CALIBRATION OF 1-D NUMERICAL CODES SOFTWARE FOR SITE RESPONSE ANALYSES

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Abstract

Ground response analyses are used to predict surface ground motions for development of design response spectra, to evaluate dynamic stresses and strains for evaluation of earthquake hazards, and to determine the earthquake induced forces that can lead to instability of earth-retaining structures. The effects of local soil on ground motion are commonly evaluated by performing numerical analyses either in frequency or time domains.

In order to evaluate the differences between frequency and time domain analysis, several analyses were conducted for homogenous stiff soil deposit with respective codes which are SHAKE and D-MOD2000. Linear and non linear analyses have been conducted. The non linear analyses with D-MOD2000 code have been carried out by using different frequencies in the Rayleigh damping formulation, i.e. fundamental and predominant frequency. For linear, PGA 0.1g is used in the analysis while for non linear PGA is scaled into three different value of 0.1, 0.3, and 0.5g.

The results for both linear and non linear approach are similar. For the non linear analyses, it is shown that the curves derived using predominant frequency perform better than those using fundamental frequency. Main differences are for non linear approach where the differences between two codes are higher for higher input motion. As the calibration using predominant frequency between the two codes perform good, the respective codes are applied to evaluate soil response in Sant' Agostino and San Carlo, in terms of PGA, due to May 20th 2012 Emilia Earthquake. There are 139 accelerometric station recorded strong motion. In this analysis, we consider one record which is in Mirandola station, the closest recording station where the Magnitude in epicentral area was 5.9 and 5.8 in Mirandola station. The recorded surface motion in Mirandola is transferred to the bedrock in 112 m depth and used as input motion for the two evaluated sites, San Carlo village and nearby municipality Sant'Agostino on 17 km distance from Mirandola station. The preliminary data presented here shows the PGA recorded in the bedrock of Mirandola station is 0.75g, while in Sant'Agostino and San Carlo is 0.92g and 0.81g.

History:

Received: October 24, 2013
Accepted: November 13, 2013

First published online:
December 31, 2013

Keywords:

Fundamental frequency
Predominant frequency
Rayleigh Damping

1. Introduction

Site response analysis has taken an important role in seismic hazard assessment in finding appropriate methods to reduce the magnitude of the earthquake. Kramer (1996) stated evaluation of ground response is one of the most crucial problems encountered in geotechnical earthquake analysis. Ground response analyses are used to predict surface ground motions for development of design response spectra, to evaluate dynamic stresses and strains for evaluation of liquefaction hazards, and to determine the earthquake induced forces that can lead to instability of earth-retaining structures.

The acceleration spectra are used for predicting the effect of earthquake magnitudes on the relative frequency content of ground-bedrock motions. Even though seismic waves generally travel tens of kilometers of rock and less than 100 m of soil, the soil plays a very important role in determining the characteristics of ground motion (Kramer, 1996). Site response itself, defined as modification of the characteristics of the seismic ground motion such as amplitude, frequency content, and duration. The modification is manifested as an amplification or de-amplification of ground motion amplitudes which is depend on site conditions include morphological and stratigraphic characteristics of soil and rock deposits as well as their physical, mechanical, and dynamic properties of soil.

The importance of site effect is quantified with the increasing number of strong motion measurements all over the world. Seed and Idriss (1982) stated the local soil conditions are one of the most important factors affecting the 'free field motions' at the earth surface. Two objectives of this paper is, firstly, calibrating time domain software to frequency domain software in order to choose the control frequency in Rayleigh damping that minimize the variation of damping. Secondly is the quantitative evaluation on site response problem to selected struck on May 20th 2012 Emilia Earthquake.

2. Research Methodology

The research conducted at Sapienza University of Rome from June 2012 to October 2012. The data presents here is preliminary.

Calibration of time domain software (D-MOD2000) to frequency domain software (SHAKE)

Five real outcropping accelerograms were selected from a recently developed Italian database. For each recording of the earthquake name, date, and magnitude along with the peak ground acceleration (PGA) is reported in Table 1.

Table 1. Earthquake records used as input motion for site response analyses

Recording Station	Earthquake (dd/mm/yy)	Mw	PGA (g)	fp	Fm
Assisi Stallone – NS	Umbria Marche – 29/09/1997	6.0	0.19	3.125	3.003
Cascia – NS	Umbria Marche – 14/10/1997	5.6	0.05	3.846	2.252
Pontecorvo – NS	Lazio Abruzzo – 07/05/1984	5.9	0.06	2.778	2.331
Tolmezzo Diga Ambiesta – NS	Friuli – 05/06/1976	6.5	0.36	3.846	2.559
Torre del Greco – NS	Irpinia – 23/11/1980	6.9	0.06	1.515	1.736

The model assumed is stiff soil deposit consisting of homogenous layer which overly on bedrock (Figure 1). The total thickness of the soil deposit is assumed H=30m. V_s is 360 m/s, and unit weight equal to 20 kN/m^3. For the bedrock, unit weight and shear wave velocity were assumed equal to 22 kN/m3 and 800 m/s (Ding, et al., 2008).

