1D NONLINEAR SITE RESPONSE ANALYSIS OF DMDP AREA, BANGLADESH

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DHAKA, BANGLADESH

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by
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A thesis submitted to the Department of Civil Engineering, Bangladesh University of Engineering and Technology, Dhaka in partial fulfillment of the requirement for the degree of Master of Science in Civil Engineering (Geotechnical)

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Declared that, except for the contents where specific reference has been made to the work of others, the studies embodied in this thesis are the result of research work, carried out by the author under the supervision of Dr. Mehedi Ahmed Ansary, Professor, Department of Civil Engineering, BUET. Neither the thesis nor any part thereof has been submitted or is being concurrently submitted to any other educational institute for the award of any degree or diploma, except for publication.

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ABSTRACT

The purpose of this research is to perform 1D site response analysis using Standard Penetration Test (SPT) and shear-wave velocity of the Dhaka Metropolitan Development Plan area (DMDP), Bangladesh. Additionally, the result obtained from the 1D analysis has been validated through microtremor analysis result. For this purpose, fifty locations were selected in the study area and the selected locations maintain approximately a uniform distribution within the whole DMDP area. Most of the locations are located on reclaimed areas with sand filling up to a depth of 10 to 15m or more. The depth of boreholes varies between 30 to 85.5m depending on the SPT-N value of 65 or more in the last consecutive 3 layers. After completing SPT a 100mm PVC pipe was installed in the same hole to obtain shear-wave velocity using the seismic downhole technique. The shear-wave velocity beyond the borehole depth has been taken from CDMP 2009 data applying the closest pair of points between the test borehole to the CDMP test point.

For estimating site responses for those selected fifty locations, a computer program DEEPSOIL was used. Soil layer depth, unit weight, shear wave velocity (Vs) and soil shear strength as inputs, soil site responses were estimated by equivalent linear and non-linear analysis. Total ten input motions were used in these analyses, which were scaled to 0.13g value for bedrock in the Dhaka region. Besides, a microtremor recording has been carried out at every location of those fifty borehole locations. Microtremor data has been collected according to the guideline of SESAME. Finally, a Horizontal to Vertical spectral Ratio (HVR) curve has been obtained of the site to compare with the 1D response analysis.

From the detailed site-specific analysis, it was observed that the amplification factor of the study area ranges 3.1 to 5.5 for nonlinear analysis and 3.8 to 8.5 for equivalent linear analysis and the amplification factor obtained from microtremor analysis ranges 1.3 to 6.6. In areas of thick and soft Holocene deposit the amplification is more than the areas where shallow valleys of Pleistocene deposits with artificially filled sand or any clay in top layer. The peak spectral acceleration (PSA) for 50 sites varies between 0.41g to 0.80g in the case of nonlinear analysis whereas the range of PSA is 0.50g to 1.12g for equivalent linear analysis. It also observed that, the peak ground acceleration (PGA) of the study points ranges 0.17g to 0.26g for non-linear analysis and 0.22g to 0.43g for equivalent linear analysis.

TABLE OF CONTENTS

LIST OF FIGURES

Page

LIST OF TABLES

List of Abbreviations and Acronyms

ASTM	American Society for Testing and Materials
BNBC	Bangladesh National Building Code
CDMP	Comprehensive Disaster Management Programme
DMDP	Dhaka Metropolitan Development Plan
EL	Equivalent Linear
ESM	European Macroseismic scale
GPS	Global Position System
GSB	Geological Survey of Bangladesh
HVSR	Horizontal to Vertical Spectral Ratio
MSL	Mean Sea Level
NL	Nonlinear
SESAME	Site EffectS assessment using AMbient Excitations
SDHT	Seismic Down-Hole Test
SPT N	Standard Penetration Resistance number
SSR	Standard Spectral Ratio
PGA	Peak Ground Acceleration
PSA	Peak Spectral Acceleration
1D	1-Dimentional
f	Natural Frequency
Fg , f_0	Predominant Frequency
g	Acceleration due to Gravity
H	Thickness of soil deposit
M_S	Surface wave magnitude of an Earthquake
M_W	Moment Magnitude of an Earthquake
S_{HS}	Horizontal Spectrum on a soft site
S_{HB}	Horizontal Spectrum on a hard site
S_{VS}	Vertical Spectrum on a soft site
S_{VB}	Vertical Spectrum on a hard site
Vs	Shear Wave Velocity
V_b , v_b	Velocity of Basement
ρ	Density
ν	Poisson ‘s Ratio
μ	vertical particle displacement

CHAPTER 1
INTRODUCTION

1.1 GENERAL

Earthquake is a common natural disaster in the seismically active areas on Earth. Bangladesh is in a seismically moderate zone in the world seismic map prepared by Global Seismic Hazard Assessment Programme (GSHAP, 1992). The country is placed close to the border of two active plates: the Indian plate in the West and the Eurasian plate in the East and North. An earthquake of even moderate magnitude on Richter scale can deliver a mass graveyard in major cities of the country particularly Dhaka, Sylhet, and Chittagong (Mazumdar et. al., 2015). In the recent past, Bangladesh has not experienced any destructive large earthquakes; but, in the past few 100 years, several large devastating earthquakes have struck this area. So far, all the major recent earthquakes have occurred away from major cities and have affected relatively sparsely populated areas (Ansary and Rahman 2013). Specialists are expecting that a major earthquake may affect in near future considering elastic rebound theory method. During the propagation of the seismic wave in soil deposits, the characteristics of strong ground motion, amplitude, frequency content, and duration, are altered because of the influence of local geologic and soil conditions commonly referred to as local site effects (Manh and Chang, 2019). In seismology and earthquake engineering, site effects are broadly identified as an important factor for (mainly) amplifying the resulting surface ground motion.

The presence of deep soil deposits is especially complex for estimating the seismic ground motions and the response spectrum at various layers of a stratified deposit can be useful for earthquake resistant design of geotechnical structure (Kumar and Dey, 2015). Under specific conditions such as the site is laterally infinite, horizontally layered, the ground surface is free of stresses, and the soil is stiffer with the depth, seismic waves propagate in the vertical, i.e., normal to the layer's direction, in such conditions, the wave propagation in a three-dimensional nonlinear soil deposits are analyzed using one-dimensional ground response techniques which are simpler and significantly reduces the computational effort (Tombari and Stefanini, 2019) One dimensional analysis can be performed by employing various methods such as linear, equivalent linear and nonlinear approaches.

One-dimensional (1D) simulation of shear waves propagating vertically through shallow soil layers, also known as ground response analysis (GRA), is a common method for getting the effects of site response on ground vibration. Several constitutive models and numerical codes have been proposed for 1D site response analysis of horizontally layered soils subjected to vertically polarized S waves over the last decades. To assess the response spectrum, 1-dimensional ground response analysis can be conducted employing various methods (linear, equivalent linear and non-linear) in both time- and frequency domains (Jia et. al., 2020). Site-specific one-dimensional (1D) site response analysis is most often performed to quantify the nonlinear site effects.

Simplified one-dimensional (1D) nonlinear seismic site response relies on modeling three aspects of soil behavior: (1) the initial stress-strain (i.e., backbone) curve; (2) the unloading-reloading hysteretic behavior; and (3) the mechanism of excess pore pressure generation during dynamic excitation (Groholski et. al., 2016). One dimensional (1D) equivalent-linear (EL) or fully non-linear (NL) approaches can be used to assess the impact of the site stratigraphy and of the soil non-linear behavior on site effects. For a given input motion, the results of 1D site response analyses can be used to estimate peak acceleration values and response spectra at the ground surface as well as along the soil profile. In this thesis using a computer program DEEPSOIL both EL and NL approaches have been applied for estimating 1D site response analysis of selected sites. Additionally, a microtremor recording has been done for every selected point to validate the result of 1D model analysis.

1.2 DESCRIPTION OF THE STUDY AREA

The Global Earthquake Disaster Risk Index has placed Dhaka among the 20 most vulnerable cities in the world. With 7 million people living in the jurisdictional boundaries of Dhaka City Corporation and 15 million in the wider Dhaka metropolitan Development plan (DMDP) area, where the greater Dhaka area is particularly at risk (Ansary et. al., 2020). Additionally, Strong and sustained economic growth in Bangladesh continues to fuel massive population growth in the country’s cities: Dhaka alone contains 37% of total urban population, conforming to the classic case of primate city in which the population of the largest city is more than the combined total of the three next largest cities (Rahman, 2014). It is estimated that almost 34,000 people inhabit each square kilometer of the city, yielding a population density that is among the highest in the world (Dasgupta et al., 2015).

Dhaka is within the second seismic zone among four seismic zones of Bangladesh according to Bangladesh National Building Code (BNBC 2020) which covering the entire country. Sometimes in several research it has been predicted that an earthquake of up to magnitude 7.5 is possible within the country. Here the nearest fault line runs just 60 km from Dhaka city.

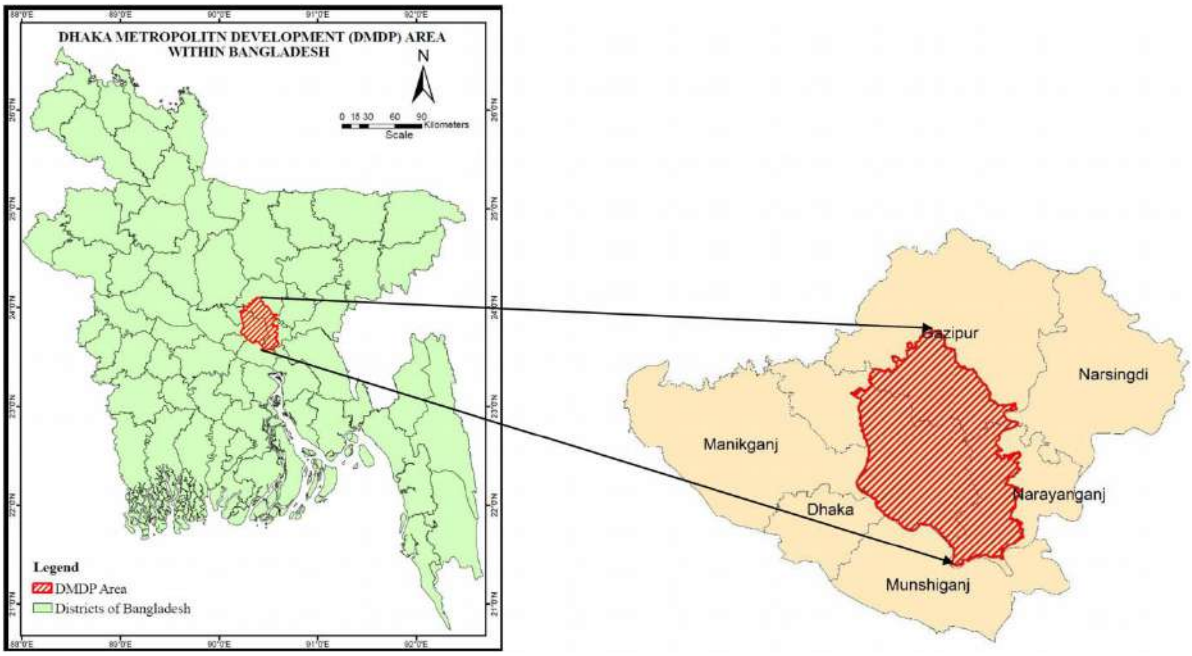


Figure 1.1 DMDP area with its surrounding region

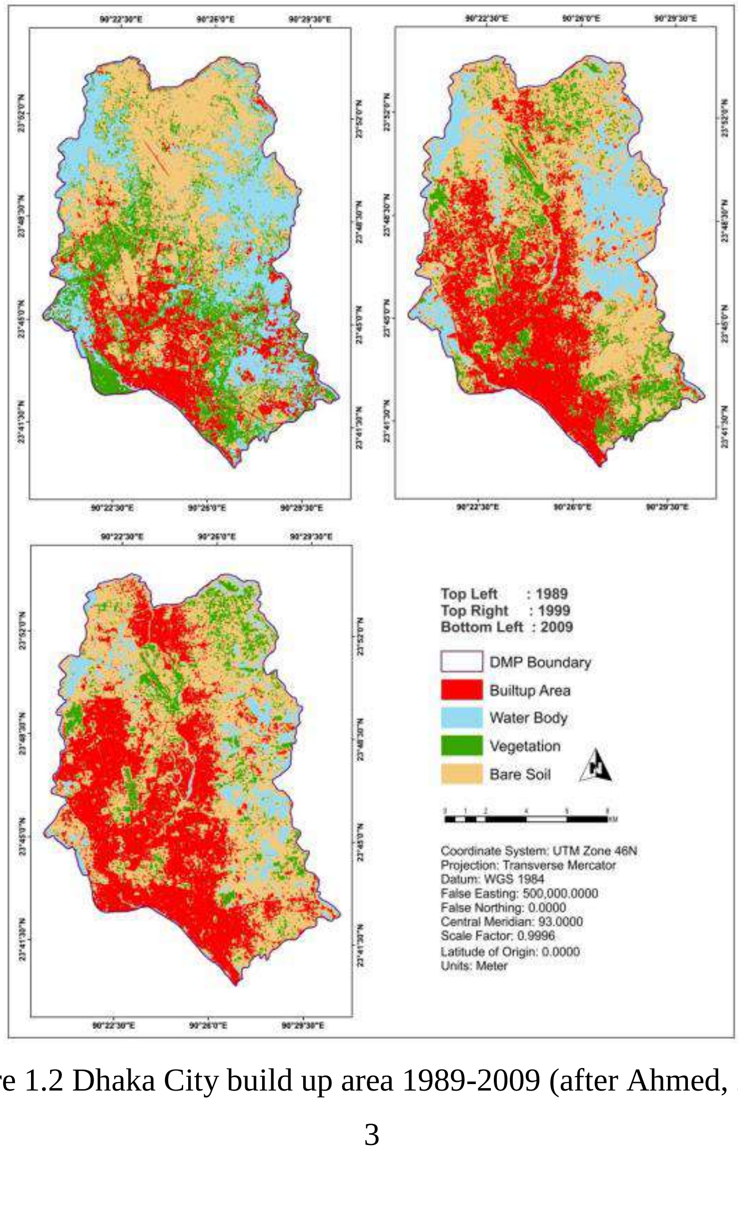


Figure 1.2 Dhaka City build up area 1989-2009 (after Ahmed, 2013)

Land use planning management and public service distribution in the urban areas of Bangladesh has failed to keep up with the pace of growth. As a result, the urban areas have been developed, being risky cities to disasters. In this research all test points have been selected within the DMDP area which can be come down with an idea of level of seismic hazards distribution for future planning, development, and safety of DMDP area.

1.2.1 Geology of the Study area

Dhaka City is occupying partly on the oldest unit named Pleistocene terrace (Madhupur Terrace) having highest elevation of 13m and partly on the Holocene floodplains having a minimum elevation of 2 m from mean sea level. The composite of Pleistocene terrace consists of yellowish brown medium stiff to very stiff clayey silt and medium dense to dense silty sand. Whereas in the Holocene floodplains are composed of gray to dark gray very soft to medium stiff clayey silt, soft silty clay and grey to yellowish brown very loose to medium dense clayey silt, silty sand (Rahman and Karim 2005). The soil deposits mainly consist of the fluvio-tidal deposits and Madhupur Clay deposits. The geological units of the study area are abandoned channel deposits, channel bar deposits, flood plain deposits, marshiland and depression deposits, natural levee deposits, alluvial gully deposits, valley deposits and madhupur clay deposits. Alam (1988) identified the following geological units in and around the Dhaka-Tongi area (Table 1.1).

Table 1.1 Stratigraphic succession in and around Dhaka-Tongi area

Age	Formation	Lithology	Thickness
Holocene	Alluvium	Lowland: River bed deposit: Grey sand and silty sand, medium to fine grained. *Local unconformity*	0-9
		Natural levee and interstream deposit: Sandy silt, silt and loam, grey and friable. Back swamp and depression deposits: Clay and silty clay, grey, bluish grey to dark grey	1.21-4.7 0.61-1.5
		Highland: Silt and clay above the present flood level	0-3.5
Pleistocene	Madhupur Clay	Red clay: Light brown to brick red and massive, pisolite with fossil wood, ferruginous and calcareous nodules and surficial deposits of slag. Mottled clay: Earthy grey with patches of orange, brown color, massive and containing calcareous and ferruginous nodules. Unconformity	31
Pliocene	Dupi Tila	Sandstone: Yellow to yellowish grey, massive, cross bedded, mostly fine to medium grained containing scattered gravel lenses, moderately consolidated	90+

Source: Karim and Haider (1999)

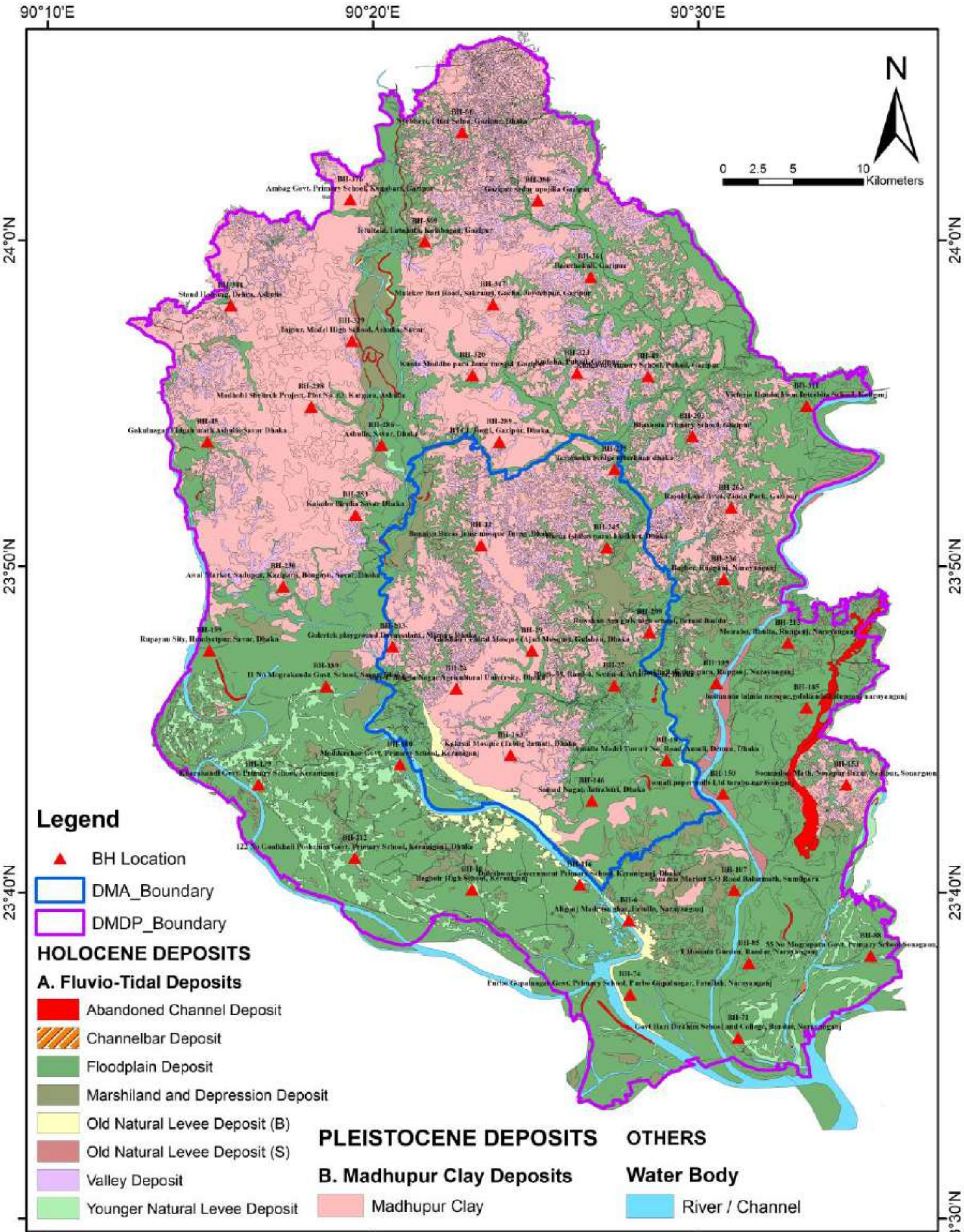


Figure 1.3 Geological Map of DMDP area

The Schematic geological cross section of DMDP area is presented in following Figure 1.4 and Figure 1.5. In the section, it is indicated that the stratum of Dhaka generally consists of three layers, which are Holocene soil including artificial fill, Pleistocene soil Madhupur Clay formation and Plio-pleistocene Dupi Tila formation.

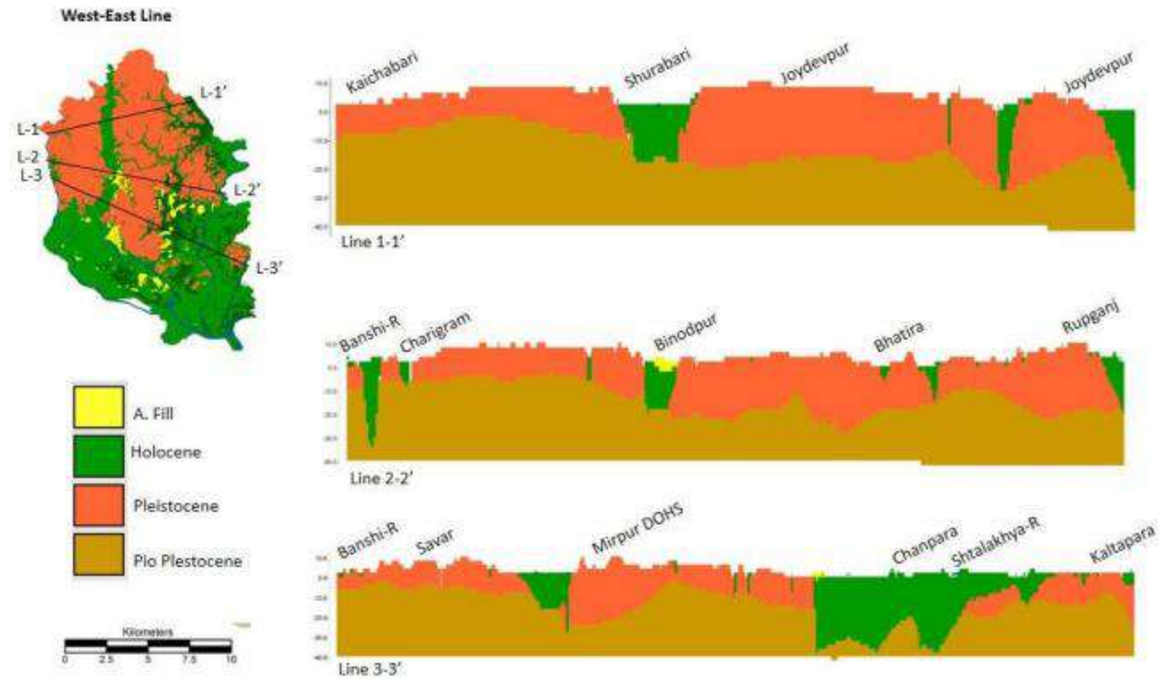


Figure 1.4 Geological Profile type West-East cross section of DMDP, Bangladesh (Source: Geological Survey of Bangladesh, 2017)

The thickness of Modhupur Clay gradually becomes thin or disappears in the direction of boundary of Dhaka. Dupi Tila disperses whole Dhaka, and surface of Dupi Tila in the central part and its surroundings are faced in shallow portion (shallower than twenty meter in depth from ground surface) and in the deeper portion (deeper than thirty meter in depth beside the boundary of Dhaka).

