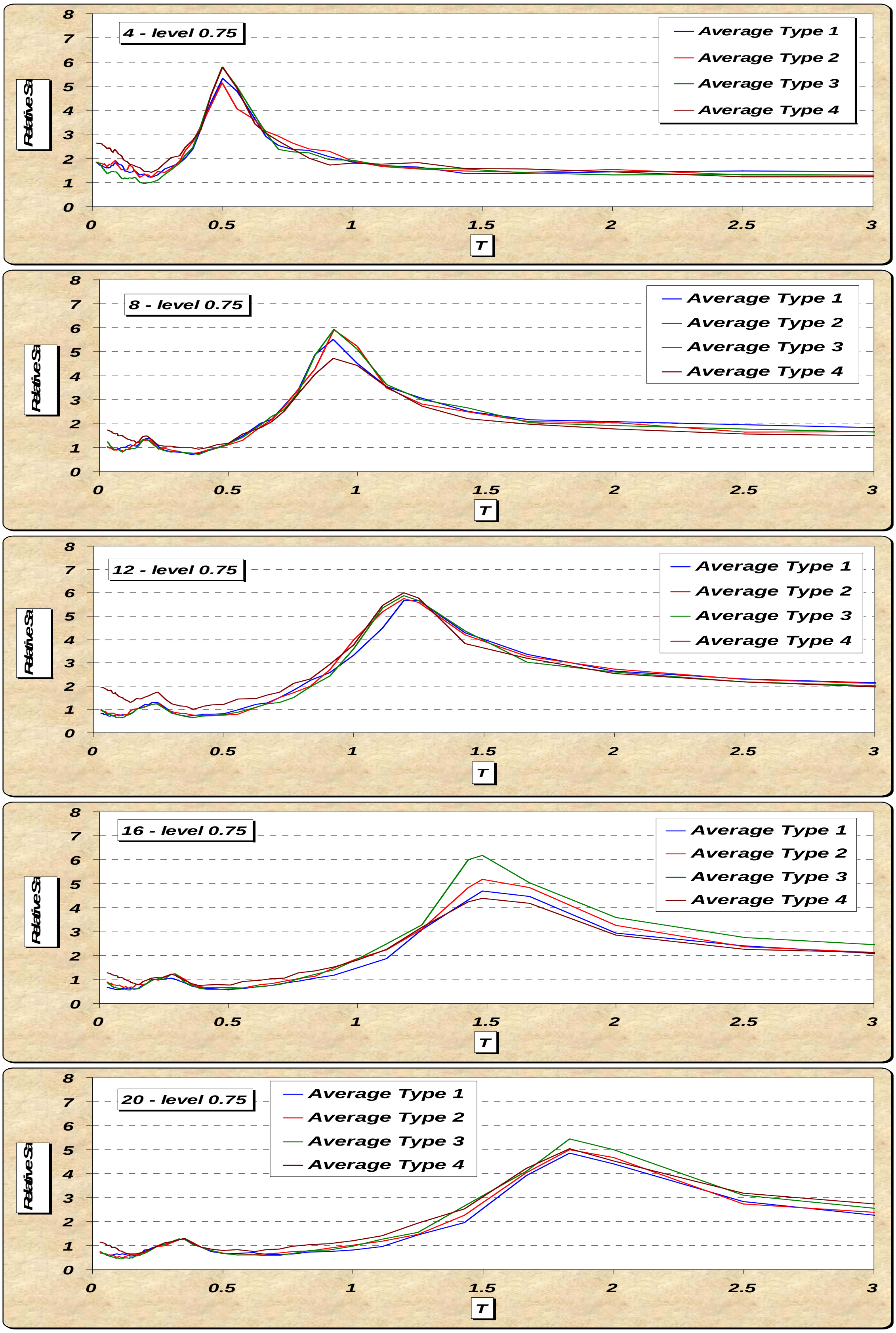

Figure 3. Comparison of average of relative ARSF for each one of the soil types and at the level of 0.75 of 4, 8, 12, 16 and 20 story models