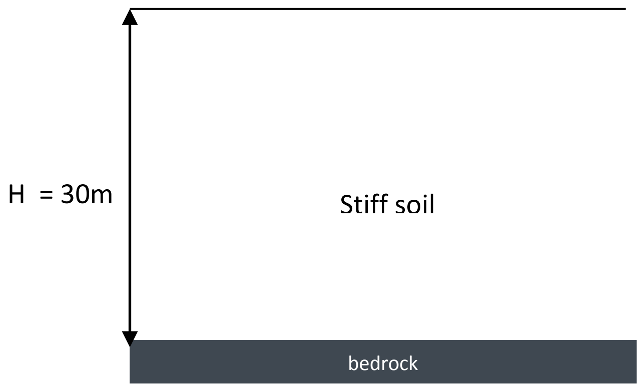


Figure 1. Model of bedrock interface

For the initial analysis, comparation between fundamental frequency (f_0) and predominant frequency (f_p) is conducted using SHAKE and D-MOD2000. As predominant frequency curves perform better than fundamental frequency (Figures 2-3), the following analysis is conducted through linear and non linear by scaling the accelerograms to 0.1g, 0.3g, and 0.5g.

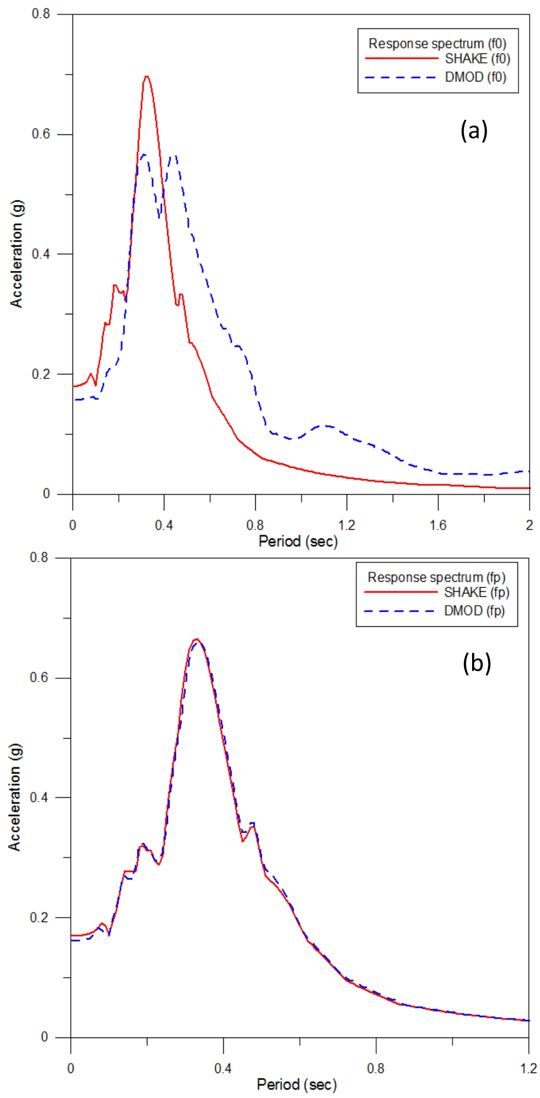
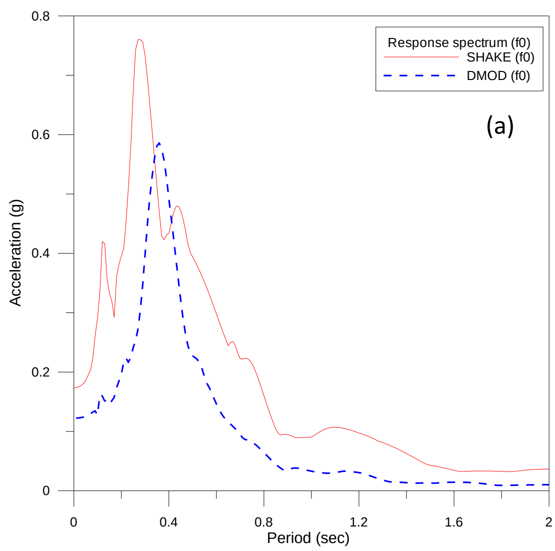


Figure 2. Assisi response spectrum from SHAKE and D-MOD using: (a) fundamental frequency (f_0); (b) predominant frequency (f_p)



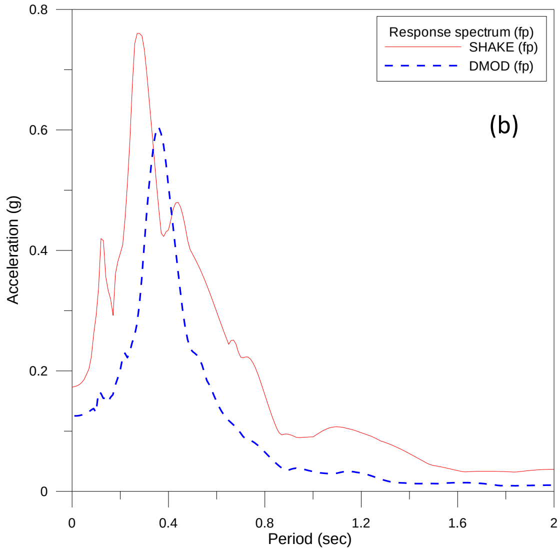


Figure 3. Cascia response spectrum from SHAKE and D-MOD using: (a) fundamental frequency (f_0); (b) predominant frequency (f_p)

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Since both time domain and frequency domain software are calibrated, it used to conduct quantitative analysis for site response at Emilia, to measure PGA at Sant' Agostino and San Carlo sites using preliminary database.