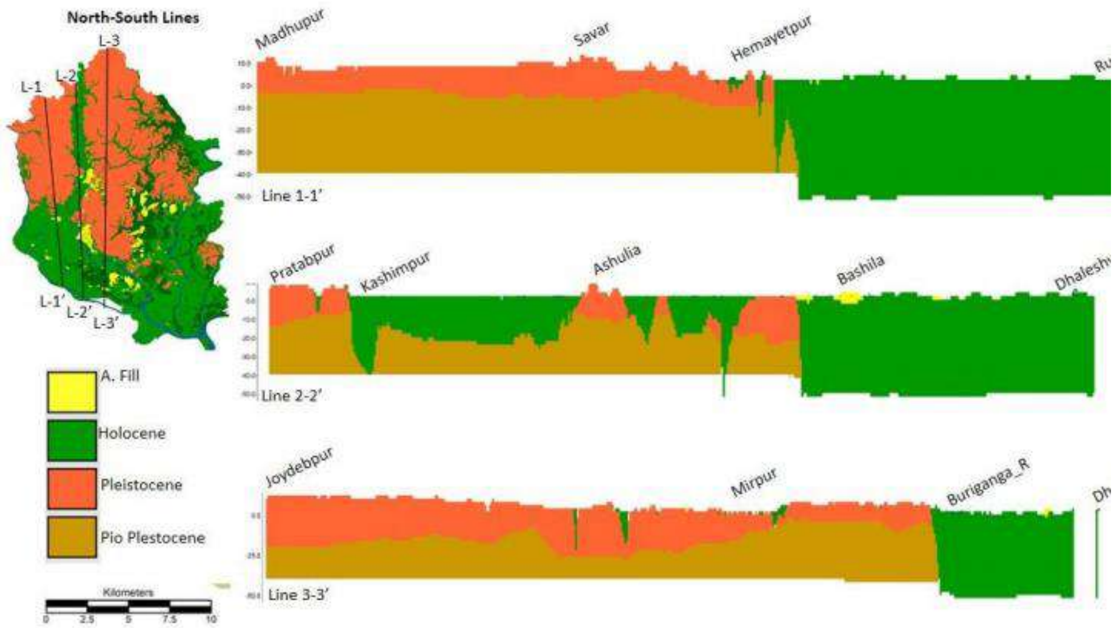


Figure 1.5 Geological Profile type North-South cross section of DMDP, Bangladesh (Source: Geological Survey of Bangladesh, 2017)

1.2.2 Geomorphology of Study Area

Dhaka city is situated at the bank of the Buriganga River in the central part of the country. The study area is bordered by the old Brahmaputra flood plain in the north and east, by the Ganges-Meghna flood plain in the south and by the Jamuna flood plain in the west. The city is nearly flat with many depressions, and regional elevations of the area gradually decrease towards the south and west. The elevations of Dhaka City vary from 2 to 14 m above mean sea level (MSL) with an average of 6.5 m (Rahman M. Z., 2019).

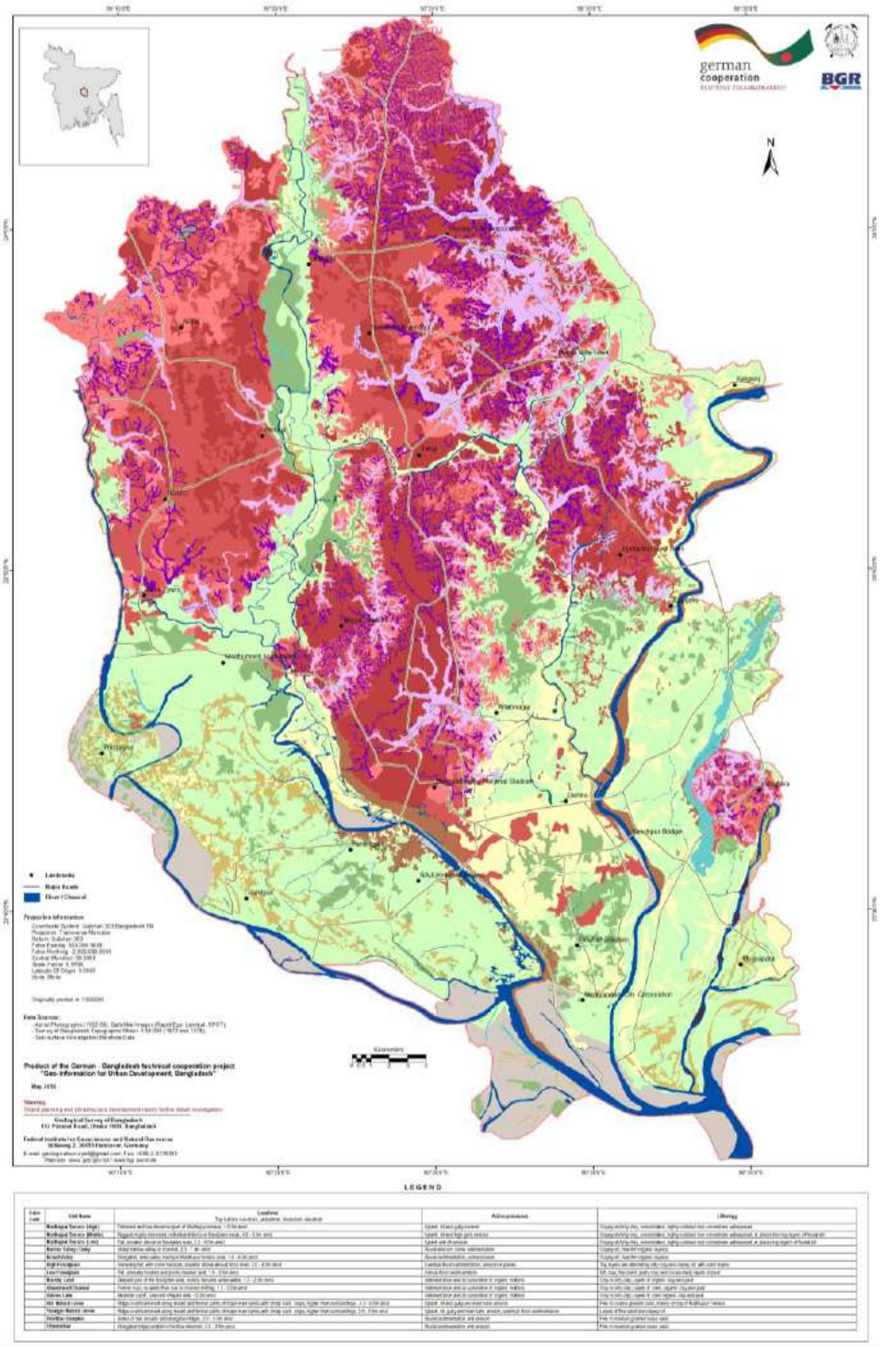


Figure 1.6 Geomorphological map of DMDP, Bangladesh (Source: Geological Survey of Bangladesh, 2022)

Dhaka city is surrounded by the four meander channels, Tongi Khal in the north, the Buriganga River in the south and south-west, the Turag River in the west and the Balu River in the east. Natural levee looks light to medium gray tone with coarse texture in aerial photographs. The Central High Area contains the central and tight north-south trending region of the study area. The block consists of the Madhupur Clay (red soil) and is covered by indigenous surface soil in places. The Complex of High and Low Areas is due to a combination of both erosional and tectonic processes, uplift and faulting followed by downcutting. The area is characterized by saddles of Madhupur Clay fluctuating with gully type depressions. Some of the streams in this block have cut through the Madhupur Clay.

Around the Dhaka-Tongi area, the rivers Buriganga, Turag and Balu drain a Complex of Low Areas, a system of low-lying alluvial plains. This complex is formed of natural levees, point bars, sand bars, abandoned channels, floodplain deposits and shallow depressions and the Madhupur Clay is absent or exists at a shallow depth (Karim and Haider, 1999)

1.3 OBJECTIVES OF THE RESEARCH

The main objectives of this research are as follows:

1) To develop 1D model at selected locations using SPT and shear-wave velocity data and perform 1D site response analysis.
2) To validate the results of the 1D model through microtremor analysis
3) To develop response spectral acceleration (PSA) curve from 1D analysis.

1.4 OUTCOMES OF THE STUDY

The main outcomes of this research are as follows:

4) Maximum Peak Ground Acceleration (PGA).
5) Amplification Factor
6) Pre-dominant Frequency of Soil
7) Response Spectra

1.5 OVERVIEW OF THE STUDY

The main purpose of this study is to do 1D site response analysis and validate the results with the microtremor analysis of soil of DMDP area. The thesis comprised of five chapters.

Chapter 1: (Introduction) is the presentation of a brief introduction to the subject states the major objects of the study, short description on the Study area, Geology and Geomorphology of the study area.

Chapter 2: (Literature Review) presents a brief description on regional tectonics; a brief review of the existing literature on Determination of Seismic wave velocities from the data obtained, different dynamic properties of soil and their determination, site amplification procedures using DEEPSOIL.

Chapter 3: (Field Investigation) presents the SPT N Value and Shear Wave Velocity at different locations. This chapter includes microtremor data collection guidelines; precautionary measures; constraints of data acquisition in the field and data recording according to SESAME.

Chapter 4: (Results and Discussion) presents detailed site response analysis using DEEPSOIL and Geopsy software. Using the software, response spectra, predominant frequency, amplification factor and peak ground acceleration at different locations is estimated.

Chapter 5: (Conclusions and Recommendations) presents a summary of the results and findings resulting from this work. It includes recommendations for future research. List of references and appendices follows.

CHAPTER 2

LITERATURE REVIEW

2.1 GENERAL

The literature review of the present study covers relevant literature on geo-information of study area and regional tectonics. This chapter also described seismic zoning map of Bangladesh. At the last portion of this chapter, the site amplification of soil and its different analysis methods is included.

2.2 GEO-INFORMATION FOR URBAN DEVELOPMENT, BANGLADESH

In 2016, the Federal Institute for Geosciences and Natural Resources, Germany (BGR) studied Geo-Information for Urban Development, Bangladesh. This study presented that the Bengal Basin and the surrounding area is divided into several major structural elements) Figure 2.1), i.e., Eastern Folded Belt, Bengal Foredeep, Western Foreland Shelf, Dauki Fault Zone, Rangpur Saddle and Himalayan Foredeep.

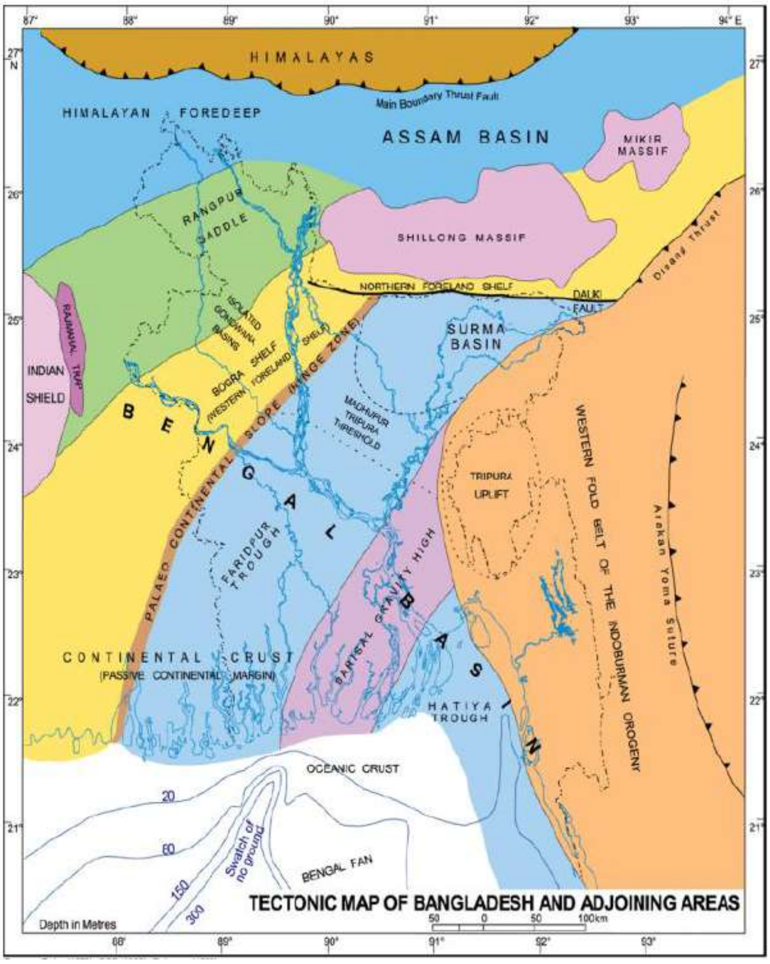


Figure 2.1 Tectonic Map of Bangladesh and Adjoining Areas (after GSB, Alam et. al, 1990).

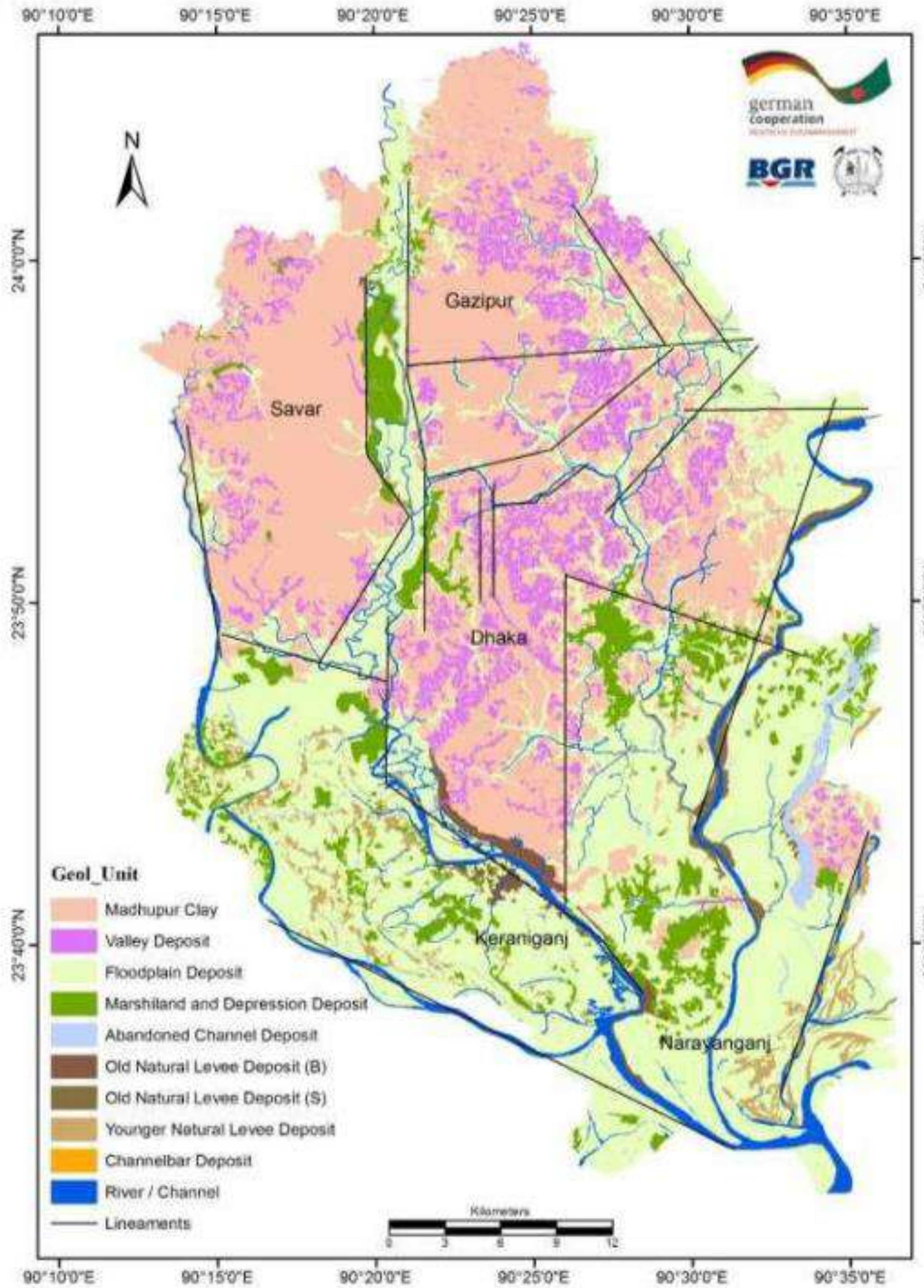


Figure 2.2 Lineaments Map (BGR, 2016)

Dauki fault is the northern boundary of most of the Bengal Basin. Thick sedimentary sequences are present in the Foredeep area of the Bengal Basin. Tectonically the study area is located in the Madhupur Tract (Madhupur Tripura Threshold) of the Faridpur Trough of the Bengal Foredeep area in the Bengal Basin. This area is characterized by many lineament zones (Figure 2.2) Dominant are the N-S lineaments between the two Madhupur Terraces in the north. Since available borehole logs do not indicate any traces of Madhupur Clay in these areas and also the DupiTila formation was not reached, it is assumed that previous deeply eroding channels are present in the vicinity of these lineament zones. It can be suspected that tectonic lineaments could have been a cause for previous channel shifting. Another dominant feature is the Dhaleswari fault striking from N-W to S-E. Drillings show that the sediments south of this supposed fault zone are very soft in comparison to other comparable sediments

2.3 SEISMICITY AND TECTONICS OF BANGLADESH

Mosharraf Hossein (1989) investigated a brief overview of the tectonics of Bangladesh. He founds that northern and eastern Bangladesh and surrounding area belong to seismically active zone and associated with the subduction of the Indian plate. The morphotectonic behavior of northern Bangladesh shows that it is deeply related to the movement of the Dauki fault system and relative upliftment of Shillong plateau. Contemporary seismicity in Dauki fault system is relatively quiet comparing to that in the Naga-Disang-Haflong thrust belt giving rise to the probability of sudden release of energy being accumulated in the vicinity of Dauki fault system. This observation corresponds with the predicted average return period of a large earthquake and the possibility of M>8 earthquakes in the vicinity of the Dauki fault within this century should not be ruled out.

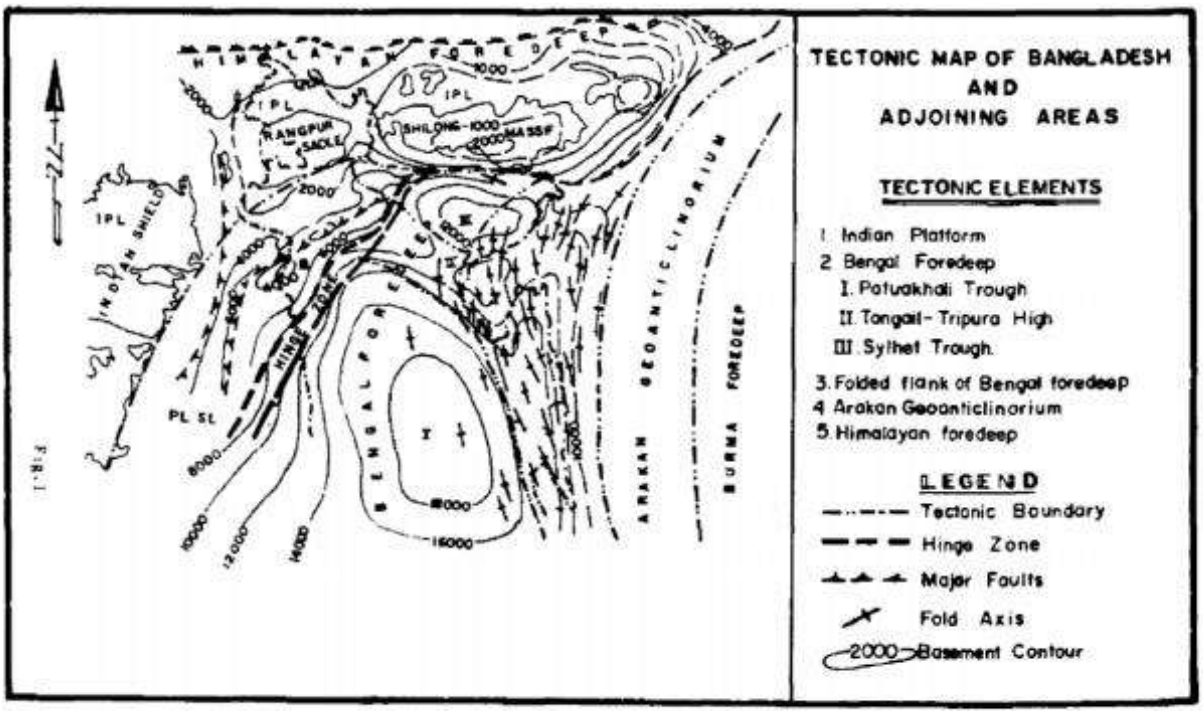


Figure 2.3 Tectonic Map of Bangladesh and Adjoining areas (after Hossein, 1989)

The seismicity in the folded belt in the east follows the general trend of Arakan. Seismotectonic behavior in the deep basin part of Bangladesh demonstrates that an intraplate movement in the basement rock has been taking place along the deep-seated faults causing relative upliftment and subsidence in the basin. Bangladesh has been divided into three seismic zones based on morphotectonic and seismic behavior.

Considering fault types, fault depth, fault characteristics, earthquake records etc., the maximum magnitude of earthquakes that can be produced in different tectonic blocks have been given in Table 2.2.

Table 2.1 Maximum estimated earthquake magnitude in different tectonic faults (Report of CDMP, 2009)

Fault	Fault type	Estimated Magnitude, Mw
Madhupur Fault (MF)	Reverse	7.5
Dauki Fault (DF)	Reverse	8.0
Plate Boundary Fault-1 (PBF-1)	Reverse	8.5
Plate Boundary Fault-2 (PBF-2)	Reverse	8.0
Plate Boundary Fault-3 (PBF-3)	Reverse	8.3

The five fault models were obtained from a report with the subject “Time-Predictable Fault Modeling of Bangladesh” (CDMP, 2009) (Figure 2.4). The shaded area is the surface projection of the faults and the lines next to the area mean the intersection of the fault surface extended to the ground surface. Most of the events are of moderate rank (magnitude 4~6) and lie at a shallow depth, which suggests that the latest movements occurred in the deposits overlying the basement rocks. The Dauki fault system are controlling major events of the northeastern region (Surma basin). The events located in and around the Madhupur tract also indicate shallow movement in the faults separating the block from the alluvium. Figure 2.3 showed the generalized tectonic map of Bangladesh. The distribution of epicenters has been found to be linear along the Dauki fault system and haphazard in other regions of Bangladesh. The investigation of the map explains that the epicenters are lying in the weak zones comprising surface or subsurface faults.