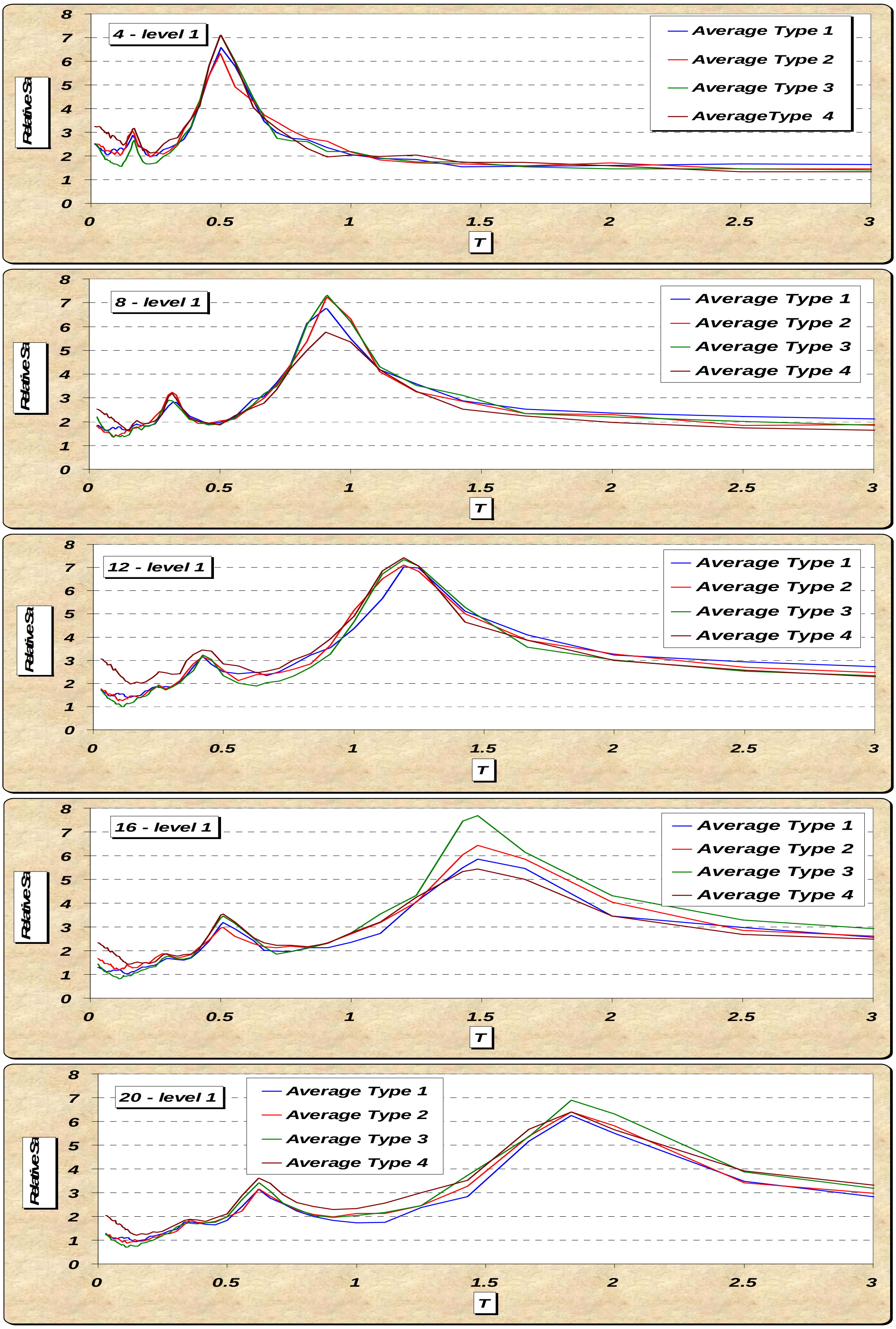

Figure 4. Comparison of average of relative ARSF for each one of the soil types and at the level of 1 of 4, 8, 12, 16 and 20 story models

Figure 5 show a comparison of ratio of average of 5% damped acceleration response spectra of floor to acceleration response spectra of ground (relative ARSF) obtained from NTHDA using the 28 earthquake excitations for each one of the structural models to the 2003 NEHRP Provisions (BSSC 2003) procedure at the levels of 0.25, 0.5, 0.75 and 1.
In this figure, the intensity of amplification factor for flexible nonstructural component proposed from the 2003 NEHRP Provisions (BSSC 2003), at the levels of 0.25 and 0.5 is conservative, and for other levels is approximatly equal to the peak ratio of ARSF.