Database derived is surface motion from Mirandola station (MRN) which is 17 km's far from the two evaluated sites. The surface motion is transferred to the bedrock using calibrated software and used to measure the site response at Sant' Agostino and San Carlo in terms of PGA.

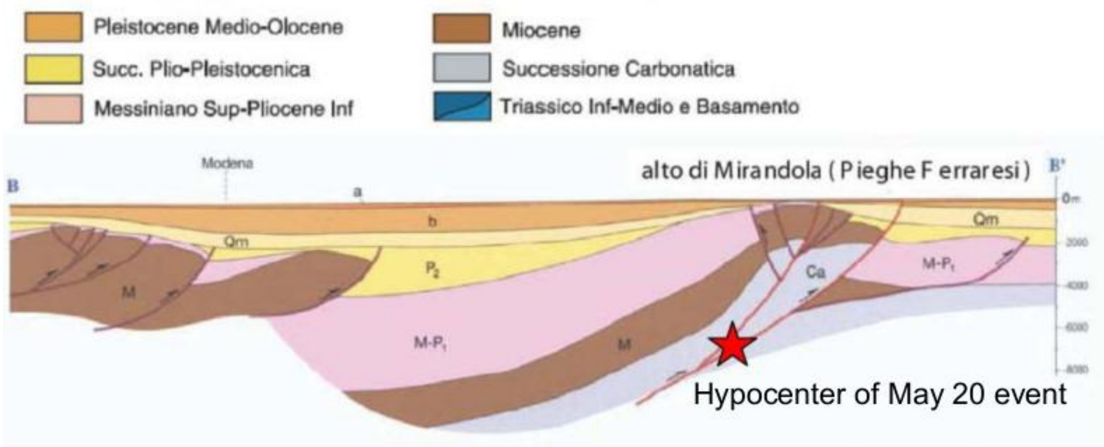


Figure 4. Soil stratigraphy in Mirandola station

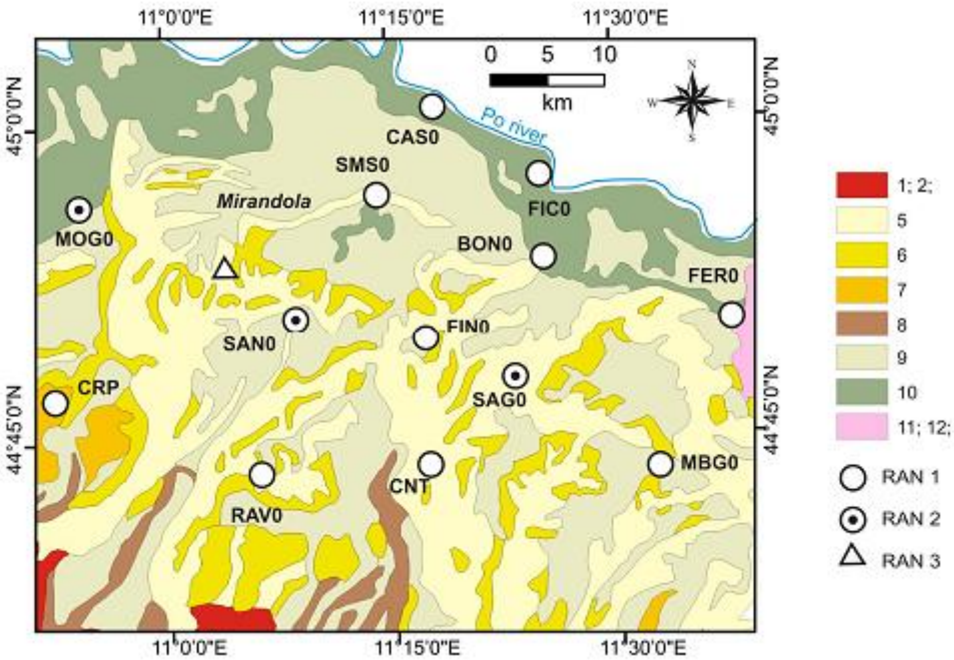


Figure 5. Geological map and temporary network distribution (Source: EPICentre, 2012)