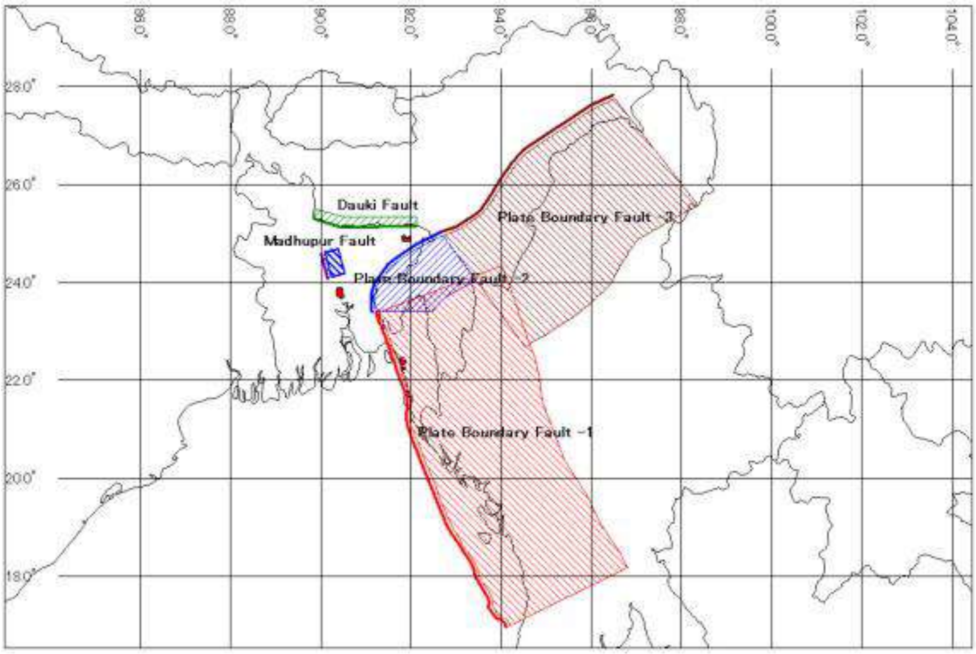


Figure 2.4 Earthquake Fault Model of Bangladesh (CDMP, 2009).

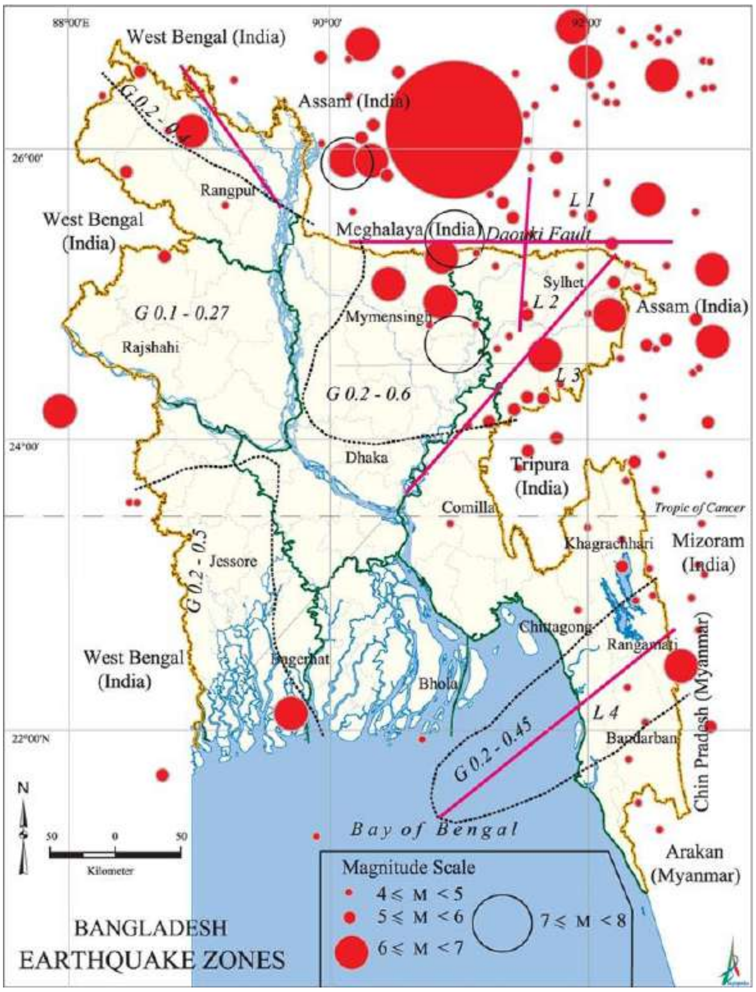


Figure 2.5 Seismo-tectonic lineaments capable of producing damaging earthquakes around Bangladesh **(Source: www.banglapedia.com)**

During the last 150 years, seven major earthquakes have affected in and around Bangladesh. The surface wave magnitude, maximum intensity according to European Macroseismic scale (EMS) and epicentral distance from Dhaka has been presented in Table 2.2.

Table 2.2 List of major earthquake affecting Bangladesh during last 150 years (Ms≥7)

Date	Name of Earthquake	Surface wave magnitude Ms	Maximum Intensity	Epicentral Distance from Dhaka (km)	Basis
10 January, 1869	Cachar earthquake	7.5	IX	250	Back calculation from intensity
14 July,1885	Bengal earthquake	7.0	VII to IX	170	Directly from Seismograph
12 June, 1897	Great Indian Earthquake	8.7	X	230	
23 May, 1912	Mandalay Earthquake, Myanmar	7.9	IX to X	650	
8 July,1918	Srimongal earthquake	7.0	VII to IX	150	
2 July,1930	Dhubri earthquake	7.1	IX	250	
15 January,1934	Bihar-nepal earthquake	8.3	X	510	
15 August,1950	Assum earthquake	8.5	X	780	
21 March, 1954	Manipur Earthquake	7.4	IX	430	
25 April, 2015	Gorkha earthquake, Nepal	8.1	IX to X	745	

2.4 SEISMIC ZONING MAP OF BANGLADESH

Considering various return periods and the acceleration attention relationship the seismicity zones and the zone coefficients may be determined from earthquake magnitude. It has been required that for design structures, seismic ground motion having 2% probability of being exceeded in design life of a structure (50 years) considered critical.

Seismic zoning map for Bangladesh has been presented in Bangladesh National Building code (BNBC) published in 2020. There are four zones in the map- zone 1, zone 2, zone 3 and zone 4. The seismic coefficients of the zones are 0.12g, 0.2g, 0.28g and 0.36g for zone 1, zone 2, zone 3and zone 4 respectively. Bangladesh National Building Code (2020) placed Dhaka city area in seismic zone 2 as shown in Figure 2.6.

Zone-1

Zone-1 comprising the southwestern part of Bangladesh is seismically quiet except the most south-west part of Satkhira which is included in seismic zone 2, with an estimated basic seismic zoning co-efficient of 0.12.

Zone-2

Zone-2 comprising the central part of Bangladesh represents the regions of recent uplifted Pleistocene blocks of the Barind and Madhupur Tracts, and the western extension of the folded belt. This includes Dhaka, Dinajpur, Pabna and Kumilla districts and its region. Seismic zoning coefficient for Zone II is 0.20.

Zone-3

Zone-3 comprising the northern portion of central part includes Rangpur, Bogra and Narshingdi and extended south regions of Bangladesh Chattagram and Cox-bazar is a zone of moderately high seismic risk with a basic seismic zoning co-efficient of 0.28.

Zone-4

Zone-4 comprising the northern and eastern regions of Bangladesh with the presence of the Dauki Fault system of eastern Mymensingh, Sylhet and the deep-seated Sylhet Fault, and proximity to the highly disturbed southeastern Assam region with the Jaflong thrust, Naga thrust and Disang thrust, is a zone of high seismic risk with a basic seismic zoning co-efficient of 0.36.

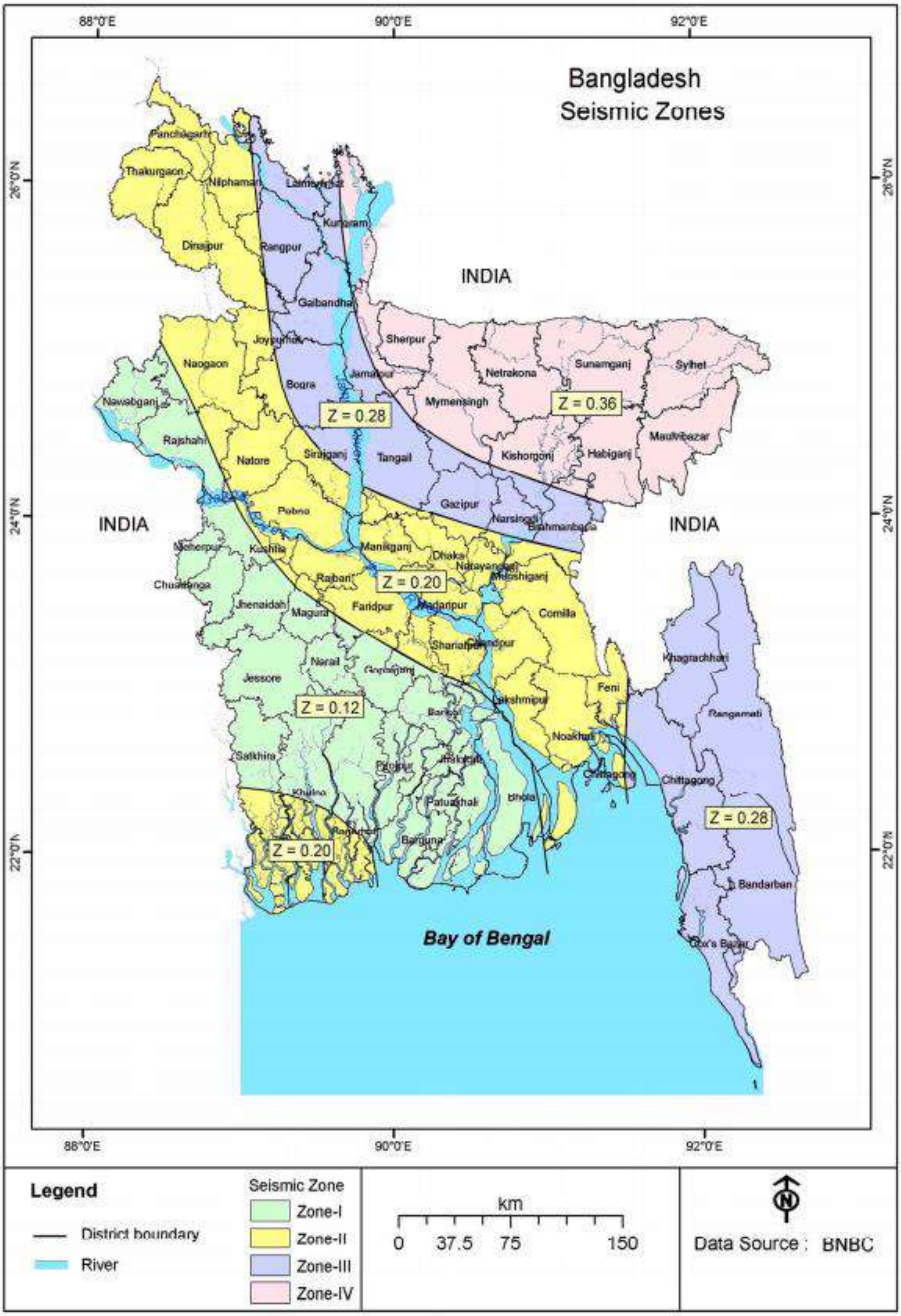


Figure 2.6 Seismic Zoning Map of Bangladesh (after BNBC, 2020)

2.5 BNBC SITE CLASSIFICATION

According to BNBC-2020, any site can be classified as a type SA, SB, SC, SD, SE, S_1, or S_2. The classification shall be carried out in accordance with Table 2.3 according to the soil properties of the upper 30 meters of the site profile. The average soil properties will be calculated according to the following equations:

$$\bar{V}_s = \sum_{i=1}^{n} d_i / \sum_{i=1}^{n} \frac{d_i}{V_{si}} \tag{2.1}$$

$$\bar{S}_u = \sum_{i=1}^{k} d_{ci} / \sum_{i=1}^{k} \frac{d_{ci}}{S_{ui}} \tag{2.2}$$

$$\bar{N} = \sum_{i=1}^{n} d_i / \sum_{i=1}^{n} \frac{d_i}{N_i} \tag{2.3}$$

Where,

n = Number of soil layers in upper 30 m

d_i =Thickness of layer i

V_{si} =Shear wave velocity of layer i

N_i = Field (uncorrected) Standard Penetration Value for layer i

k = Number of cohesive soil layers in upper 30 m

d_{ci} = Thickness of cohesive layer i

S_{ui} = Undrained shear strength of cohesive layer i

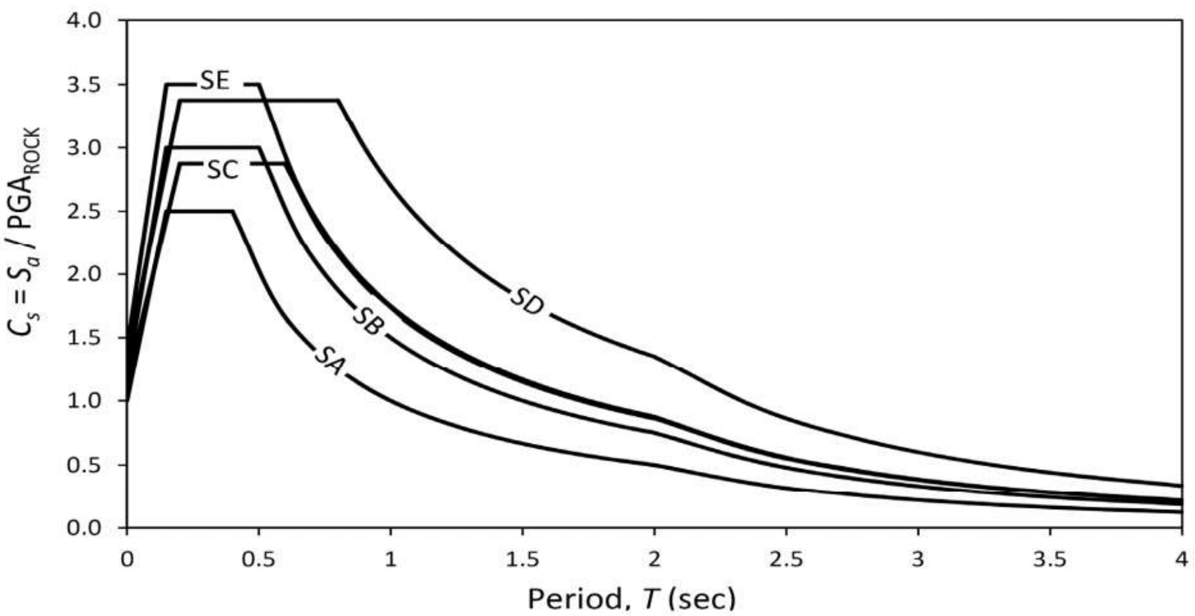


Figure 2.7 Normalized design acceleration response spectrum for different site classes (after BNBC, 2020)

Table 2.3: Site Classification Based on Soil Properties (after BNBC, 2020)

Site Class	Description of soil profile up to 30 meters depth	Average Soil Properties in top 30 meters		
		Shear wave velocity, $\bar{V}_s$ (m/s	SPT Value, $\bar{N}$ (blows/30 cm)	Undrained shear strength, $\bar{S}u$ (kPa)
SA	Rock or other rock-like geological formation, including at most 5 m of weaker material at the surface.	>800	--	--
SB	Deposits of very dense sand, gravel, or very stiff clay, at least several tens of meters in thickness, characterized by a gradual increase of mechanical properties with depth.	360-800	>50	>250
SC	Deep deposits of dense or medium dense sand, gravel or stiff clay with thickness from several tens to many hundreds of meters.	180-360	15-50	70-250
SD	Deposits of loose-to medium cohesionless soil (with or without some soft cohesive layers), or of predominantly soft to firm cohesive soil.	<180	<15	<70
SE	A soil profile consisting of a surface alluvium layer with Vs values of type SC or SD and thickness varying between about 5 m and 20 m, underlain by stiffer material with Vs > 800 m/s.	--	--	--
S_1	Deposits consisting, or containing a layer at least 10 m thick, of soft clays/silts with a high plasticity index (PI > 40) and high-water content	<100 (indicative)	--	10-20
S_2	Deposits of liquefiable soils, of sensitive clays, or any other soil profile not included in types SA to SE or S1	--	--	--

2.6 SITE AMPLIFICATION

To estimate the effect of an earthquake, it is necessary to evaluate the expected ground motion characteristics, and the subsequent response of soil and structures to those ground motions. A site amplification phenomenon is dependent on frequency of input motion. The characteristics of earthquake motions are influenced by several mechanisms related to the local soil and rock properties. Site amplification is quantified using Eq. 2.4, known as the amplification factor (Kramer, 1996). Amplification also can compute from horizontal to vertical ratio (HVR) analysis. The amplitude of HVR curve is the amplification of that site.

$$\text{Amplification Factor} = \mu\ \text{ground}/\mu\ \text{rock} \qquad (2.4)$$

Where, μ= vertical particle displacement

2.7 METHODS OF SITE RESPONSE ANALYSIS

Site response is primarily influenced by properties that influence wave propagation, particularly stiffness and damping. The shear strength of soil is mainly influenced to ground failure. Soil is the most nonlinear material, and its behavior is very complex during strong shaking. Seismologists have traditionally treated soil as a linear material and rarely considered soil nonlinearity in the assessment of site conditions. Soil nonlinearity is prevalent even at low strain values. The pioneering work of Seed, H.B. and Idriss, I.M., (1969) brought attention to the nonlinear behavior of soils during seismic shaking. Observations during 1964 Alaska, Niigata earthquakes and the 1967 Caracas earthquake formed the basis for the work. Since then, site response has become an integral part of geotechnical earthquake engineering.

Not until the 1985 Michoacan earthquake, soft soils were thought to de-amplify motions at peak ground accelerations larger than 0.1 to 0.2 g (Seed, H.B. et al., 1983), while motions at stiff soils were thought to be largely unaffected by the ground motion intensity. The Mexico City earthquake (1985) also brought attention to the need for a better understanding of the dynamic properties of soft clays (Finn, W.D.L., 1991). The development of design codes has followed the advancements in understanding of site response. The use of spectral shapes without amplification factors for peak acceleration reflected the observations by Seed, H.B. et al., (1976) that accelerations in soils and rocks were approximately equal. Factors that underlain the ground response are peak ground acceleration, predominant frequency and amplitude. Techniques used widely to quantify site response include the following:

i. Experimental Methods

a. Standard Spectral Ratio (SSR)

b. Microtremor Measurements

- H/V noise ratio (Nogoshi-Nakamura technique)
- H/V spectral ratio of weak motion

ii. Numerical Methods

a. One dimensional site response analysis

- Transfer functions
- Equivalent linear approximation of nonlinear response
- Deconvolution

b. Advanced Methods

iii. Empirical and Semi-Empirical Methods

a. Empirical attenuation laws

2.7.1 Experimental Methods

Standard Spectral Ratio (SSR) Method

Borchardt, R.D., introduced (1970) this method for recordings at nearby site to compare which are subjected to source and path effects. If the reference site is free from site effects, then his method provides a reliable estimate of possible site response. The recording site has to be unaffected by any site effects and the reference site must be acceptable for the assumption of behavioral difference unaffected by source radiation or travel path. For this reason, reference site has to be located near to the location of testing to ensure that the difference in the records is due to only site effects but not due to source or path effects (caused when hypo central distance is more than 10 times of array aperture). SSR technique gives an upper bound of actual site effects at high frequencies and under estimation at frequencies below fundamental frequency for site effects

Microtremor Measurements

The use of microtremors, an idea pioneered by Kanai et al. (1954) turns into one of the most interesting approaches in site effects studies, due to its relatively low economic cost and the possibility of recordings without strict spatial or time restrictions (Rodriguez and Midorikawa, 2002). In recent studies, ambient noise measurements have been widely used (Seo, 1994). The results obtained from the application of long period ambient noise measurements (Ohta et al., 1978; Yamanaka et al., 1993, 1994) allow the application microtremor for site effects. Short period ambient noise measurements have been used to a wide range of seismic settings (Morales et al., 1991, Field et al., 1995; Seo, 1994). The H/V spectral ratio method (Nakamura 1989) has been discussed at great length and proven to be a suitable, quick and effective method (Bard P. Y., 1998) for determining the predominant period of soil.

Earthquake and Microtremor Spectral Ratio

Research of microtremor studies have shown that the peak amplitude of the microtremor H/V ratio tends to underestimate the peak amplitude of earthquake spectral ratios with respect to a reference (bedrock) site (Bard, 1999). The H/V spectral ratio determined from microtremors has shown a clear peak that is well correlated with the fundamental resonance frequency at “soft” soil sites (Bard, 2004; Horike et al., 2001; Lachet et al., 1996; Field and Jacob, 1995; Lachet and Bard, 1994). Numerical analysis suggests that microtremor site response can only be generated when the impedance contrast is greater than 3.5 (Malischewsky and Scherbaum, 2004), thus the good correlation at “soft” soil sites. Only a few studies claim rough agreement between the peak amplitude of the microtremor H/V ratio and earthquake site-to-reference spectral ratios (Molnar and Cassidy, 2006; Mucciarelli et al., 2003; Horike et al., 2001). In general, the site response shown by the earthquake site-to-reference spectral ratio method is regarded as the best approximation for engineering use, whereas H/V spectral ratios from earthquakes and/or microtremors are regarded as providing the fundamental peak and lower bound estimate of amplification for a soil site.

The remarkable similarity has been demonstrated in Figure 2.8 between the earthquake site-to-reference and H/V ratio response, with the microtremor H/V ratio response at three strong-motion earthquake recording sites in greater Victoria. Traditionally strong-motion instrument has been used for earthquake recordings, rather than recordings from weak motion sensors, as these instruments are designed to record the largest ground motions, and are generally present at sites of geologic interest (i.e. not bedrock). There are six BC Hydro substations in greater Victoria with a permanent strong-motion instrument. Since 1996, up to seven weak motion (peak ground acceleration ≤ 5.5 % g) earthquakes, ranging in magnitude from M_L 3.6 to M_W 6.8, have been recorded at these sites.