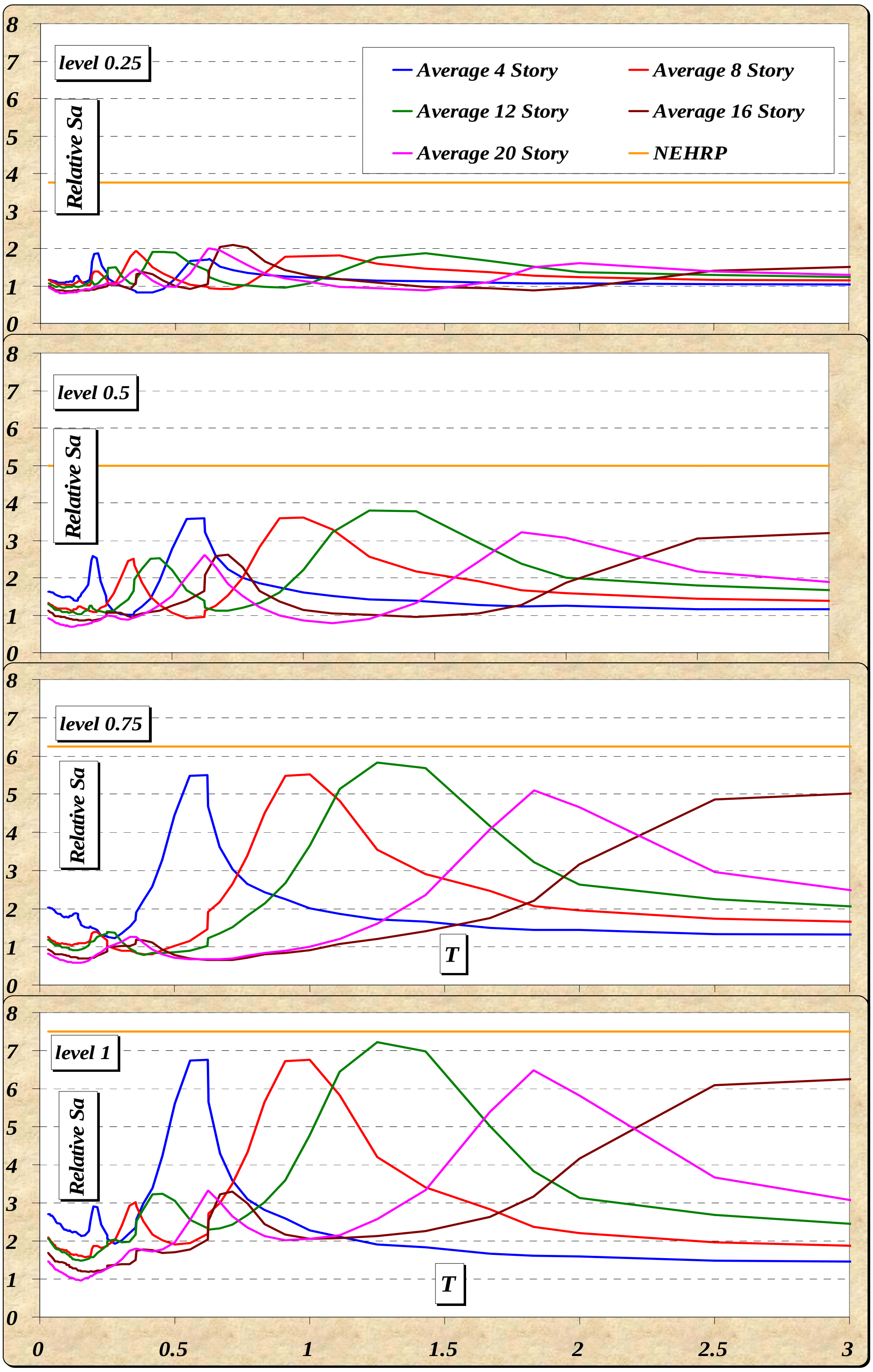

Figure 5. Comparison of ratio of average of ARSF for each one of models and the NEHRP (2003) procedure at the levels of 0.25, 0.5, 0.75 and 1

4. SUMMARY AND CONCLUSIONS

The paper presents an investigation about Acceleration Response Spectra of Floor (ARSF) for calculating the input acceleration for flexible acceleration sensitive nonstructural components.
The ratio of average of 5% damped acceleration response spectra of floor to acceleration response spectra of ground (relative ARSF) obtained from the structural models at the levels of 0.25, 0.5, 0.75 and 1 of the height.
Finally, the results of these analyses are compared to the 2003 NEHRP Provisions (BSSC 2003) procedure for calculating building floor accelerations. The results show that the intensity of amplification factor for flexible nonstructural component proposed from the 2003 NEHRP provisions (BSSC 2003), at the levels of 0.25 and 0.5 is conservative, and for other levels is approximatly equal to the peak relative ARSF.

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