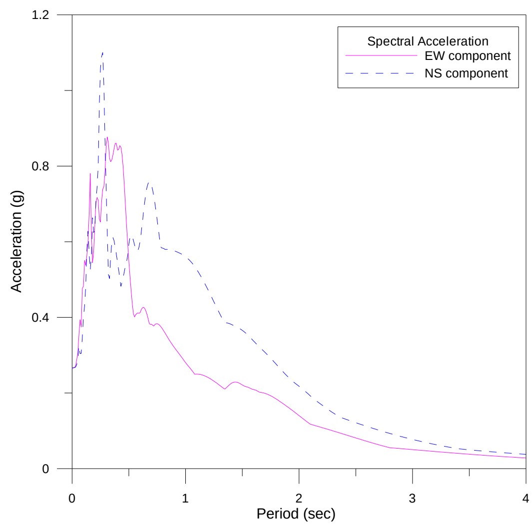


Figure 6. Recorded surface response spectra from MRN for EW-NS component

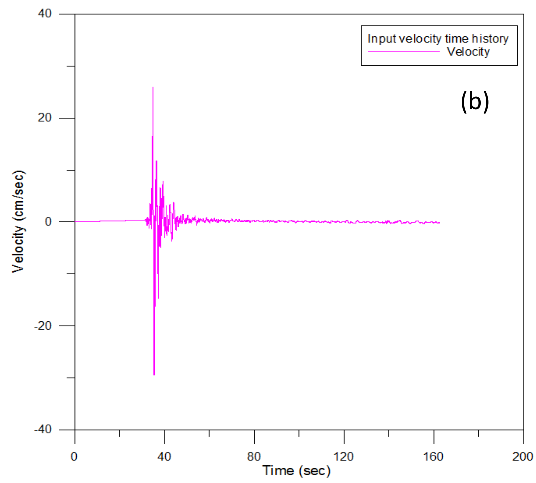
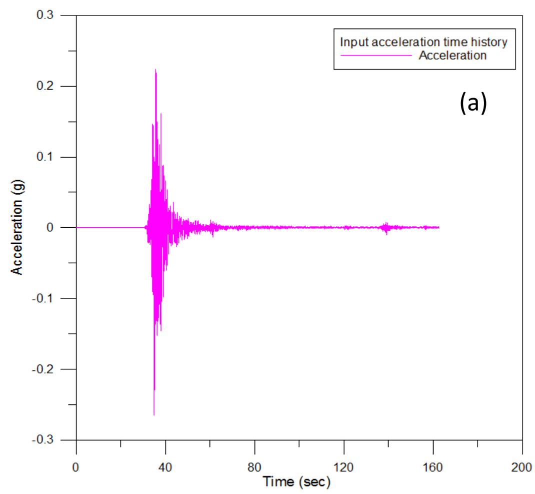


Figure 7. Time history from MRN for EW component : (a) acceleration, (b) velocity



3. Results and Discussion

The results for calibration of time domain software (D-MOD2000) to frequency domain software (SHAKE) shown in Figures 8-9 as follows.

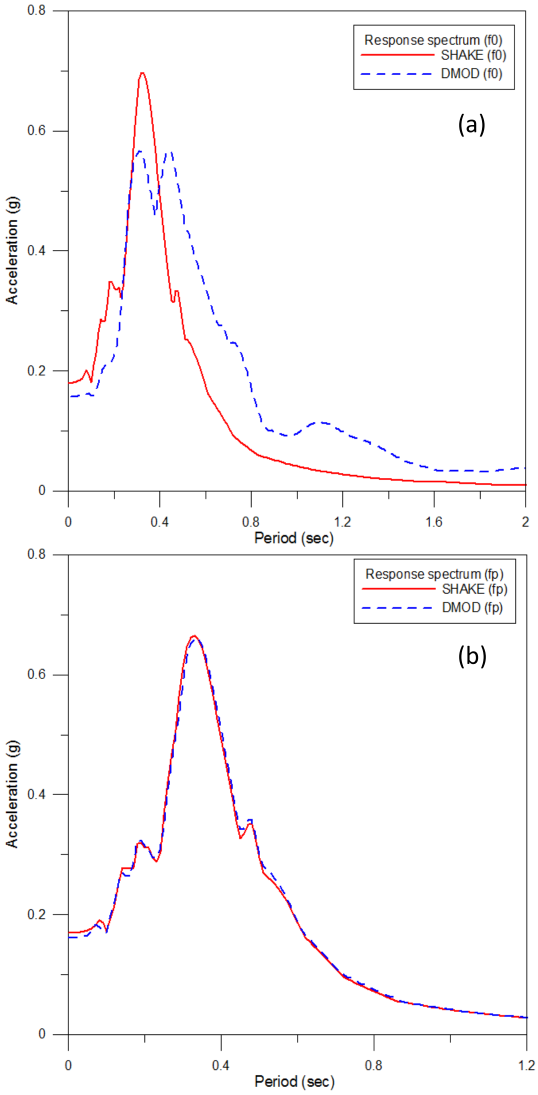
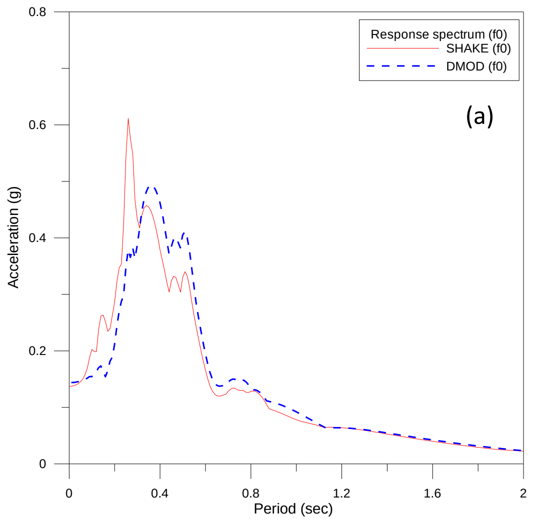