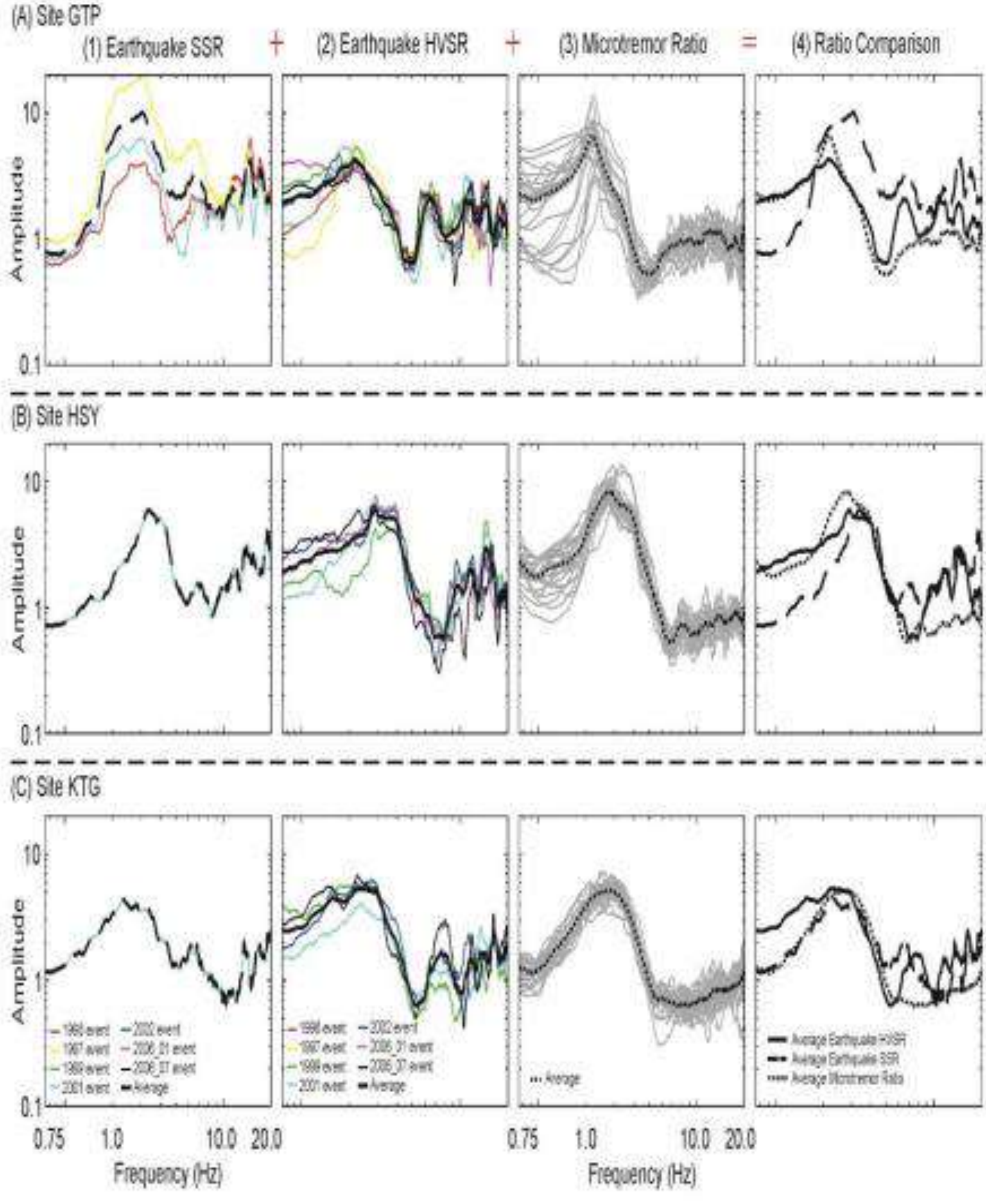


Figure 2.8 Comparison of (1) the average earthquake site-to-reference spectral ratios (SSR) with (2) the average earthquake H/V spectral ratios (HVSR) of up to seven earthquakes, and (3) the average microtremor H/V spectral ratio at three strong-motion instrument sites in greater Victoria. (after Molnar et al., 2007)

All six BC Hydro instrument sites show similar response regardless of excitation source (weak-motion earthquakes or microtremors) and spectral ratio method (Molnar and Cassidy, 2006). This suggests that microtremor recordings are valid for estimation of linear earthquake response at sites in greater Victoria.

Observed and Analytical Amplitude Ratio

A microtremor research has been carried out at thirteen locations in Japan (Ansary et al, 1996). Soil model has been developed for theoretical analysis using the existing boreholes and PS loggings. The transfer function of the shear wave (The surface motion versus the incidental motion at some depth) and the amplitude ratio for the fundamental mode of Rayleigh wave have been calculated at the sites using those soil models. For the calculation of transfer function of shear wave, a damping ratio of 2 % has been used, assuming input motion at the outcrop.

Figure 2.9 shows the transfer function of shear wave, amplitude ratios of Rayleigh wave and microtremor for six locations in Japan. During the comparison of theoretical curves, the amplitude ratio, AR (T), of microtremor used have been expressed by the following equation:

$$\mathrm{AR}(T) = \frac{\sqrt{F_{NS}(T)F_{EW}(T)}}{F_{UD}(T)} \tag{2.5}$$

Where $F_{NS}(T)$, $F_{EW}(T)$ and $F_{UD}(T)$ are average Fourier spectra of six-time instants.

The trend of three curves, i.e., two theoretical and one observed, somewhat resembles each other for these sites. Ansary et al. (1996) found that the period at which the Rayleigh wave amplitude ratio either suddenly drops or peaks, microtremor amplitude ratio closely resembles it. In a general sense, amplitude ratio for pure Rayleigh wave is always lower than the amplitude ratio of microtremor. The reason is that microtremor may contain some shear wave and Love wave contents as well as Rayleigh wave. Ansary et al. (1996) concluded that the characteristics of the microtremor's amplitude ratio are similar to that of Rayleigh wave and the period corresponding to the peak amplitude ratio corresponds to the peak periods of Rayleigh wave amplitude ratio and Shear wave transfer function.

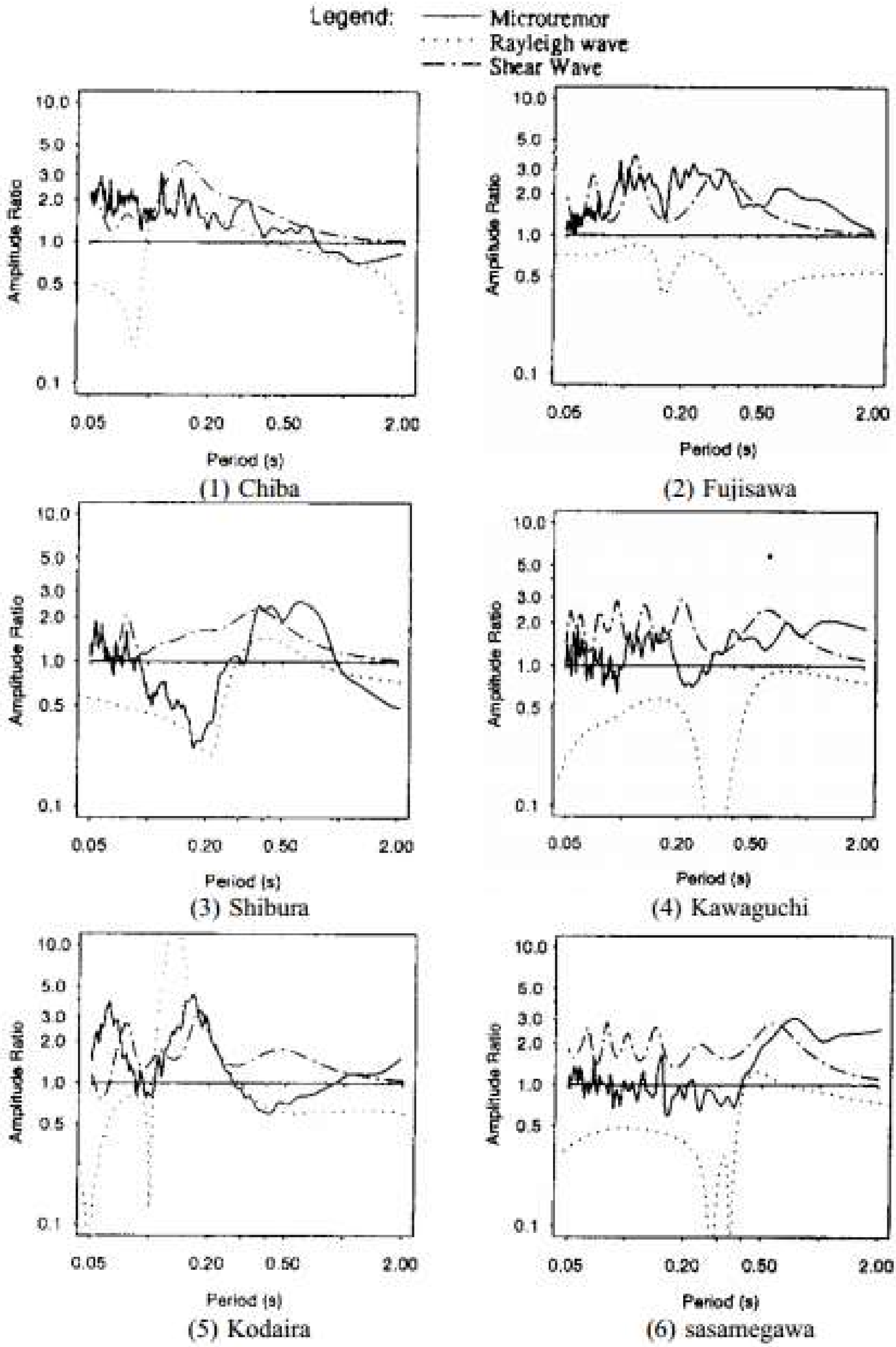


Figure 2.9 Amplitude ratios of microtremor and theoretical Rayleigh-wave plotted with transfer function of shear wave. (after Ansary et al., 1996)

H/V Noise Ratio method

Many researchers (Ohmachi, et. al., 1991; Lermo, et al., 1993; Field, and Jacob, 1995) have shown that, how H/V ratio of noise can be used to identify the fundamental resonant frequency and amplification factor of sediments. This method doesn‘t depends on reference site. It is also called as Nogoshi-Nakamura technique which was introduced in early seventies. ‘H‘ represents the horizontal component of the Fourier Spectra of microtremors and ‘V‘ is the corresponding vertical component. H/V is more stable than the raw noise spectra. It exhibits a clear peak in soft soils which could be correlated with the fundamental resonant frequency. Field observations combined with several theoretical investigations validate the randomly distributed near surface source lead to H/V ratios. Though the frequency of the peak linked to the peak frequency of the ground, amplitude of this peak is not well associated with the S wave amplification at the site's resonant frequency. Amplitude is highly sensitive to poisons ratio to near the surface. Figure 2.10 represents the H/V method and SSR method of recording.

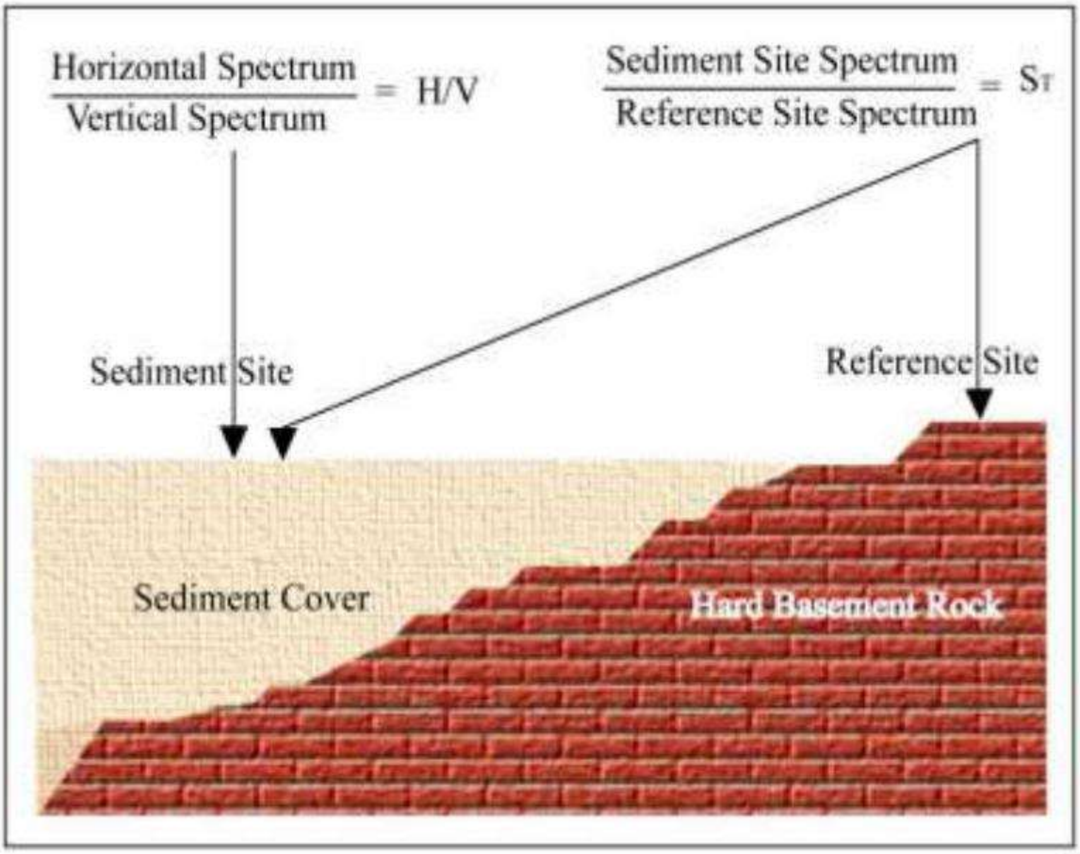


Figure 2.10 Assumptions of microtremor method to derive transfer function for sedimentary basins using H/V (Nakamura, 1989) and standard spectral ratios (modified from Ibs-von Seht and Wohlenberg, 1999).

Techniques for analyzing microtremors are generally divided into two main categories: non-reference site (H/V) and reference site (Hs/Hr) techniques. In Hs/Hr method, assumptions are that at nearby sites, source and path effects are believed to be identical and reference site is free of any site effect. Therefore, motion recorded at the reference station is representative of the excitation arriving at the interface sediments under the soft soil site and spectral ratio, H_s/H_r, constitute a reliable estimate of site response. This technique, introduced first by Borcherdt (1970), is still widely used and is very popular for the analysis of weak or strong motion records. It has been applied to microtremor measurements by Kagami et al. (1986) with good results. In the traditional spectral ratio method, H_s/H_r, site and source effects are estimated from observations at a reference site. In practice, adequate reference site are not always available especially in flat areas. Therefore, methods have been developed that do not need reference sites (Bard, 2004).

H/V spectral ratio of weak motion

The H/V spectral ratio (HVSR) technique of microtremors gained popularity in the early nineties, after the publication of several papers (Nakamura, 1989; Field and Jacob, 1993; Lermo and Chavez-Garcia, 1994) claiming the ability of this technique to estimate the site response of soft sedimentary deposits satisfactorily. The method is rather attractive in developing countries characterized by a moderate seismicity area, where only very limited resources are available for seismic hazard studies. HVSR technique is a combination of Langston‘s receiver function method and Nakamura‘s proposal to use HVSR ratio with recordings of ambient vibrations. Receiver function method was used for determining the velocity structure of the crust from the horizontal to vertical spectral ratio (HVSR) of the seismic P-waves. H/V method is based on the records of the ambient noise (microtremors) in environment. Microtremor consists of both body and surface waves. Suzuki, T. (1933) pointed out that H/V spectrum ratio of Rayleigh waves reflects the surface structure. Nogoshi, M., and Igarashi, T. (1971) in their paper distinguished the components of the microtremor whether body waves or surface waves. Nakamura, Y., (1989) estimated that some site characteristics are related with the site transfer function, using microtremor measurements. It consists in deriving the ratio between the Fourier spectra of the horizontal and the vertical components of the microtremor recording obtained at the surface; this ratio is called thereafter the H/V ratio.

Lachet and Bard (1994) investigated the HVSR approach on ambient noise recordings to clarify if this method reflected characteristics of the site as opposed to the source. Their study concluded the HVSR approach was able to clearly show the HVSR peak of a sedimentary site independent of source effects. The HVSR analysis is considered to remove the source effect by dividing the horizontal by the vertical component as described by Nakamura (1989); Lachet and Bard (1994); Bard (1998); Nakamura (2000) and Nakamura (2008). The HVR technique has proven to be useful to estimate the fundamental period of soil deposits. This technique consists of estimating the ratio between the Fourier amplitude spectra of the horizontal (H) to the vertical (V) components of the ambient noise vibrations recorded at one single station (Ansary et. al., 2022).

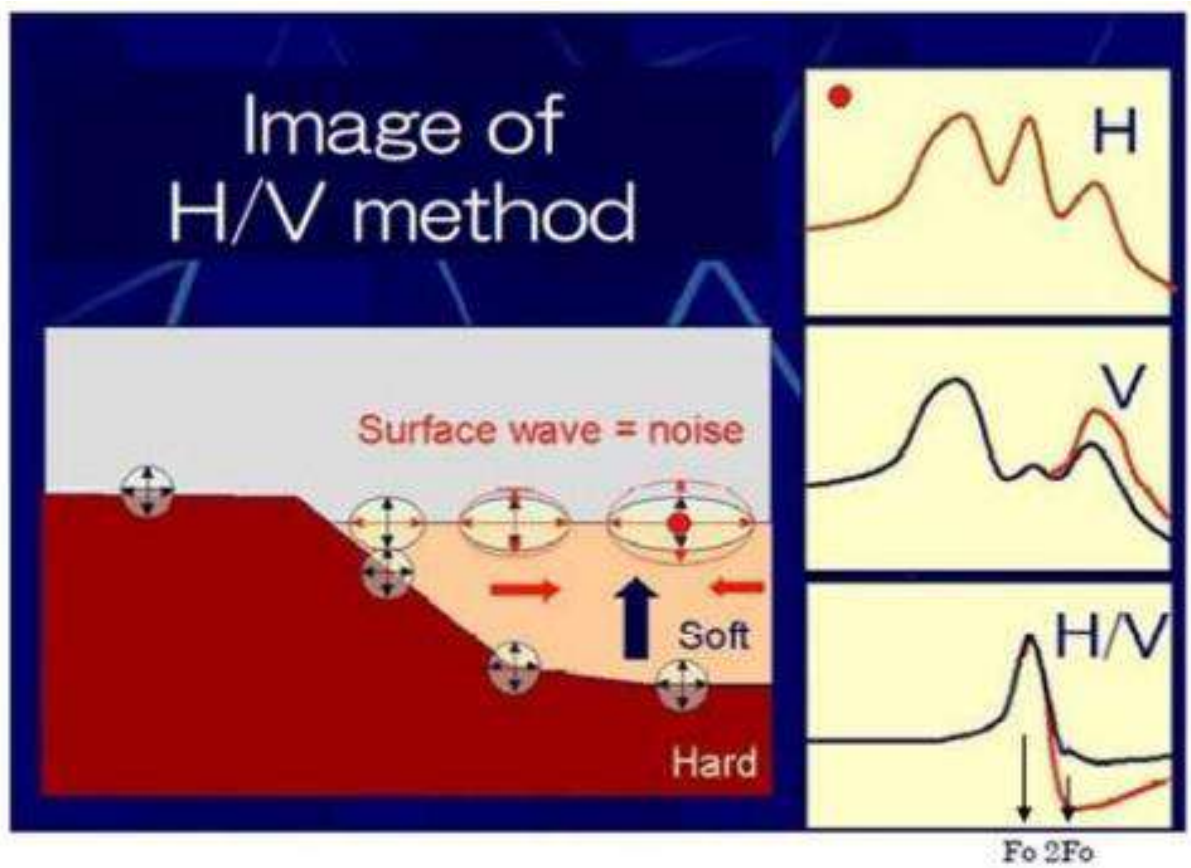


Figure 2.11 Cartoon of the HVSR method, where Rayleigh wave ellipticity of the basement and ground surface is shown in the left panel. The Fourier transform of the horizontal (top) and vertical (center) component, and the resulting HVSR (bottom) are shown on the right. The image is from Nakamura (2008).

2.7.2 Numerical Methods

When high quality geotechnical data is available and the site characteristics are well known, site effects can be estimated using numerical analysis. Using geotechnical information and sufficient density of boreholes are available then numerically based zoning can be done. But this requires an in depth understanding of both analytical models and of the numerical schemes that are used. This may lead to less reliable results due to lack of such expertise in numerical analyses.

One Dimensional Analysis

One dimensional analysis is the most general method of site response analysis. Two dimensional and three-dimensional analyses can be utilized using finite element method and thin layer methods that even assess the effect of topography and basin structure on wave propagation (Bielak, et al., 1999). This method is widely used for response analysis as it provides conservative results and evaluated from case histories of different earthquakes. In this analysis 1D propagation of the seismic waves are considered. One of the basic assumptions in one dimensional analysis is that soil is horizontally layered, and response of soil is dependent on vertical propagation of SH wave from the bedrock below. The soil and bedrock are assumed to be infinite in horizontal direction. The assumptions are justified as velocity of wave generally decreases from the earth‘s interior towards to the surface, and hence by successive refractions into a nearly vertical path the stress waves from the focus are bent. Vertical ground motions are generally not as important from the viewpoint of structural design as horizontal ground motions. Soil properties generally vary more rapidly in the vertical direction than in the horizontal direction. The methods of one-dimensional analysis can be broadly categorized as follows:

1. Linear analysis
2. Equivalent linear analysis
3. Nonlinear analysis

Linear analysis

Linear approach is the simplest approach to evaluate ground response in one dimensional site response analysis. Nonlinear behavior of soil is approximated by iterative procedure with equivalent linear soil properties. Linear approach has been implemented in the following procedures, which are commonly used for ground response analysis (Kramer, 1996).

- Transfer functions
- Equivalent linear approximation of nonlinear response
- Deconvolution

Equivalent Linear Analysis

Equivalent linear analysis has been developed by Schnabel, et al., 1972 to capture the nonlinear cyclic response of soil under frequency domain solution. This method is widely used for engineering purposes as the results well converged with the field recordings. Schnabel, et al., (1972) addressed nonlinear hysteretic stress–strain properties of cohesionless soil by using an equivalent linear method of analysis. The method was originally based on the lumped mass model of sand deposits lying on rigid base to which the seismic motions were used. Later, this method was simplified to wave propagation model with an energy transmitting boundary. The seismic excitation could be applied at any level in the new model. Up to a strain level of 10^{-3} soil model can be simplified to an equivalent linear model. Equivalent linear method implies that strain always returns to a value of zero after cyclic loading and failure cannot occur. In a frequency domain analysis, it is assumed that modulus and damping properties are constant.

The Equivalent Linear (EL) model employs an iterative procedure in the selection of the shear modulus and damping ratio soil properties as pioneered in program SHAKE. These properties can be defined by discrete points or by defining the soil parameters that define the backbone curve of one of the nonlinear models (Hashash et al, 2020).

Many packages are available for one dimensional analysis such as SHAKE, DEEPSOIL, EDUSHAKE, PROSHAKE, Cyber Quake etc.

Nonlinear Approach

Nonlinear response of soil cannot be evaluated precisely using linear approach. Using direct numerical integration in small time intervals in time domain this limitation can be overcome by using the nonlinear response of soil. Nonlinear analysis is generally performed by using a discrete model such as finite element and lumped mass models and performing time domain step-by-step integration of equations of motion. In nonlinear analysis to give meaningful results, the stress-strain characteristics of the particular soil must be realistically modeled to give a meaningful result. The integration of motion in small time intervals will permit the use of any linear or nonlinear stress-strain models. The data from borings or measurements of shear wave velocity are used to create the soil model. When such data are not available, generic ground conditions can be used (Shima, and Imai, 1982). Nonlinearity in site characterization and analysis must be taken under serious consideration since all soils have highly in nonlinear properties.