Figure 8. Assisi response spectrum from SHAKE and DMOD using: (a) f0 and (b) fp



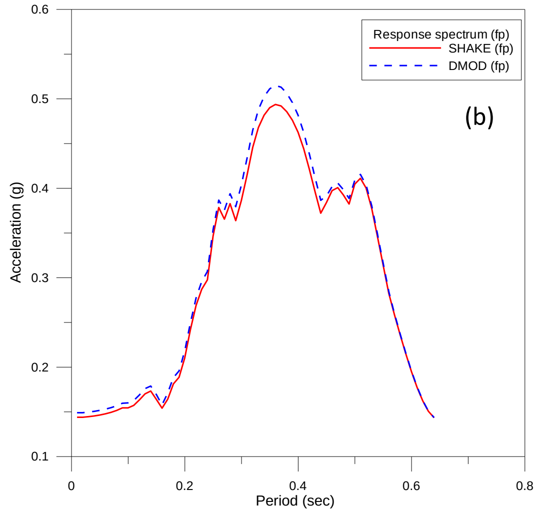
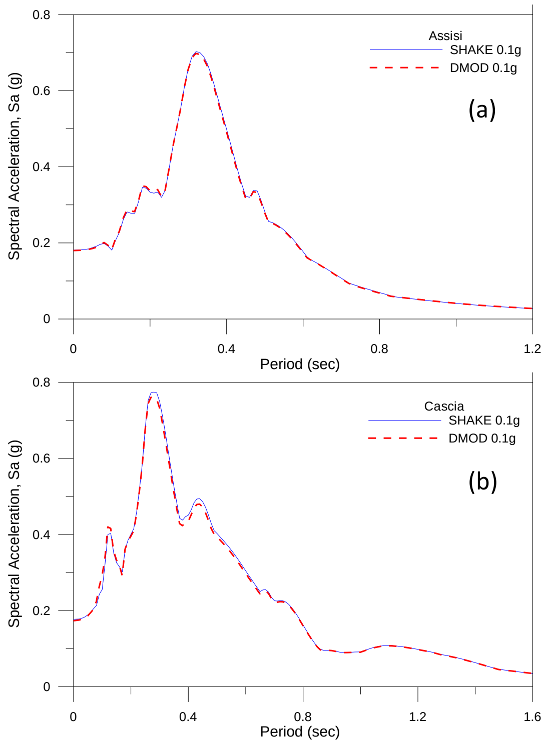


Figure 9. Tolmezzo response spectrum from SHAKE and DMOD using: (a) f0 and (b) fp

As results for predominant frequency performs good, the following step is to do the analysis for linear and non linear. Linear analysis is done for 0.1g while for non linear analysis, the curves is performed for PGA scaled to 0.1g, 0.3g, and 0.5g. Figure 10 below shows performance of curve for linear analyses.

Linear



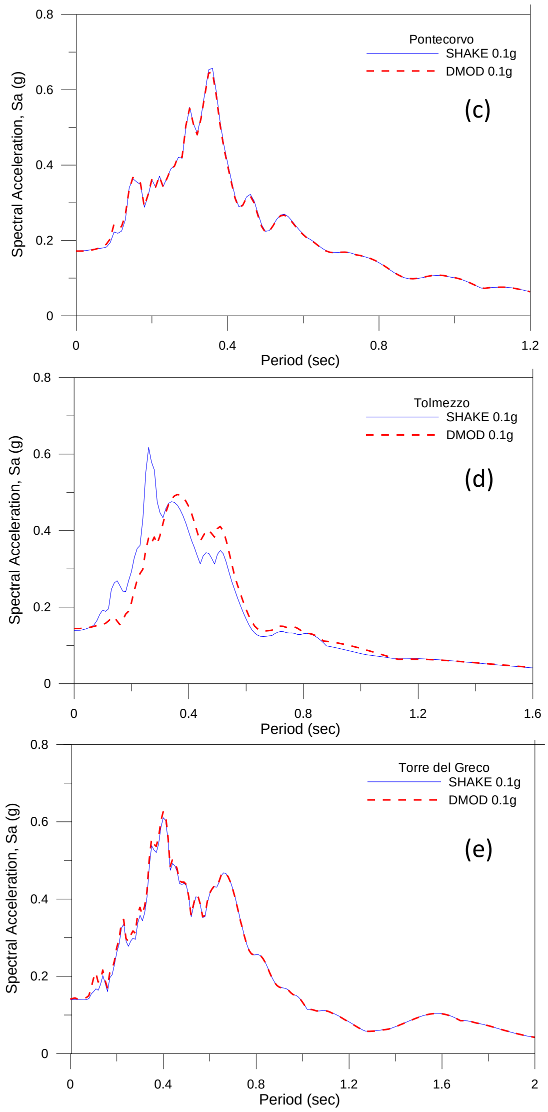
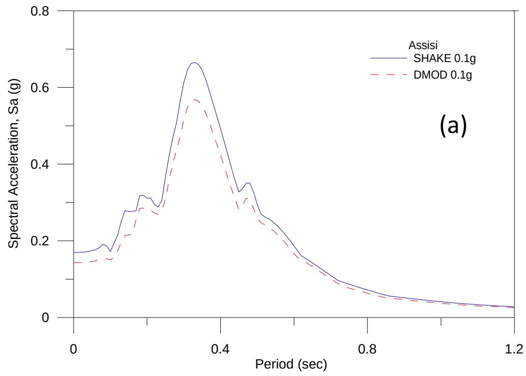