There are many types of software, which can incorporate the nonlinear response of soils such as PLAXIS, SASSI2000, FLAC, QUAKE/W, Cyclic 1D, DEEPSOIL etc.

Two-Dimensional Analysis

The one-dimensional site response analysis is useful for sloping ground with parallel soil layers. Since these conditions are not so common, one-dimensional analysis may not give very accurate results in most of the cases. In the case of sites where embedded structures like pipelines or tunnels are present, one-dimensional analysis may not give desired results. In these case two dimensional analyses can be done either based on frequency domain or time domain methods.

This analysis can be done using dynamic finite element methods adopting either equivalent linear approach or nonlinear approach (Kramer, 1996). For modeling two dimensional cases, numerical modeling software like PLAXIS, FLAC, QUAKE etc. can be used. Various researchers suggested number of alternatives to this approach such as shear beam approach and layered inelastic shear beam approach for high computational cost. In case of earthen dams analysis shear beam approach is widely used.

Three-Dimensional Analysis

There may be cases in which, two-dimensional approach may not adequate, there is variation in soil profile in all three dimensions. Three-dimensional analysis is better for studying the response of three-dimensional structures. The method and the approaches are similar to the two-dimensional analysis method. Equivalent linear finite element method, nonlinear finite element method etc. are the adopted approaches for three-dimensional analysis.

Ground Response Analysis

During an earthquake, propagation of seismic waves through soil column alters the amplitude, frequency and duration of ground motion by the time it reaches the surface because of local site effects. The effects of ground motion are propagated in the form of waves from one layer to another. The evaluation of such response of the site in action of dynamic loading is termed as ground response analysis. Site effects can be measured by empirical correlations between rock ridge motion and motion at soil sites. Different correlations are used for stiff soils and deep cohesionless soils. Depending on the geometry and conditions of loading the different analysis method i.e., one, two- and three-dimensional analysis are suggested.

Ground response analysis also termed as soil amplification study comprises the calculation of site natural periods, evaluation of liquefaction potential, ground motion amplification, stability analysis etc. The important features that are considered for analysis are characteristics of soil overlying bedrock, bedrock location and inclination, topography of bedrock and soil deposits, faults in the soil deposits.

Assessment of damping factors of the soil in no easy work. Important stages in site specific ground response analysis are dynamic characterization of the site and selection of rock motions. Sometimes. empirical relationships are useful considering large area and time constrained. But due to inadequate data and the scope of applicable site conditions, empirical relationships cannot be applied to all conditions. Numerical simulations are practical in such conditions as they cover a range of ground motions and site effects for the locations where no previous data available.

2.8 ANALYSIS USING DEEPSOIL

A computer program DEEPSOIL 7.0 (Hashash et al, 2020), has been used to compute the seismic responses of horizontally layered soil deposits of the study area. It is a one-dimensional site response analysis program that can be performed to linear, equivalent linear and non-linear approach of analysis. The linear analysis can be done either in frequency domain or time domain, the equivalent linear analysis can be done in frequency domain and the non-linear analysis can be done in time domain only. However, in cases of high seismic intensities at rock and/or high strain levels in the soil layers, an equivalent soil stiffness and damping for each layer cannot properly represent the behavior of the soil column over the entire duration of a seismic event. In such conditions the ground motion propagation through deep soil deposits can be simulated using this software. The equivalent linear approach implemented in DEEPSOIL is similar that in SHAKE (Schnabel et al., 1972). Any number of material properties and layers under some conditions can be used and the user can choose frequency dependent or independent complex shear modulus formulations (Park, and Hashash, 2004). The user has the option of obtaining the site response results using the equivalent linear method automatically whenever nonlinear site response analysis is conducted. It is highly recommended that EL results are always examined whenever a NL analysis is conducted (Hashaash et al., 2020)

For performing 1D nonlinear analysis following inputs about soil are required i.e., number of layers of the profile, thickness of each layer, shear wave velocity, Shear strength, unit weight and water table depth. The steps involved in the analysis are:

- Selection of analysis method
    - Linear
    - Equivalent Linear
    - Nonlinear
- Solution types
    - Time Domain
    - Frequency Domain
- Defining of soil properties and soil model properties
    - Layer thickness, Shear properties, Unit weight
    - Reference curve-Sand/Clay
    - Water table depth
- Defining of rock properties
    - Elastic/rigid half space
- Input ground motion
- Analysis control
    - Frequency Domain
    - Time Domain
        - Step Control
            - *Flexible*
            - *Fixed*
        - Maximum Strain Increment
        - Number of Sub-Increment
- Output

After the completion of the analysis, the following output for each selected layer will be directly exported to a text file "Results - motion.txt" in the working directory specified using the Options menu

CHAPTER 3
FIELD INVESTIGATIONS

3.1 GENERAL

The objective of this chapter is to describe detailed data collection procedure for this study work. This chapter briefly describes the Standard Penetration Test (SPT) data collection methodology, the theory of Seismic Downhole Test (SDHT) to determine shear wave velocity and the SESAME guidelines of microtremor study. The Precautionary Measures and constraints during data acquisition for microtremor have also been discussed. The calculation procedure of the site class in accordance with BNBC 2020 and site classes for all the selected locations have been shown here in this chapter. Also, all data of SPT N value, Shear Wave velocity and Microtremor records of DMDP area have been presented in this chapter.

3.2 SELECTED TEST LOCATIONS

As a part of preparing Risk Sensitive Land Use Planning (RSLUP) of DMDP area, under the Urban Resilience Project: RAJUK Part, RAJUK has executed a total of 378 SPT and 400 SDHT for the entire DMDP area. Among those, a total of 50 locations in the DMDP area have been selected for this research where both the SPT and SDHT data were collected. The selected locations are spread across the entire study area in a uniform manner. Also, site selection has been executed according to the guideline of SESAME, WP12 (2004) as there is a microtremor measurement has been carried out in every site.

The Standard Penetration Test (SPT), Seismic Downhole Test (SDHT) and microtremor records have been conducted for each of the selected location. The selected locations in and around Dhaka city are situated on various geological units mainly Holocene deposits and Pleistocene deposits as discussed in Chapter 1. Figure 3.1 shows the 50 selected locations in and around Dhaka City which are marked as red triangle on the geological map of the study area. Also, the test locations conducted by CDMP (2009) have been marked in the same geological map mentioned earlier. The co-ordinates, SPT conducted depth and address of selected locations have been tabulated in the Table 3.1.

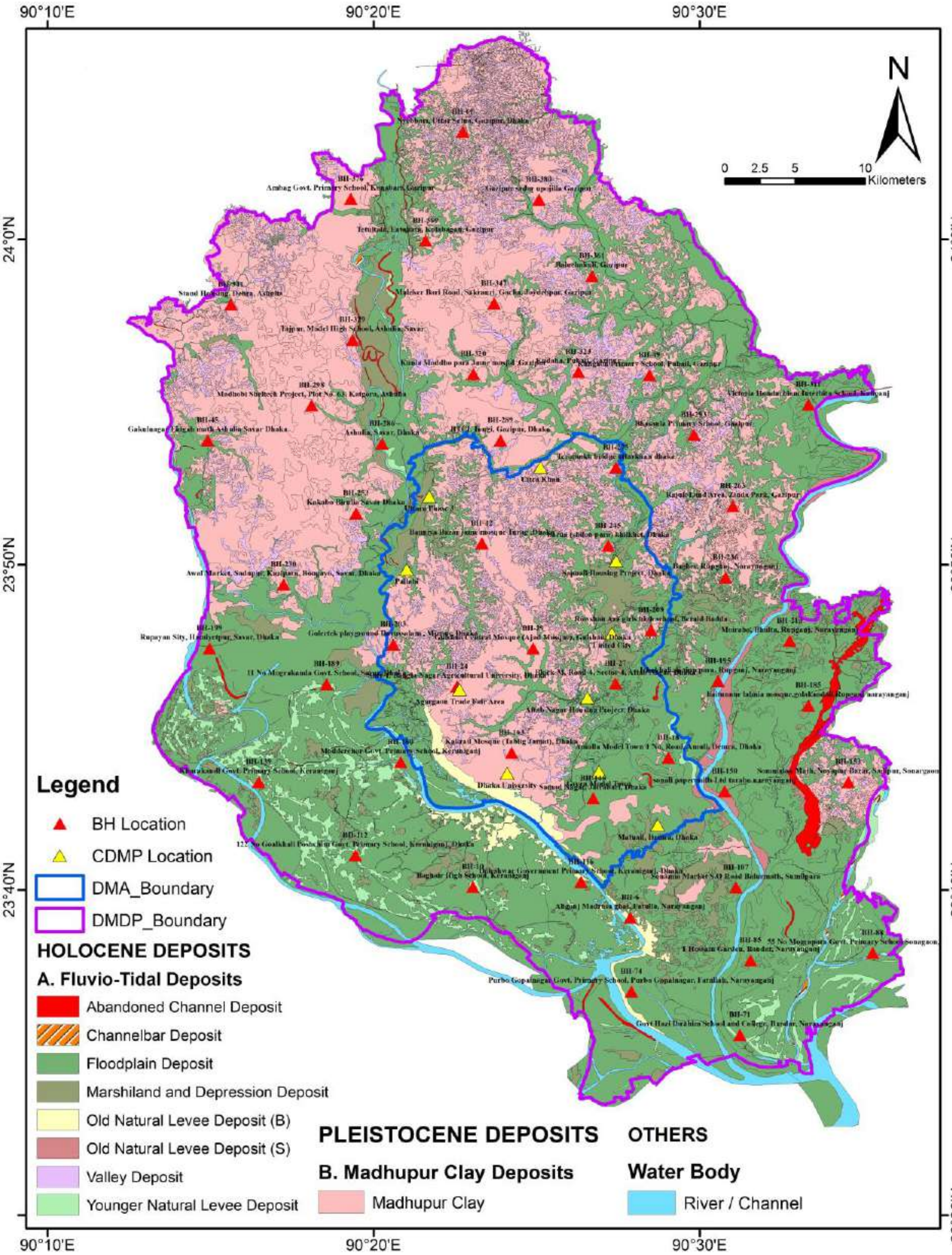


Figure 3.1 Superimposed study points on Geological Map of DMDP

Table 3.1 Location of SPT Boreholes of the study area

Sl No.	Borehole No.	Site Address	Latitude	Longitude	SPT Depth (m)
1	BH006	Aligonj Madrasa ghat, Fatulla, Narayanganj	23.652611	90.464583	42
2	BH010	Baghair High School, Keraniganj	23.668303	90.384225	34.5
3	BH018	Amulla Model Town 1 No. Road, Amuli, Demra, Dhaka	23.734428	90.483998	49.5
4	BH024	Sher-E Bangla Nagar Agricultural University, Dhaka	23.771041	90.376138	30
5	BH027	Block-M, Road-4, Sector-4, Aftab Nagar, Dhaka	23.772512	90.456972	48
6	BH029	Gulshan Central Mosque (Ajad Mosque), Gulshan, Dhaka	23.790473	90.414868	30
7	BH045	Gakulnagar Eidgah math Ashulia Savar Dhaka	23.89717	90.248601	49.5
8	BH042	Bauniya Bazar jame mosque Turag ,Dhaka	23.844371	90.388748	31.5
9	BH049	Khilgaon Primary School, Pubail, Gazipur	23.930554	90.474382	43.5
10	BH061	Nyebbari, Uttar Salna, Gazipur, Dhaka	24.055288	90.379039	34.5
11	BH071	Govt Hazi Ibrahim School and College, Bandar, Narayanganj	23.592452	90.520625	54
12	BH074	Purbo Gopalnagar Govt. Primary School, Purbo Gopalnagar, Fatullah, Narayanganj	23.614722	90.465194	85.5
13	BH085	T Hossain Garden, Bandar, Narayanganj	23.630702	90.526057	31.5
14	BH088	55 No Mograpara Govt. Primary School Sonagaon, Sonargaon	23.6345	90.5885	40.5
15	BH107	Sonamia Market S.O Road Balurmath, Sumilpara	23.668045	90.51864	40.5
16	BH112	122 No Goalkhali Poshchim Govt. Primary School, Keraniganj, Dhaka	23.684463	90.324049	52.5
17	BH116	Doleshwar Government Primary School, Keraniganj, Dhaka	23.670799	90.439376	45
18	BH139	Kharakandi Govt. Primary School, Keraniganj	23.722002	90.274655	51
19	BH146	Samad Nagar, Jatrabari, Dhaka	23.713667	90.445583	30
20	BH150	sonali paper mills Ltd tarabo narayanganj	23.71732	90.512787	45

Sl No.	Borehole No.	Site Address	Latitude	Longitude	SPT Depth (m)
21	BH153	Sommalon Math, Noyapur Bazar, Sadipur, Sonargaon	23.722003	90.57602	40.5
22	BH160	Modderchor Govt. Primary School, Keraniganj	23.732211	90.347266	55.5
23	BH163	Kakrail Mosque (Tablig Jamat), Dhaka	23.737031	90.403856	37.5
24	BH185	baitunnur lalmia mosque,golakandail Rupganj narayanganj	23.761301	90.555648	34.5
25	BH189	11 No Mograkanda Govt. School, Savar, Dhaka	23.772218	90.309381	51
26	BH195	Ichakhali, Kaiup para, Rupganj, Narayanganj	23.773831	90.509379	33
27	BH199	Rupayan Sity, Hamiyetpur, Savar, Dhaka	23.790512	90.249486	50
28	BH203	Golertek playground Darussalam , Mirpur, Dhaka	23.792504	90.343403	30
29	BH209	Rowshan Ara girls high school, Beraid Badda	23.799836	90.475157	30
30	BH213	Moirabo, Bhulta, Rupganj, Narayanganj	23.794405	90.546166	34.5
31	BH230	Awal Market, Sadupur, Kazipara, Savar, Dhaka	23.823236	90.287336	72
32	BH236	Bagber, Rupganj, Narayanganj	23.826891	90.513313	37.5
33	BH245	Barua (shilon para) khilkhet, Dhaka	23.843133	90.453333	30
34	BH253	Kakabo Birulia Savar Dhaka	23.859753	90.32443	51
35	BH263	Rajuk Land Area, Zinda Park, Gazipur	23.863466	90.517055	30
36	BH275	Teromukh bridge uttarkhan dhaka	23.883211	90.457226	37.5
37	BH286	Ashulia, Savar, Dhaka	23.895458	90.3377	43.5
38	BH289	BTCL Tongi, Gazipur, Dhaka	23.897118	90.398196	52.5
39	BH293	Bhasania Primary School, Gazipur	23.899969	90.497052	30
40	HB298	Madhobi Sheltech Project, Plot No. 63, Katgora, Ashulia	23.915088	90.301686	57
41	BH311	Victoria Hondachiam Interbita School, Kaliganj	23.915488	90.555621	31.5
42	BH320	Kunia Moddho para Jame mosjid ,Gazipur	23.93111	90.384373	37.5
43	BH323	Kudaba, Pubail, Gazipur	23.932206	90.437981	52.5

Sl No.	Borehole No.	Site Address	Latitude	Longitude	SPT Depth (m)
44	HB329	Tajpur, Model High School, Ashulia, Savar	23.948603	90.32261	46.5
45	BH341	Stand Housing, Dehra, Ashulia	23.966698	90.260496	43.5
46	BH347	Maleker Bari Road, Sakrauri, Gacha, Joydebpur, Gazipur	23.967296	90.394856	49.5
47	BH361	Baluchakuli, Gazipur	23.981325	90.445001	31.5
48	BH369	Tetultala, Eatahata, Kolabagan, Gazipur	23.999478	90.359928	40.5
49	BH376	Ambag Govt. Primary School, Konabari, Gazipur	24.020923	90.321711	51
50	BH380	Gazipur sadar upojilla Gazipur	24.0205	90.417833	43.5

The test locations in CDMP report are given in following table 3.2 and presented in Figure 3.1.

Table 3.2 Site locations according to CDMP (2009) report

Location No	Location	Lattitude	Longitude
DMT-1	Dhaka University	23.7265	90.40172
DMT-2	Green Model Town	23.7273	90.4486
DMT-3	United City	23.7982	90.4553
DMT-4	Uttara Phase 3	23.8684	90.36199
DMT-5	Agargaon Trade Fair Area	23.7694	90.3774
DMT-6	Pallabi	23.831	90.35037
DMT-7	Uttra Khan	23.8832	90.41873
DMT-8	Aftab Nagar Housing Project, Dhaka	23.7652	90.44269
DMT-9	Sapnali Housing Project, Dhaka	23.8353	90.45738
DMT-10	Matuail, Demra, Dhaka	23.6999	90.47865

3.3 STANDARD PENETRATION TEST (SPT)

The entire SPT tests were categorized into three (3) tasks – Reconnaissance, Field Exploration and Laboratory Tests. The reconnaissance includes checking location of the site, topography, accessibility etc. The field exploration has been carried out using rotary drill with hydraulic arrangement. Rotary drilling rig was used for drilling boreholes in wash boring method and collecting field data according to ASTM D1586 – 18 (Standard Test Method for Standard Penetration Test and Split-Barrel Sampling of Soils). Field SPT N-value was recorded at each 1.5 m interval in each borehole. Standard laboratory tests were carried out to reveal physical and mechanical properties of the subsurface soil profile. Figure 3.2 shows the field data collection by rotary drilling in a wash boring method.

SPT at BH195

SPT at BH320

SPT at BH061

SPT at BH033

Figure 3.2 Photo captured during Standard Penetration Test (SPT)

The selected criteria for determining the borehole depth were “a borehole had been drilled up to a depth of at least 30 m and the N-value was 50 with 230 mm or less penetration in last consecutive 3 layers”.

Disturbed and undisturbed sampling both were carried out in the field according to proper ASTM standard. Disturbed or split-barrel sampling was done according to ASTM D1586 – 18 (Standard Test Method for Standard Penetration Test and Split-Barrel Sampling of Soils) and sample was collected in zipper bag and stored in airtight plastic box. For undisturbed sampling, Shelby tube was used according to ASTM D1587/D1587M – 15 (Standard Practice for Thin-Walled Tube Sampling of Fine-Grained Soils for Geotechnical Purposes).

Table 3.3 Soil class, unit weight and SPN N values for BH006

BH-006				
Depth to Sampler Tip (m)	Layer Thickness (m)	Soil Classification	Unit Weight (kN/m^3)	SPT N-value (N_{60})
1.5	1.5	Poorly Graded SAND with Silt (NP)	14.5	3
3	1.5	SILT (NP)	16.4	4
4.5	1.5	SILT	16.4	5
6	1.5	SILT (NP)	15.8	7
7.5	1.5	SILT	15.8	8
9	1.5	Fat CLAY	15.8	19
10.5	1.5	Fat CLAY	15.8	21
12	1.5	Fat CLAY	15.8	24
13.5	1.5	Fat CLAY	16.5	23
15	1.5	Fat CLAY	16.5	25
16.5	1.5	Silty SAND (NP)	16.5	30
18	1.5	Sandy SILT (NP)	17.2	36
19.5	1.5	Silty SAND (NP)	17.1	39
21	1.5	Lean CLAY	17.1	13
22.5	1.5	Lean CLAY	17.1	14
24	1.5	Lean CLAY	17.1	48
25.5	1.5	SILT (NP)	19.2	50
27	1.5	SILT (NP)	19.2	56
28.5	1.5	SILT (NP)	19.7	82
30	1.5	SILT with Sand (NP)	18.9	67
31.5	1.5	Silty SAND (NP)	18.4	84
33	1.5	Silty SAND (NP)	18.7	80
34.5	1.5	Sandy SILT (NP)	18.5	60
36	1.5	Silty SAND (NP)	18.7	65
37.5	1.5	SILT with Sand (NP)	20	75
39	1.5	SILT with Sand (NP)	20.4	84
40.5	1.5	SILT with Sand (NP)	20.8	110
42	1.5	SILT (NP)	21.6	171

All the collected samples were tested in the Geotechnical Laboratory with properly calibrated equipment to reveal their physical and mechanical properties. All the tests were carried out according to ASTM standard.

3.3.1 Site Classification based on SPT

The standard penetration values are obtained from the SPT test and are grouped together for this investigation. After making the necessary calculations for the upper 30 m in the soil equation 2.2 has been used (calculation detailed in Table 3.4) to determine N values (blows/30 cm). and depth of hole BH_006, it was discovered that the N value is 10.8, which. places it in the site class SD according to BNBC (discussed in Table 2.3 in chapter 2)

Table 3.4: Calculation for determining site class

Layer no	Depth (m)	Field SPT- N	d (m)	d/SPT-N	SPT value, $\bar{N}$ (blows/30cm)
1	1.5	3	1.5	0.50	
2	3	4	1.5	0.38	
3	4.5	5	1.5	0.30	
4	6	6	1.5	0.25	
5	7.5	7	1.5	0.21	
6	9	16	1.5	0.09	
7	10.5	17	1.5	0.09	
8	12	19	1.5	0.08	
9	13.5	18	1.5	0.08	$\bar{N} = \frac{\sum d}{\sum \frac{d}{SPT-N}}$
10	15	20	1.5	0.08	
11	16.5	24	1.5	0.06	
12	18	29	1.5	0.05	=10.8
13	19.5	31	1.5	0.05	Site Class = SD
14	21	10	1.5	0.15	
15	22.5	11	1.5	0.14	
16	24	11	1.5	0.14	
17	25.5	38	1.5	0.04	
18	27	40	1.5	0.04	
19	28.5	45	1.5	0.03	
20	30	66	1.5	0.02	
			$\sum$ d= 30	$\sum \frac{d}{SPT-N}$ =2.78	

Table 3.5 Site class for all the boreholes

Serial No.	Borehole No.	Site Address	Site Class Based on SPT
1	BH006	Aligonj Madrasa ghat, Fatulla, Narayanganj	SD
2	BH010	Baghair High School, Keraniganj	SD
3	BH018	Amulla Model Town 1 No. Road, Amuli, Demra, Dhaka	SD
4	BH024	Sher-E Bangla Nagar Agricultural University, Dhaka	SC
5	BH027	Block-M, Road-4, Sector-4, Aftab Nagar, Dhaka	SD
6	BH029	Gulshan Central Mosque (Ajad Mosque), Gulshan, Dhaka	SC
7	BH045	Gakulnagar Eidgah math Ashulia Savar Dhaka	SC
8	BH042	Bauniya Bazar jame mosque Turag ,Dhaka	SD
9	BH049	Khilgaon Primary School, Pubail, Gazipur	SD
10	BH061	Nyebbari, Uttar Salna, Gazipur, Dhaka	SC
11	BH071	Govt Hazi Ibrahim School and College, Bandar, Narayanganj	SC
12	BH074	Purbo Gopalnagar Govt. Primary School, Purbo Gopalnagar, Fatullah, Narayanganj	SC
13	BH085	T Hossain Garden, Bandar, Narayanganj	SD
14	BH088	55 No Mograpara Govt. Primary School Sonagaon, Sonargaon	SD
15	BH107	Sonamia Market S.O Road Balurmath, Sumilpara	SD
16	BH112	122 No Goalkhali Poshchim Govt. Primary School, Keraniganj, Dhaka	SD
17	BH116	Doleshwar Government Primary School, Keraniganj, Dhaka	SD
18	BH139	Kharakandi Govt. Primary School, Keraniganj	SD
19	BH146	Samad Nagar, Jatrabari, Dhaka	SD
20	BH150	sonali paper mills Ltd tarabo narayanganj	SD
21	BH153	Sommalon Math, Noyapur Bazar, Sadipur, Sonargaon	SC
22	BH160	Modderchor Govt. Primary School, Keraniganj	SC
23	BH163	Kakrail Mosque (Tablig Jamat), Dhaka	SC
24	BH185	baitunnur lalmia mosque,golakandail Rupganj narayanganj	SD

Serial No.	Borehole No.	Site Address	Site Class Based on SPT
25	BH189	11 No Mograkanda Govt. School, Savar, Dhaka	SC
26	BH195	Ichakhali, Kaiup para, Rupganj, Narayanganj	SD
27	BH199	Rupayan Sity, Hamiyetpur, Savar, Dhaka	SD
28	BH203	Golertek playground Darussalam , Mirpur, Dhaka	SC
29	BH209	Rowshan Ara girls high school, Beraid Badda	SD
30	BH213	Moirabo, Bhulta, Rupganj, Narayanganj	SD
31	BH230	Awal Market, Sadupur, Kazipara, Bongayo, Savar, Dhaka	SC
32	BH236	Bagber, Rupganj, Narayanganj	SD
33	BH245	Barua (shilon para) khilkhet, Dhaka	SD
34	BH253	Kakabo Birulia Savar Dhaka	SC
35	BH263	Rajuk Land Area, Zinda Park, Gazipur	SD
36	BH275	Teromukh bridge uttarkhan dhaka	SD
37	BH286	Ashulia, Savar, Dhaka	SD
38	BH289	BTCL Tongi, Gazipur, Dhaka	SC
39	BH293	Bhasania Primary School, Gazipur	SC
40	HB298	Madhobi Sheltech Project, Plot No. 63, Katgora, Ashulia	SC
41	BH311	Victoria Hondachiam Interbita School, Kaliganj	SD
42	BH320	Kunia Moddho para Jame mosjid ,Gazipur	SD
43	BH323	Kudaba, Pubail, Gazipur	SC
44	HB329	Tajpur, Model High School, Ashulia, Savar	SD
45	BH341	Stand Housing, Dehra, Ashulia	SD
46	BH347	Maleker Bari Road, Sakrauri, Gacha, Joydebpur, Gazipur	SC
47	BH361	Baluchakuli, Gazipur	SC
48	BH369	Tetultala, Eatahata, Kolabagan, Gazipur	SC
49	BH376	Ambag Govt. Primary School, Konabari, Gazipur	SC
50	BH380	Gazipur sadar upojilla Gazipur	SD

3.4 SEISMIC DOWNHOLE TEST (SDHT)

Seismic Downhole test is an in-situ test and determine the velocity of primary (P) and secondary (S) seismic waves to provide the dynamic elastic small-strain soil parameters. The P and S waves velocities are used in geotechnical foundation analysis, static and dynamic soil analysis, liquefaction triggering potential assessment etc. Downhole seismic test is carried out according to ASTM D7400.

3.4.1 Theory of Seismic Downhole test

Geophysical methods are divided into two groups. In The first group the natural resource for seismic simulation is considered. This group includes gravity, magnetics, radiometry, thermometry and seismicity. The second group includes the methods that measure response of non-natural or synthetic resource for seismic stimulation. This group includes methods like seismic refraction, reflection, geo electric, induced polarization and electromagnetic.

The most used methods in geo physical engineering are seismic and electric investigations. Seismic methods include refraction, reflection, down hole, cross hole, and tomography cross hole. The theory of seismic, refraction, down hole, up hole, cross hole and tomography have been presented here. This method is commonly used to determine the compressional and shear wave velocities versus depth. These velocities data are used to help assess the seismic response and determine stratigraphy of a particular site. In a down-hole seismic survey, a seismic source is placed on the surface near a borehole, and a geophone is placed at selected depths in the borehole. The raw data obtained from a down-hole survey are the travel times for compression and shear waves from the source to the geophones and the distances between the source and geophones.

Compressional waves are generated by striking a sledge hammer on a square metallic plate. The strike transfers to bottom of borehole and is received by a 3-componenet geophone. The offset (distance between plate and top of borehole) was about 2 to 3 meters. Shear waves are generated by striking a horizontal sledge hammer on a wooden planked. Shear waves travel slower than compressional waves. Therefore, compressional waves often interfere with shear waves. This interference sometimes makes identification of the first shear wave arrival difficult. To improve the resolution of the shear wave arrival, the seismic source is designed to produce a signal which contains a large shear wave component and a signal enhancement seismograph is used to process the received signals from the geophone. Schematic of Down-hole survey is shown in Figure 3.3

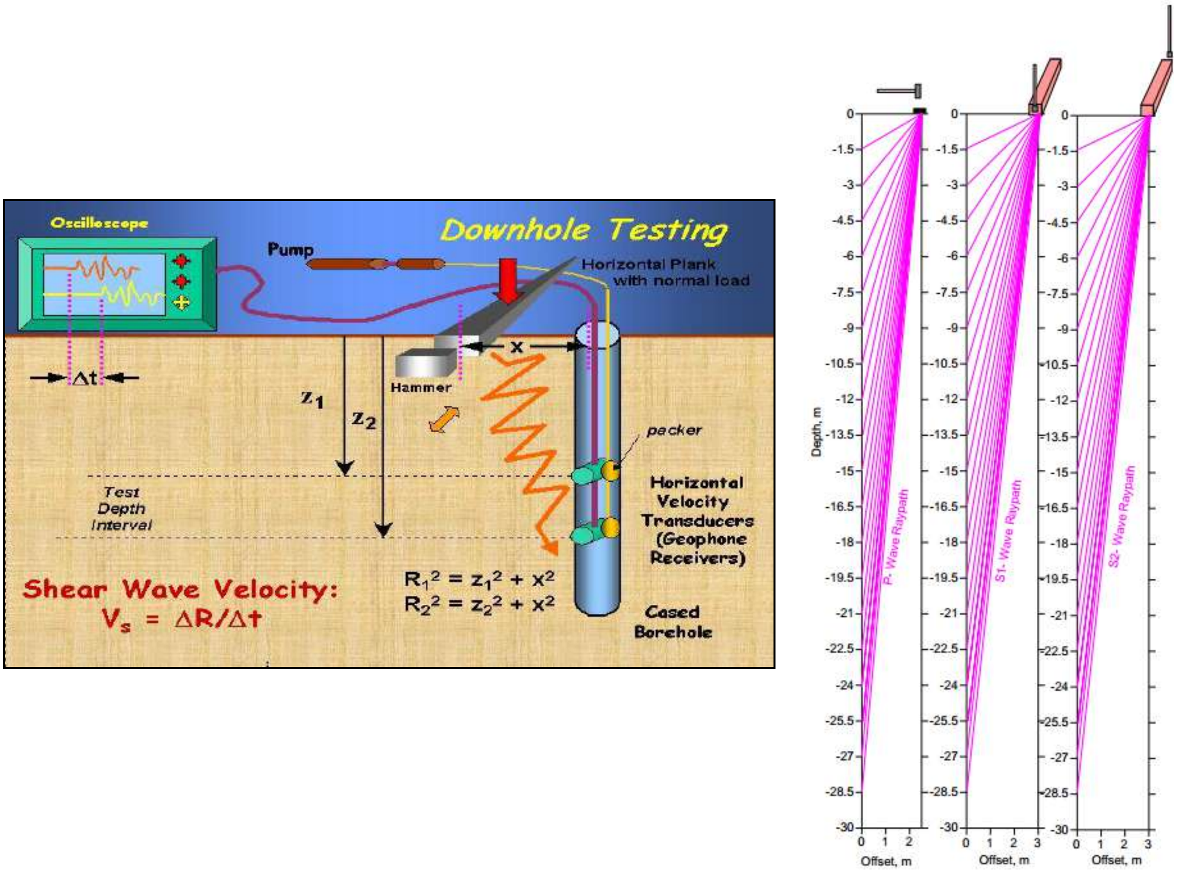


Figure 3.3 Schematic of Seismic Downhole Survey

The Down-hole sensors consist of a three-component geophone. This assembly contains three sensor elements: one vertical and two orthogonal horizontal elements. The geophone assemblies at a fixed separation are used so that interval velocities can be determined from the same set of impulses. This method reduces timing errors caused by differences in seismic triggering and variations in source impulse characteristics. The data are analyzed by determining the interval velocity for each geophone placement. Interval velocity is determined by first computing the distance from the source to each geophone and the difference in arrival times between the upper and lower geophones. The interval velocity is computed by dividing the difference in distance between the geophones by the difference in arrival times.

3.4.2 Borehole Preparation for SDHT

The boreholes were drilled with minimum sidewall disturbance, to a diameter about 100 mm [4 in.]. After completing the drilling which was done during SPT data collection, the borehole casing with 75mm internal diameter PVC pipe was placed. Before inserting the casing, the bottom of the pipe with a cap was closed. Fine grained sand with cement grout was inserted between the casing and the borehole sidewall. The soil mixture had been formulated to approximate closely the density of the surrounding in situ material after solidification. The annular space between the sidewall of the borehole and the casing had been filled from bottom to top in a uniform pattern displacing mud and debris with minimum sidewall disturbance.

The selected locations address, co-ordinates and SDHT conducted depth have been tabulated in the Table 3.6.

Table 3.6 SDHT test locations with depth of data collection

Sl No.	Borehole No.	Latitude	Longitude	SDHT Depth (m)
1	BH006	23.652611	90.464583	41
2	BH010	23.668303	90.384225	34
3	BH018	23.734428	90.483998	49
4	BH024	23.771041	90.376138	30
5	BH027	23.772512	90.456972	48
6	BH029	23.790473	90.414868	30
7	BH045	23.89717	90.248601	31
8	BH042	23.844371	90.388748	49
9	BH049	23.930554	90.474382	42
10	BH061	24.055288	90.379039	34
11	BH071	23.592452	90.520625	52
12	BH074	23.614722	90.465194	00
13	BH085	23.630702	90.526057	30
14	BH088	23.6345	90.5885	39
15	BH107	23.668045	90.51864	38
16	BH112	23.684463	90.324049	52
17	BH116	23.670799	90.439376	44
18	BH139	23.722002	90.274655	51
19	BH146	23.713667	90.445583	32
20	BH150	23.71732	90.512787	45
21	BH153	23.722003	90.57602	40
22	BH160	23.732211	90.347266	54
23	BH163	23.737031	90.403856	37
24	BH185	23.761301	90.555648	36
25	BH189	23.772218	90.309381	51
26	BH195	23.773831	90.509379	33
27	BH199	23.790512	90.249486	49
28	BH203	23.792504	90.343403	30
29	BH209	23.799836	90.475157	30
30	BH213	23.794405	90.546166	33
31	BH230	23.823236	90.287336	70
32	BH236	23.826891	90.513313	37
33	BH245	23.843133	90.453333	30

Sl No.	Borehole No.	Latitude	Longitude	SDHT Depth (m)
34	BH253	23.859753	90.32443	51
35	BH263	23.863466	90.517055	30
36	BH275	23.883211	90.457226	39
37	BH286	23.895458	90.3377	43
38	BH289	23.897118	90.398196	52
39	BH293	23.899969	90.497052	30
40	HB298	23.915088	90.301686	55
41	BH311	23.915488	90.555621	31
42	BH320	23.93111	90.384373	39
43	BH323	23.932206	90.437981	52
44	HB329	23.948603	90.32261	45
45	BH341	23.966698	90.260496	43
46	BH347	23.967296	90.394856	49
47	BH361	23.981325	90.445001	31
48	BH369	23.999478	90.359928	40
49	BH376	24.020923	90.321711	51
50	BH380	24.0205	90.417833	45

3.4.3 Data Acquisition of SDHT

The downhole test starts by preparing the energy source at its desired location. The receiver firmly clamped into place. The recording equipment was checked and timing was verified. The outputs of the receivers were monitored without activating the energy source to evaluate the ambient seismic noise in the ground and to establish a basis for filtering the noise, if necessary. Some photographs are shown in Figure 3.4.

The specification of data acquisition and equipment in this study are shown in table 3.7.

Table 3.7 Specification of equipment and data acquisition

Casing Diameter: 63 mm	Triggering method: geophone 10 HZ
Receivers: 3-component borehole 30 Hz with 70 m cable	Number of trace for each shot: 3 trace, 1 trace for p-wave and 2 trace for S-wave
Clamp method: Mechanical	Number of traces for each depth: 9
P-source offset: 0.0 - 2.0 m	Datalogger:24 bit
S-source offset: 2.0 - 3.0 m	Amplifier Gain: 12 to 26
Pipe Stickup: 0-.5 m	Sampling interval: 0.267 millisecond
P- source: Vertical sledge hammer 5 lb or 10 lb on steel plate	Recording time: 423.195 millisecond
S- source: horizontal sledge hammer 10 lb on wooden plank	Number of samples: 1585
Interval depth of testing: 1 m	Data format: SEG2 or ASCII

For site response analysis the shear wave velocity is needed for the depth up to the bed rock (approximately 200m to 300m for the study area) which data could not be got from seismic downhole test of this project. In this study the shear wave velocity for deeper depth has been taken from the nearer test result of CDMP report 2009.

SDHT at BH311

SDHT at BH088

SDHT at BH045

SDHT at BH027

SDHT at BH085

SDHT at BH0275

Figure 3.4 Photo captured during Seismic Down-Hole Test (SDHT)

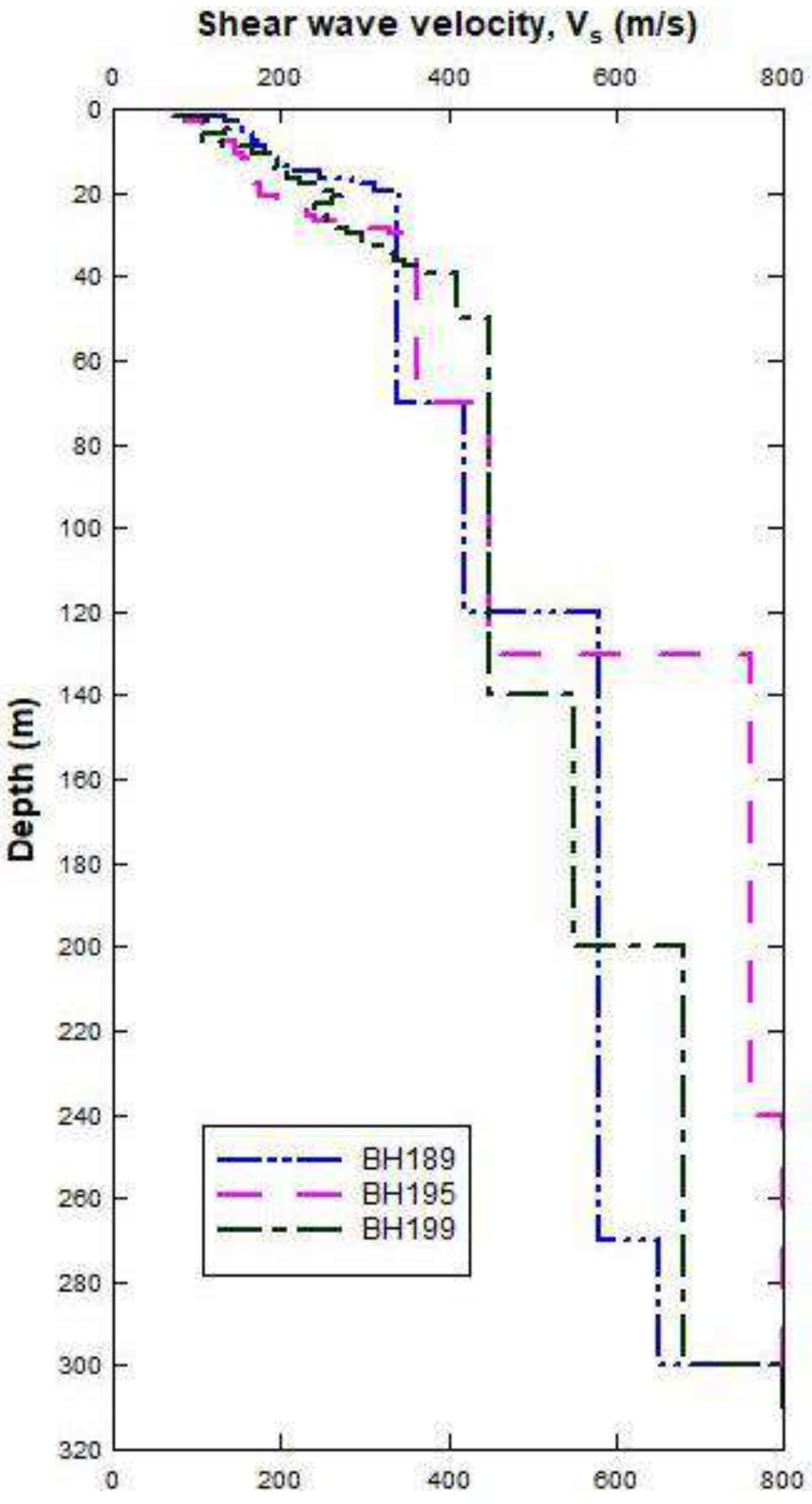


Figure 3.5 Shear wave velocity profile for BH189, BH195 and BH199

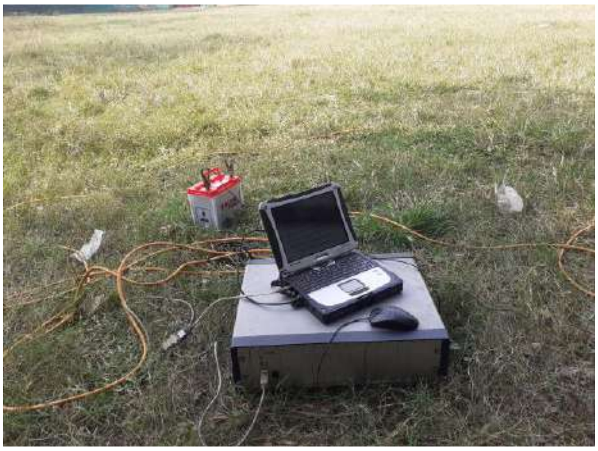
3.5 MICROTREMOR DATA COLLECTION

Microtremors are ambient vibrations of the ground caused by natural or artificial disturbances such as wind, sea waves, human activities, traffic and industrial machinery. In this study, microtremor records have been performed in DMDP area during the period of November 2021 to December 2021. The data collection has been carried out often on Friday, Saturday and government holidays.

Microtremor at BH024

Microtremor at BH369

Microtremor at BH293



Microtremor at BH116

Figure 3.6 Photo captured during Microtremor Data Collection

In this study broad band sensor type of seismograph microtremor measurement apparatus has been used to obtain data. The seismograph is Central Recording System CR-6plus produced by GeoSIG Ltd. The CR-6plus seismograph consists of the 15 channels, 24-bit acquisition box system with built-in computer with all its auxiliary tools such as keyboard, mouse controls, USB inlets and outlets, 8 GB recording memory, Sensor, Cable, Battery, GPS and a high-resolution screen for seismic data previews. GeoDAS software provided by manufacturer is used to record microtremor data. Five sensors have been used for data recording. The sampling frequency has been used 100 Hz. The amplification factor used is 20db in observation system. Figure 3.6 shows some pictures of microtremor measurement at different locations. Precautionary Measures in the Field

Some of the main points of precautionary measures have been taken for data acquisition from the field gathered from many experiences and the guidelines of SESME project:

i. Avoiding use of nonstandard recording/instrument/sensor setting parameters that influence on the H/V curves.
ii. Avoiding measurements on soft/irregular soils such as mud, grass, ploughed soil, ice, gravel, not compacted snow etc.
iii. Avoiding Artificial soil/sensor coupling
iv. Avoiding measurements under wind or heavy rain
v. Avoiding some noise of short period local sources during measurement, such las footsteps, cars, tractors, engines etc.
vi. Avoiding working times of factory and heavy activities.
vii. Keeping away infrastructure such as water pipes and electricity lines.
viii. Keeping away from large rivers and drainage system
ix. Keeping away from buildings and big structures.
x. Keeping away from trees and high plantation areas.
xi. Keeping away from highway traffic and railways
xii. Avoiding waterlogged and highly water saturation areas.

Based on the SESAME program, the guidelines for the field data survey that has been reported in the official manual, are listed in Table 3.6**.**

Table 3.8 The guidelines for the field data survey based on SESAME program

Type of parameter	**Main recommendations**	
Recording duration	Minimum expected f_0 [Hz]	Recommended minimum recording duration [min]
	0.2	30'
	0.5	20'
	1	10'
	2	5'
	5	3'
	10	2'

Type of parameter	Main recommendations
Measurement spacing	→ Microzonation: start with a large spacing (for example a 500 m grid) and, in case of lateral variation of the results, densify the grid point spacing, down to 250 m, for example. → Single site response: never use a single measurement point to derive an f_0 value, make at least three measurement points
Recording parameters	→ level the sensor as recommended by the manufacturer. → fix the gain level at the maximum possible without signal saturation
In situ soil-sensor coupling	→ set the sensor down directly on the ground, whenever possible. → avoid setting the sensor on "soft grounds" (mud, ploughed soil, tall grass, etc.), or soil saturated after rain
Artificial soil-sensor coupling	→ avoid plates from "soft" materials such as foam rubber, cardboard, etc. → on steep slopes that do not allow correct sensor levelling, install the sensor in a sand pile or in a container filled with sand. → on snow or ice, install a metallic or wooden plate or a container filled with sand to avoid sensor tilting due to local melting.
Nearby structures	→ Avoid recording near structures such as buildings, trees, etc. in case of wind blowing (faster than approx. 5 m/s). It may strongly influence H/V results by introducing some low frequencies in the curves → Avoid measuring above underground structures such as car parks, pipes, sewer lids, etc.
Weather conditions	→ Wind: Protect the sensor from the wind (faster than approx. 5 m/s). This only helps if there are no nearby structures. Rain: avoid measurements under heavy rain. Slight rain has no noticeable influence. → Temperature: check sensor and recorder manufacturer's instructions. → Meteorological perturbations: indicate on the field sheet whether the measurements are performed during a low-pressure meteorological event

Type of parameter	Main recommendations
Disturbances	→ Monochromatic sources: avoid measurements near construction machines, industrial machines, pumps, generators, etc. → Transients: In case of transients (steps, cars,...), increase the recording duration to allow for enough windows for the analysis, after transient removal.

3.5.2 Constraints of Data Acquisition in the Field

Microtremor data acquisition has been subjected to the following constraints:

i. Difficulties to take permission of the access to the selected site.
ii. Traffic conditions near the selected site especially with high traffic rates.
iii. Some industrial activities in some selected locations which have effects on certain times of data acquisition.
iv. Technical problems associated with the use of seismograph and seismometer in the field.
v. Construction and drilling work in the surrounding area.
vi. The presence of infrastructure underground pipelines in some locations in urban area.
vii. Difficulty in choosing the quiet peak times such as dawn and night because of security conditions.