Figure 10. Linear response spectrum between SHAKE and D-MOD for PGA scaling o.1g (a) Assisi, (b) Cascia, (c) Pontecorvo, (d) Tolmezzo, (e) Torre del Greco

Non Linear



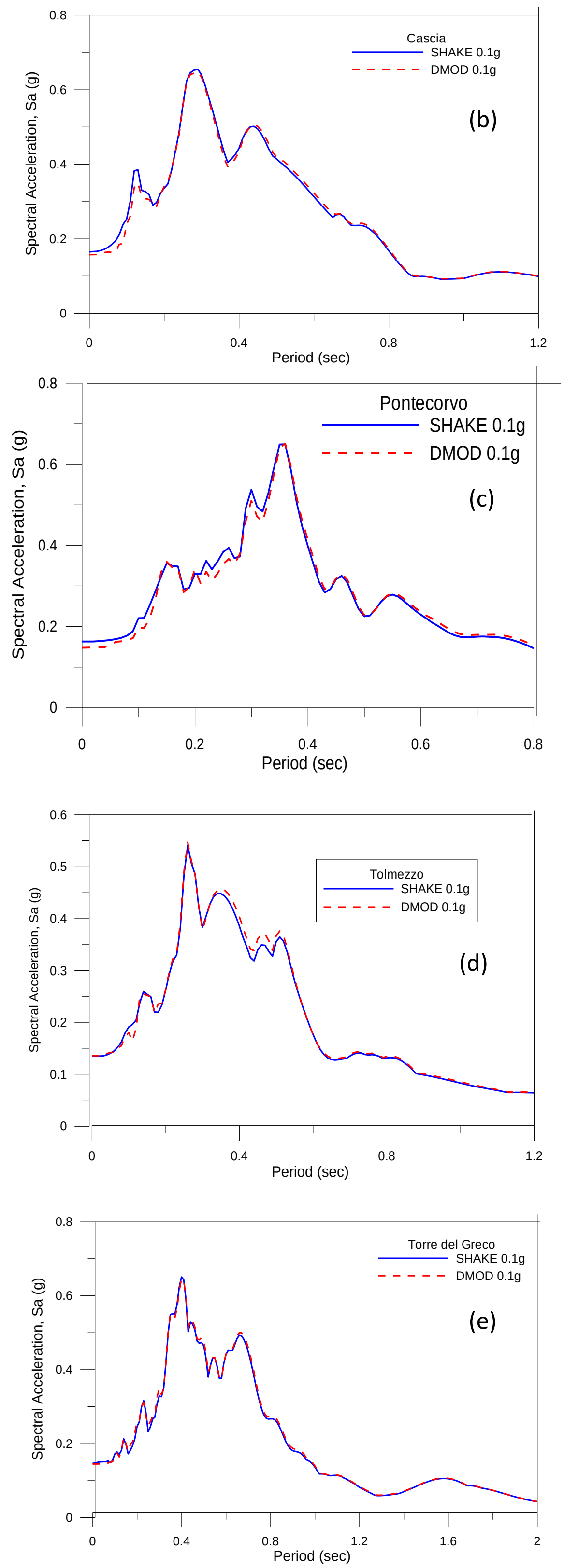


Figure 11. Non Linear response spectrum between SHAKE and DMOD for PGA scaling 0.1g: (a) Assisi, (b) Cascia, (c) Pontecorvo, (d) Tolmezzo, (e) Torre del Greco

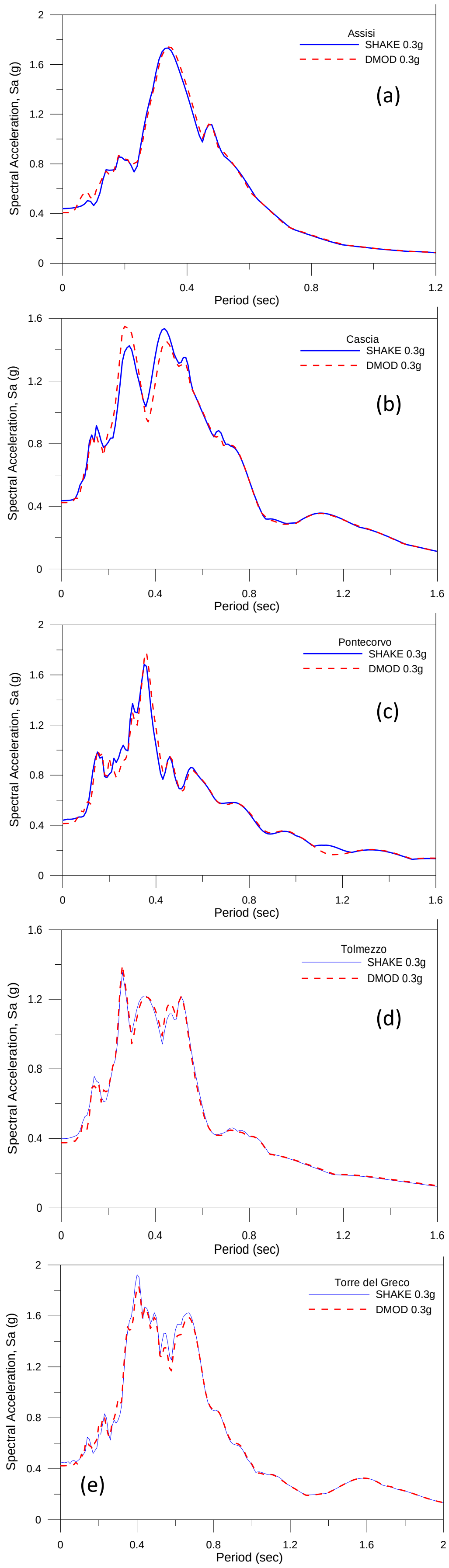


Figure 12. Non Linear response spectrum between SHAKE and DMOD for PGA scaling 0.3g: (a) Assisi, (b) Cascia, (c) Pontecorvo, (d) Tolmezzo, (e) Torre del Greco

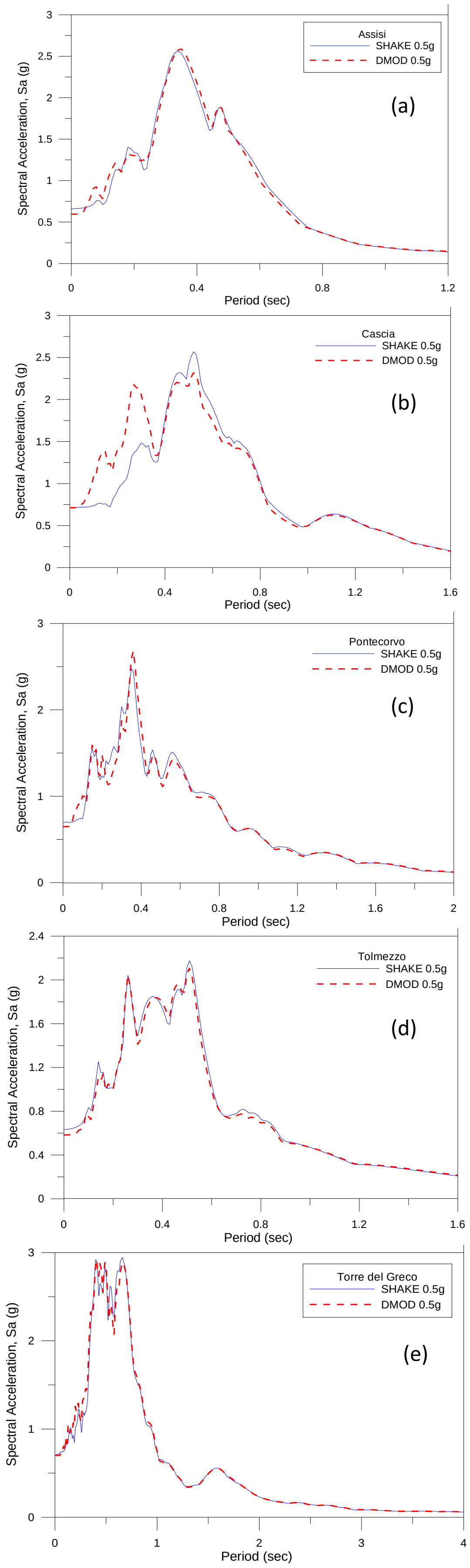


Figure 13. Non Linear response spectrum between SHAKE and DMOD for PGA scaling 0.5g: (a) Assisi, (b) Cascia, (c) Pontecorvo, (d) Tolmezzo, (e) Torre del Greco

There are slightly differences between performance of linear and non linear curves. While the differences seem clear as the scale PGA increased.

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Surface ground motion at Mirandola is transferred (deconvolve) to bedrock using respective frequency domain software (EERA) within frequency 20 Hz.

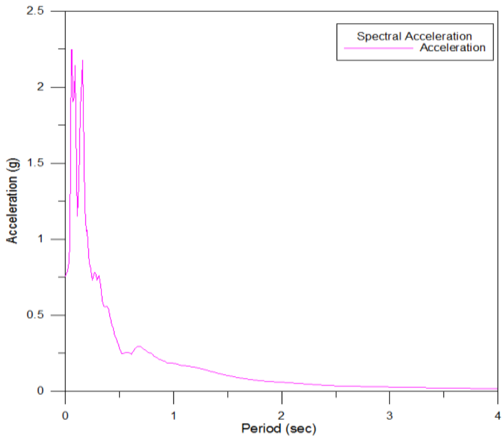

Figure 14. Deconvolve acceleration response spectrum of Mirandola station for EW component