CHAPTER 4
RESULT AND DISCUSSION

4.1 GENERAL

Most of the places of DMDP area are underlain by loose sandy silts and silty clay which can be more vulnerable during an earthquake due to amplification of the ground motion of the young, loose soil deposits in the study area. Site response analysis comprises of estimation of local site effects and the surface ground motion.

It is shown that local site condition has an important role on ground motion from the study of damage in recent earthquakes. Site response analysis studies play a significant role in seismic microdonation studies. This chapter deals with the estimation of amplification factor, surface PGA, predominant frequency of soil and response spectra curve for study locations. A comparison of the results getting from the 1D analysis and microtremor analysis also presented here in this chapter. Additionally, acceleration response spectra computed from 1D analysis and BNBC (2020) response spectra have been compared and a new design response spectrum has been proposed for the study area in the end of this chapter.

4.2 SITE RESPONSE ANALYSIS

During Earthquake the propagation of the seismic wave in soil deposits, the characteristics of strong ground motion, amplitude, frequency content, and duration, are altered because of the influence of local geologic and soil conditions commonly referred to as local site effects. The effects of ground motion are propagated one layer to other layer in the form of waves. Site response analyses can be used to compute site effects on ground motions. This approach involves the propagation of earthquake motions from the bed rock, through the overlying soil layers, and to the ground surface. In most cases, one-dimensional (1D) site response analysis is performed to assess the effect of soil conditions on ground shaking because vertically propagating and horizontally polarized shear waves dominate the earthquake ground motion wave field (Kramer, 1996).

In this study, 1D site response analysis has been performed using the DEEPSOIL software. the software requires input parameters that describe the ground profile on the site of interest. This includes soil layer thickness, material properties (e.g., shear module, damping ratio) and boundary conditions (e.g., fixed or unrestricted limits). DEEPSOIL requires seismic input as either a ground motion record or a design spectrum. This refers to the seismic motion applied to the base of the soil profile. DEEPSOIL uses the finite element approach to solve motion equations for earth layers. The software discredits the soil profile in an array of finite elements and the dynamic response of each element is calculated with respect to applied soil motion and soil properties. The software provides various output results, including amplification curves for ground motion, response spectra, shear deformation patterns, and displacements. These results can be used to assess the potential for soil liquefaction, evaluate the potential for ground failure, and estimate the response of soil-based structures.

The applied input motions in DEEPSOIL analysis are listed below

i. RSN1549_CHICHI_TCU129-N
ii. RSN1787_HECTOR_HEC000
iii. RSN2114_DENALI_PS10-317
iv. RSN3750_CAPEMEND_LFS270
v. RSN3756_LANDERS_MVP090
vi. RSN4458_MONTENE UL90
vii. RSN5657_IWATE_IWTH25EW
viii. RSN6927_DARFIELD_LINCN23E
ix. RSN8165_DUZCE_496-NS
x. RSN8606_SIERRA

The above input motions have been selected from Pacific Earthquake Engineering Research Centre (PEER) as input motion for the purpose of site response analysis using DEEPSOIL software. A brief detail of ten time-histories of input motions are given in the table 4.1.

In this study the design basis earthquake (DBE) is considered for determining the ground motion and the ground motion is selected at a level of ground shaking is equal to 2/3 (two-thirds) of the maximum considered earthquake (MCE) ground motion (BNBC-2020). The DBE for this study is determined to be 0.13g as acceleration of rock, and it is obtained by multiplying the acceleration of rock considering the MCE (0.2g) by 2/3. So, the input’s PGA value has been scaled to 0.13g in every input motion.

Table 4.1 Details of time histories Input Motion (PEER-Ground-Motion-Data-Base-Reader)

Record Sequence Number	**Earthquake Name**	**Year**	**Station Name**	**Magnitude Mw**	**Mechanism**	**R_{JB} (km)**	**R_{RUP} (km)**	**V_S30 (m/s)**	**Horizontal-1 Acc. File Name**	**Horizontal-2 Acc. Filename**
1549	Chi-Chi, Taiwan	1999	TCU129	7.6	Reverse Oblique	1.83	1.83	511.18	CHICHI_TCU129-E.AT2	CHICHI_TCU129-N.AT2
1787	Hector Mine	1999	Hector	7.13	Strike Slip	10.35	11.66	726.00	HECTOR_HEC000.AT2	HECTOR_HEC090.AT2
2114	Denali, Alaska	2002	TAPS Pump Station #10	7.9	Strike Slip	0.18	2.74	329.4	DENALI_PS10-047.AT2	DENALI_PS10-317.AT2
3750	Cape Mendocino	1992	Loleta Fire Station	7.01	Reverse	23.46	25.91	515.65	CAPEMEND_LFS270.AT2	CAPEMEND_LFS360.AT2
3756	Landers	1992	Morongo Valley Hall	7.28	Strike Slip	40.67	40.67	368.2	LANDERS_MVP000.AT2	LANDERS_MVP090.AT2
5657	Iwate, Japan	2008	IWTH25	6.9	Reverse	0.0	4.8	506.44	MONTENE.GRO_ULO000.AT2	MONTENE.GRO_ULO090.AT2
6927	Darfield, New Zealand	2010	LINC	7.0	Strike Slip	5.07	7.11	263.2	IWATE_IWTH25NS.AT2	IWATE_IWTH25EW.AT2
8165	Duzce, Turkey	1999	IRIGM 496	7.14	Strike Slip	4.21	4.21	760.0	DARFIELD_LINCN23E.AT2	DARFIELD_LINCN67W.AT2
8606	El Mayor-Cucapah,Mexico	2010	Westside Elementary School	7.2	Strike Slip	10.31	11.44	242.0	DUZCE_496-NS.AT2	DUZCE_496-EW.AT2

4.2.1 Site Response Analysis for BH006

The location is Aligonj Madrasa ghat, Fatulla, Narayanganj. The co-ordinate of the location is lat: 23° 39' 9.3996"N and long: 90° 27' 52.4988"E and the performed SPT borehole depth is 42m and the performed seismic downhole test depth is 41m.

Spectral Ratio Analysis

The comparison of spectral ratio analysis using SPT and shear wave velocity data by DEEPSOIL program and the Horizontal to Vertical Spectral Ratio (HVR) obtained from the microtremors using Geopsy program is shown in Figure 4.1a. Both equivalent linear and nonlinear methods have been applied in the case of DEEPSOIL analysis. For estimation of ground response site amplification factors at sub surface layers are often used as one of the parameters. The amplification factor is the maximum amplitude of the HVR curve.

Hence the amplification factor obtained from the microtremors analysis is 3.40 at 0.53 Hz, the amplification factor obtained from nonlinear method is 3.93 at 0.44 Hz and the amplification factor obtained from equivalent linear method is 5.32 at 0.42 Hz.

Response Spectra

Response spectra obtained from DEEPSOIL program in both equivalent linear and nonlinear method is presented in the following Figure 4.1b. The peak spectral acceleration (PSA) obtained using the nonlinear method is 0.47g and PSA obtained using equivalent linear method is 0.65g for the specific site.

Maximum Peak Ground Acceleration (PGA)

Maximum Peak Ground Acceleration (PGA) at different depths for this site is shown in Figure 4.1c at surface, which is obtained from equivalent linear and nonlinear analysis. The averages of PGA values at surface are observed 0.24g for equivalent linear analysis and 0.18g for nonlinear analysis.

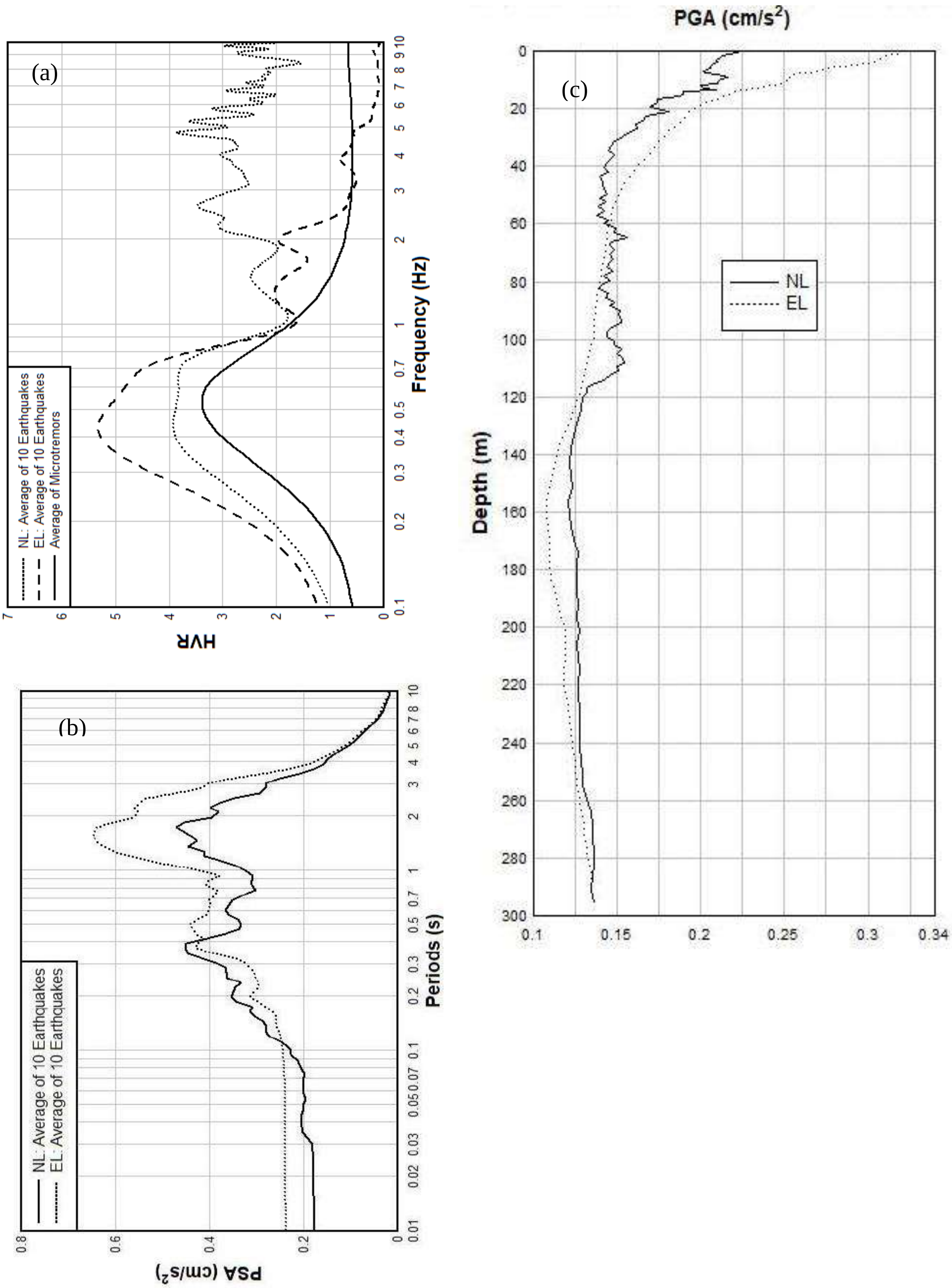


Figure 4.1 (a) Horizontal to Vertical Spectral Ratio (HVR), (b) Response Spectra and (c) Maximum peak ground acceleration (PGA) for the site-BH006

4.2.2 Site Response Analysis for BH010

The location is Baghair High School, Keraniganj. The co-ordinate of the location is lat: 23° 40' 5.8908"N and long: 90° 23' 3.21"E and the performed SPT borehole depth is 34.5m and the performed seismic downhole test depth is 34.0m.

Spectral Ratio Analysis

The comparison of spectral ratio analysis using SPT and shear wave velocity data by DEEPSOIL program and the Horizontal to Vertical Spectral Ratio (HVR) obtained from the microtremors using Geopsy program is shown in Figure 4.2a. Both equivalent linear and nonlinear methods have been applied in the case of DEEPSOIL analysis. For estimation of ground response site amplification factors at sub surface layers are often used as one of the parameters. The amplification factor is the maximum amplitude of the HVR curve.

Hence the amplification factor obtained from the microtremors analysis is 3.21 at 0.99Hz, the amplification factor obtained from nonlinear method is 4.86 at 0.83Hz and amplification factor obtained from equivalent linear method is 6.10 at 0.43 Hz.

Response Spectra

Response spectra obtained from DEEPSOIL program in both equivalent linear and nonlinear method is presented in the following Figure 4.2b. The peak spectral acceleration (PSA) obtained using the nonlinear method is 0.58g and PSA obtained using equivalent linear method is 0.88g for the specific site.

Maximum Peak Ground Acceleration (PGA)

Maximum Peak Ground Acceleration (PGA) at different depths for this site is shown in Figure 4.2c at surface, which is obtained from equivalent linear and nonlinear analysis. The averages of PGA values at surface are observed 0.32g for equivalent linear analysis and 0.22g for nonlinear analysis. `

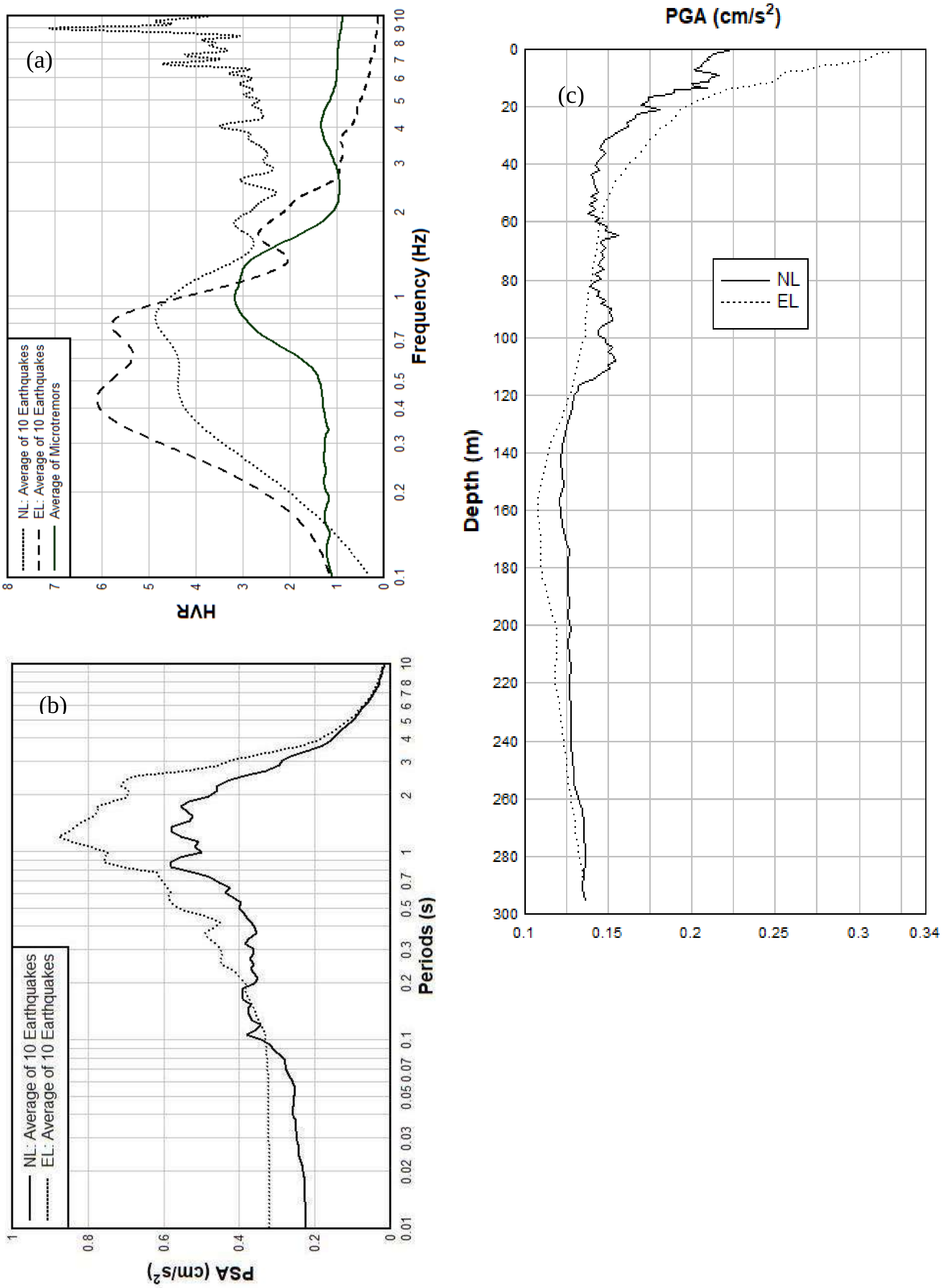


Figure 4.2 (a) Horizontal to Vertical Spectral Ratio (HVR), (b) Response Spectra and (c) Maximum peak ground acceleration (PGA) for the site-BH010

4.2.3 Site Response Analysis for BH018

The location is at Amulla model town, road no-01, Demra, Dhaka. The co-ordinate of the location is latitude: 23° 44' 3.9408"N and longitude: 90° 29' 2.3922"E and the performed borehole depth of SPT is 49.5m and the performed seismic downhole test depth is 49.0m.

Spectral Ratio Analysis

The comparison of spectral ratio analysis using SPT and shear wave velocity data by DEEPSOIL program and the Horizontal to Vertical Spectral Ratio (HVR) obtained from the microtremors using Geopsy program is shown in Figure 4.3a. Both equivalent linear and nonlinear methods have been applied in the case of DEEPSOIL analysis. For estimation of ground response site amplification factors at sub surface layers are often used as one of the parameters. The amplification factor is the maximum amplitude of the HVR curve.

Hence the amplification factor obtained from the microtremors is 4.178 at 0.90 Hz, the amplification factor obtained from nonlinear method is 3.72 at 0.83 Hz and amplification factor obtained from equivalent linear method is 4.36 at 0.39 Hz.

Response Spectra

Response spectra obtained from DEEPSOIL program in both equivalent linear and nonlinear method is presented in the following Figure 4.3b. The peak spectral acceleration (PSA) obtained using the nonlinear method is 0.49g and PSA obtained using equivalent linear method is 0.59g for the specific site.

Maximum Peak Ground Acceleration (PGA)

Maximum Peak Ground Acceleration (PGA) at different depths for this site is shown in the Figure 4.3c at surface, which is obtained from equivalent linear and nonlinear analysis. The averages of PGA values at surface are observed 0.24g for equivalent linear analysis and 0.18g for nonlinear analysis.

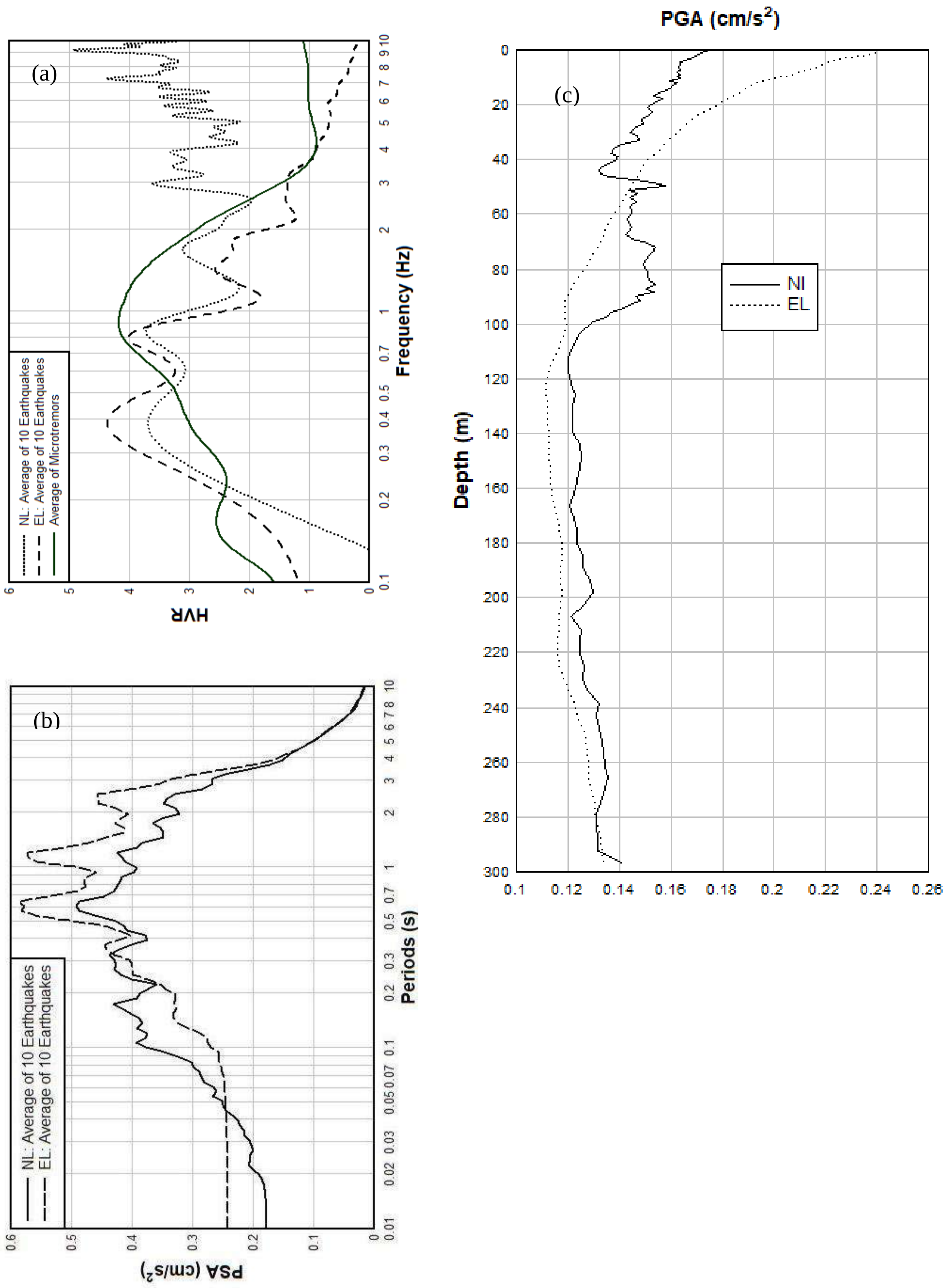


Figure 4.3 (a) Horizontal to Vertical Spectral Ratio (HVR), (b) Response Spectra and (c) Maximum peak ground acceleration (PGA) for the site-BH018

4.2.4 Site Response Analysis for BH024

The location is at Sher-E Bangla Nagar Agricultural University, Dhaka. The co-ordinate of the location is lat: 23° 46' 15.7476"N and long: 90° 22' 34.0962"E and the performed borehole depth of SPT is 30.0m and the performed seismic downhole test depth is 30.0m.

Spectral Ratio Analysis

The comparison of spectral ratio analysis using SPT and shear wave velocity data by DEEPSOIL program and the Horizontal to Vertical Spectral Ratio (HVR) obtained from the microtremors using Geopsy program is shown in Figure 4.4a. Both equivalent linear and nonlinear methods have been applied in the case of DEEPSOIL analysis. For estimation of ground response site amplification factors at sub surface layers are often used as one of the parameters. The amplification factor is the maximum amplitude of the HVR curve.

Hence the amplification factor obtained from the microtremors is 5.6 at 0.45 Hz, amplification factor obtained from nonlinear method is 3.52 at 0.37 Hz and amplification factor obtained from equivalent linear method is 4.12 at 0.37 Hz.