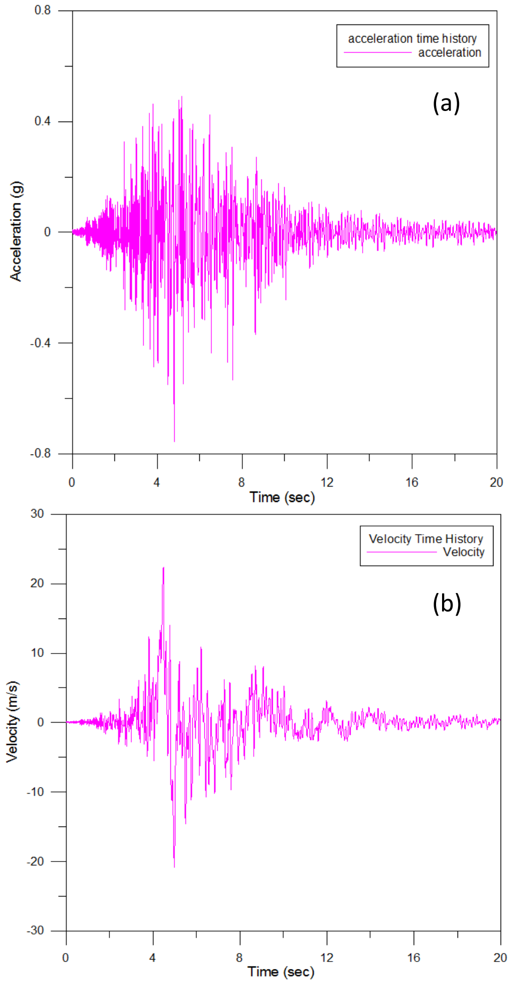

Figure 15. Deconvolve time histories of Mirandola station for EW component: (a) Acceleration, (b) Velocity

Direct Analysis

Sant' Agostino

Depth of the soil deposit and the density at the Sant' Agostino is determined 120 m and 17-19 kN/m^3. Albarello *et al.(2011),* proposed the joint inversion procedure for the reconstruction of the shear wave velocity profile in the four measurement zone (Figure 16) based on assumption of the variation of shear wave velocity with depth which follows a power law:

$$V_s = V_0.z^x \quad (1)$$

For Sant'Agostino (A1): V_0=75 m/s with x=0,53;
For San Carlo (A2, A3, A4): V_0=99 m/s with x=0,35;
For Mirabello (A5, A6): V_0=105 m/s with x=0,33;
For Mirandola (A7): V_0=133 m/s with x=0,32.

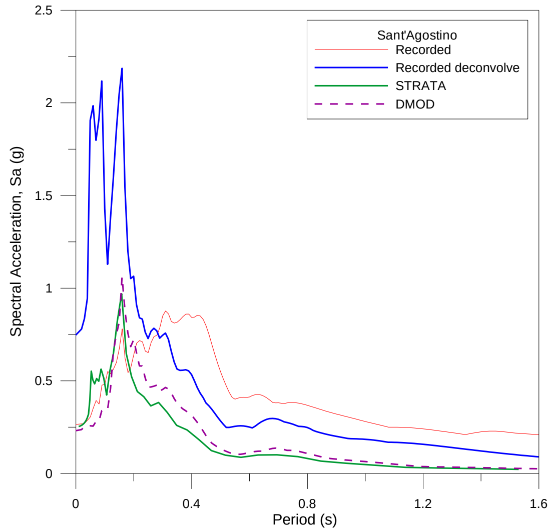

Figure 16. Direct analysis response spectra for Sant' Agostino

San Carlo

Depth of the soil deposit and the density at the San Carlo is determined 110 m and 17-19 kN/m^3. As mentioned before, the shear wave velocity profile for San Carlo is defined with the equation (1) proposed by Albarello *et al.,* (2011). Coefficient for V_0 is 99, z is depth of the soil deposit, and x is 0.35.

Figure 17 below shows preliminary result for San Carlo.

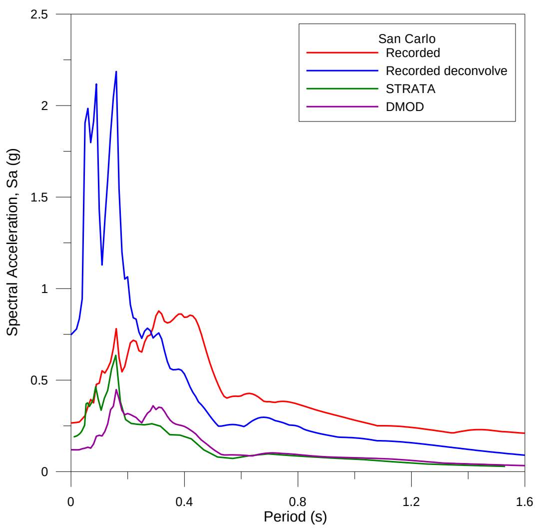

Figure 17. Direct analysis response spectra for San Carlo

Social Impact

Site response analysis can be used for determining the parameter response of an area to earthquake where the motion is recorded. Its parameter response will lead to construct better building standards in earthquake response.

4. Conclusions

After all the research activities undertaken in this thesis, it cean be summarized to a conclusion as follows:

1. Linear
   - f_p (predominant frequency of input motion) performs well than f_0 (fundamental frequency of soil deposit)
   - DMOD show results comparable to frequency codes (SHAKE/EERA/STRATA) if the reference frequency for Rayleigh damping coefficient is properly set
2. Non Linear
   - F_p (predominant frequency) performs better than f_0 (fundamental frequency of soil deposit)
   - Differences are higher for higher intensity of input motion: DMOD is a true non linear code while frequency codes adopt an equivalent linear approach
3. Preliminary results of deconvolution at Mirandola station show PGA=0.75g at rock outcropping, PGA=0.92g for Sant' Agostino and PGA=0.81g for San Carlo sites.
4. These preliminary results indicate the relevance of site effects and non linearity in the epicentral area of Emilia earthquake as the existence of soft soil at the shallow depth.

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