Response Spectra

Response spectra obtained from DEEPSOIL program in both equivalent linear and nonlinear method is presented in the following Figure 4.4b. The peak spectral acceleration (PSA) obtained using the nonlinear method is 0.43g and PSA obtained using equivalent linear method is 0.55g for the specific site.

Maximum Peak Ground Acceleration (PGA)

Maximum Peak Ground Acceleration (PGA) at different depths for this site is shown in the Figure 4.4c at surface, which is obtained from equivalent linear and nonlinear analysis. The averages of PGA values at surface are observed 0.22g for equivalent linear analysis and 0.17g for nonlinear analysis.

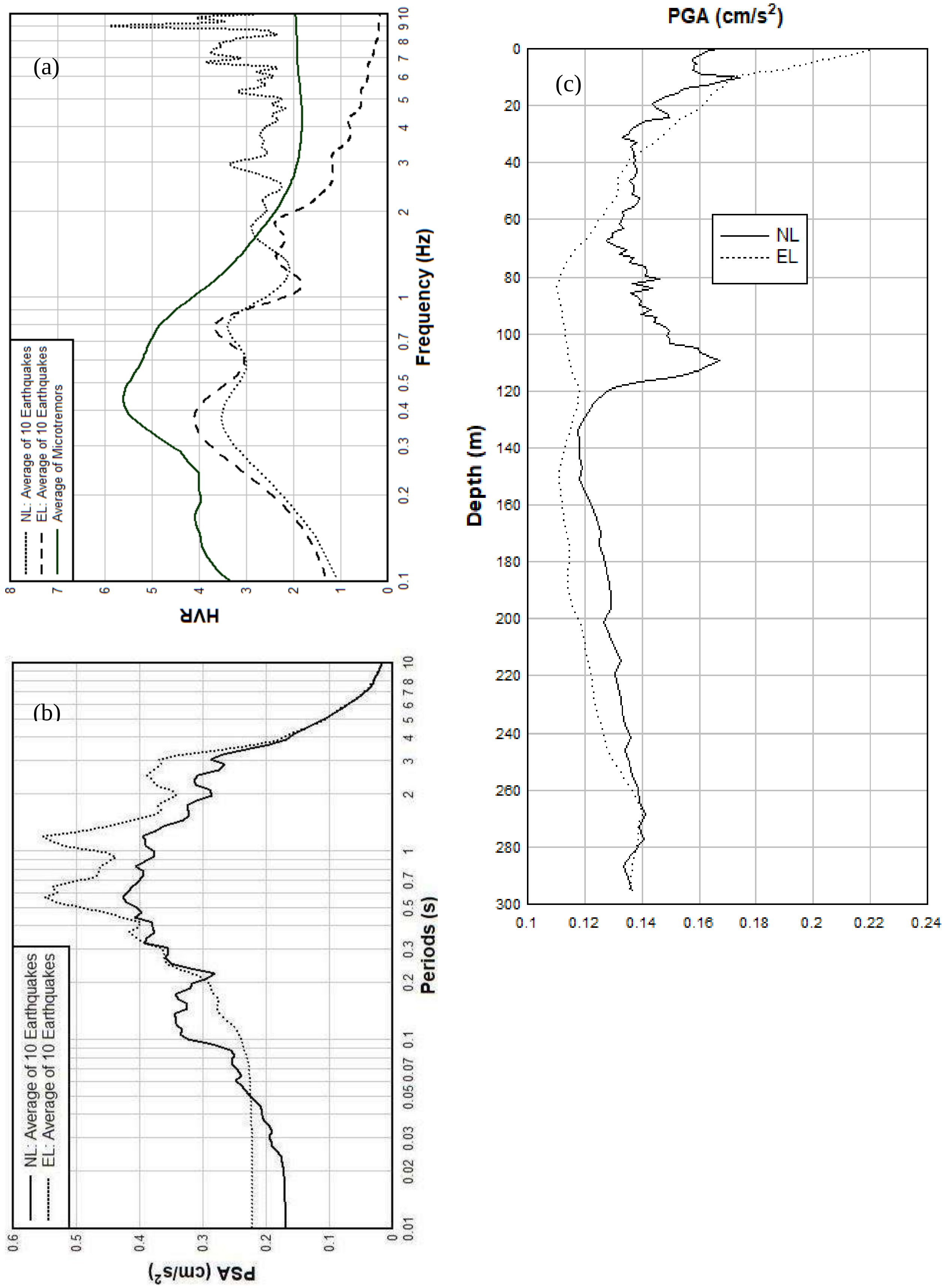


Figure 4.4 (a) Horizontal to Vertical Spectral Ratio (HVR), (b) Response Spectra and (c) Maximum peak ground acceleration (PGA) for the site-BH024

4.2.5 Site Response Analysis for BH027

The location is at Block-M, Road-4, Sector-4, Aftab Nagar, Dhaka. The co-ordinate of the location is lat: 23° 46' 21.0426"N and long: 90° 27' 25.0986"E and the performed borehole depth of SPT is 48.0m and the performed seismic downhole test depth is 48.0m.

Spectral Ratio Analysis

The comparison of spectral ratio analysis using SPT and shear wave velocity data by DEEPSOIL program and the Horizontal to Vertical Spectral Ratio (HVR) obtained from the microtremors using Geopsy program is shown in Figure 4.5a. Both equivalent linear and nonlinear methods have been applied in the case of DEEPSOIL analysis. For estimation of ground response site amplification factors at sub surface layers are often used as one of the parameters. The amplification factor is the maximum amplitude of the HVR curve.

Hence the amplification factor obtained from the microtremors is 3.428at 0.82 Hz, the amplification factor obtained from nonlinear method is 4.760 at 0.43 Hz and the amplification factor obtained from equivalent linear method is 4.68 at 0.92 Hz.

Response Spectra

Response spectra obtained from DEEPSOIL program in both equivalent linear and nonlinear method is presented in the following Figure 4.5b. The peak spectral acceleration (PSA) obtained using the nonlinear method is 0.78g and PSA obtained using equivalent linear method is 0.83g for the specific site.

Maximum Peak Ground Acceleration (PGA)

Maximum Peak Ground Acceleration (PGA) at different depths for this site is shown in the Figure 4.5c at surface, which is obtained from equivalent linear and nonlinear analysis. The averages of PGA values at surface are observed 0.34g for equivalent linear analysis and 0.26g for nonlinear analysis.

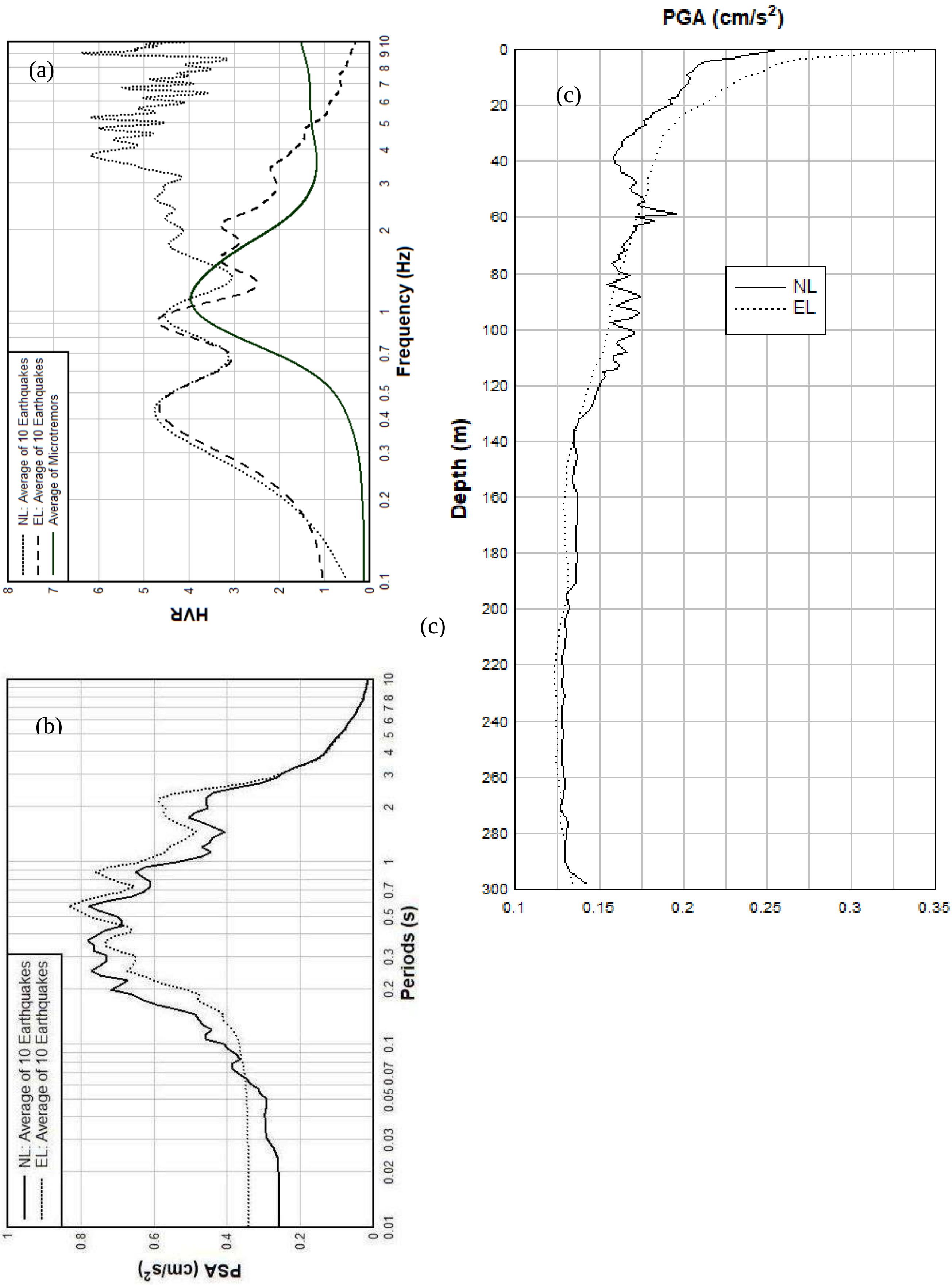


Figure 4.5 (a) Horizontal to Vertical Spectral Ratio (HVR), (b) Response Spectra and (c) Maximum peak ground acceleration (PGA) for the site-BH027

4.2.6 Site Response Analysis for BH029

The location is at Gulshan Central Mosque (Ajad Mosque), Gulshan, Dhaka. The co-ordinate of the location is lat: 23° 47' 25.7022"N and long: 90° 24' 53.5242"E and the performed borehole depth of SPT is 30.0m and the performed seismic downhole test depth is 30.0m.

Spectral Ratio Analysis

The comparison of spectral ratio analysis using SPT and shear wave velocity data by DEEPSOIL program and the Horizontal to Vertical Spectral Ratio (HVR) obtained from the microtremors using Geopsy program is shown in Figure 4.6a. Both equivalent linear and nonlinear methods have been applied in the case of DEEPSOIL analysis. For estimation of ground response site amplification factors at sub surface layers are often used as one of the parameters. The amplification factor is the maximum amplitude of the HVR curve.

Hence the amplification factor obtained from the microtremors is 3.89 at 2.68 Hz, the amplification factor obtained from nonlinear method is 3.81 at 0.43 Hz and the amplification factor obtained from equivalent linear method is 4.82 at 0.87Hz.

Response Spectra

Response spectra obtained from DEEPSOIL program in both equivalent linear and nonlinear method is presented in the following Figure 4.6b. The peak spectral acceleration (PSA) obtained using the nonlinear method is 0.52g and PSA obtained using equivalent linear method is 0.70g for the specific site.

Maximum Peak Ground Acceleration (PGA)

Maximum Peak Ground Acceleration (PGA) at different depths for this site is shown in Figure 4.6c at surface, which is obtained from equivalent linear and nonlinear analysis. The averages of PGA values at surface are observed 0.29g for equivalent linear analysis and 0.19g for nonlinear analysis.

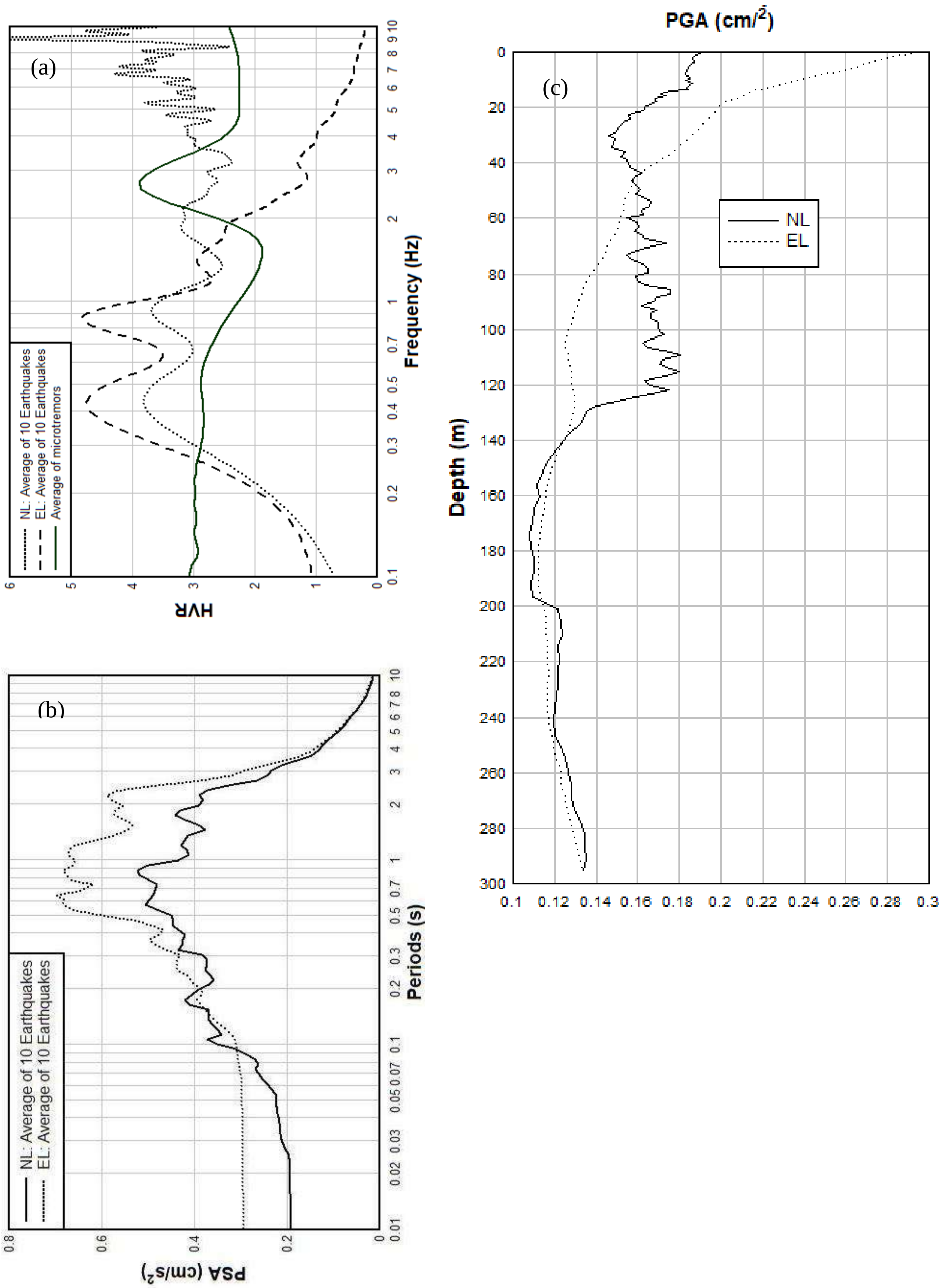


Figure 4.6 (a) Horizontal to Vertical Spectral Ratio (HVR), (b) Response Spectra and (c) Maximum peak ground acceleration (PGA) for the site-BH029

4.2.7 Site Response Analysis for BH042

The location is at Bauniya Bazar jame mosque Turag, Dhaka. The co-ordinate of the location is lat: 23° 50' 39.735''N and long: 90° 23' 19.4928''E and the performed borehole depth of SPT is 31.5m and the performed seismic downhole test depth is 31.0m.

Spectral Ratio Analysis

The comparison of spectral ratio analysis using SPT and shear wave velocity data by DEEPSOIL program and the Horizontal to Vertical Spectral Ratio (HVR) obtained from the microtremors using Geopsy program is shown in Figure 4.7a. Both equivalent linear and nonlinear methods have been applied in the case of DEEPSOIL analysis. For estimation of ground response site amplification factors at sub surface layers are often used as one of the parameters. The amplification factor is the maximum amplitude of the HVR curve.

The amplification factor obtained from the microtremors is 3.01 at 0.71 Hz, the amplification factor obtained from nonlinear method is 3.94 at 0.41 Hz and the amplification factor obtained from equivalent linear method is 4.58 at 0.82 Hz.

Response Spectra

Response spectra obtained from DEEPSOIL program in both equivalent linear and nonlinear method is presented in the following Figure 4.7b. The peak spectral acceleration (PSA) obtained using the nonlinear method is 0.549g and PSA obtained using equivalent linear method is 0.74g for the specific site.

Maximum Peak Ground Acceleration (PGA)

Maximum Peak Ground Acceleration (PGA) at different depths for this site is shown in Figure 4.7c at surface, which is obtained from equivalent linear and nonlinear analysis. The averages of PGA values at surface are observed 0.29g for equivalent linear analysis and 0.21g for nonlinear analysis.

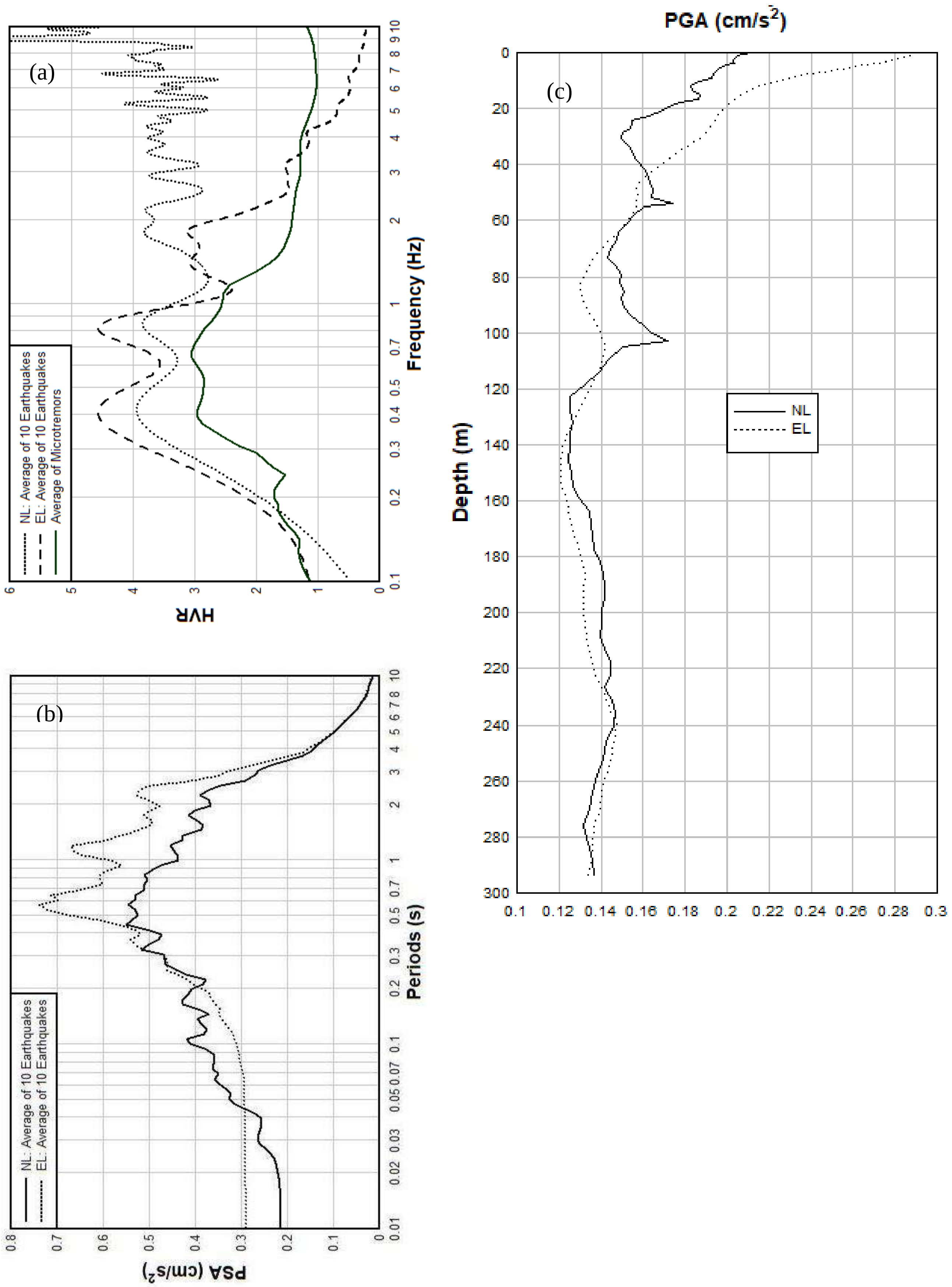


Figure 4.7 (a) Horizontal to Vertical Spectral Ratio (HVR), (b) Response Spectra and (c) Maximum peak ground acceleration (PGA) for the site-BH042

4.2.8 Site Response Analysis for BH045

The location is at Gakulnagar Eidgah math, Ashulia, Savar, Dhaka. The co-ordinate of the location is lat: 23° 53' 49.8114"N and long: 90° 14' 54.9672"E and the performed borehole depth of SPT is 49.5m and the performed seismic downhole test depth is 49.0m.

Spectral Ratio Analysis

The comparison of spectral ratio analysis using SPT and shear wave velocity data by DEEPSOIL program and the Horizontal to Vertical Spectral Ratio (HVR) obtained from the microtremors using Geopsy program is shown in Figure 4.8a. Both equivalent linear and nonlinear methods have been applied in the case of DEEPSOIL analysis. For estimation of ground response site amplification factors at sub surface layers are often used as one of the parameters. The amplification factor is the maximum amplitude of the HVR curve.

Hence the amplification factor obtained from the microtremors is 3.16 at 0.40 Hz, the amplification factor obtained from nonlinear method is 4.03 at 0.40 Hz and the amplification factor obtained from equivalent linear method is 4.49 at 0.39 Hz.

Response Spectra

Response spectra obtained from DEEPSOIL program in both equivalent linear and nonlinear method is presented in the following Figure 4.8b. The peak spectral acceleration (PSA) obtained using the nonlinear method is 0.49g and PSA obtained using equivalent linear method is 0.678g for the specific site.

Maximum Peak Ground Acceleration (PGA)

Maximum Peak Ground Acceleration (PGA) at different depths for this site is shown in the Figure 4.8c at surface, which is obtained from equivalent linear and nonlinear analysis. The averages of PGA values at surface are observed 0.27g for equivalent linear analysis and 0.19g for nonlinear analysis.

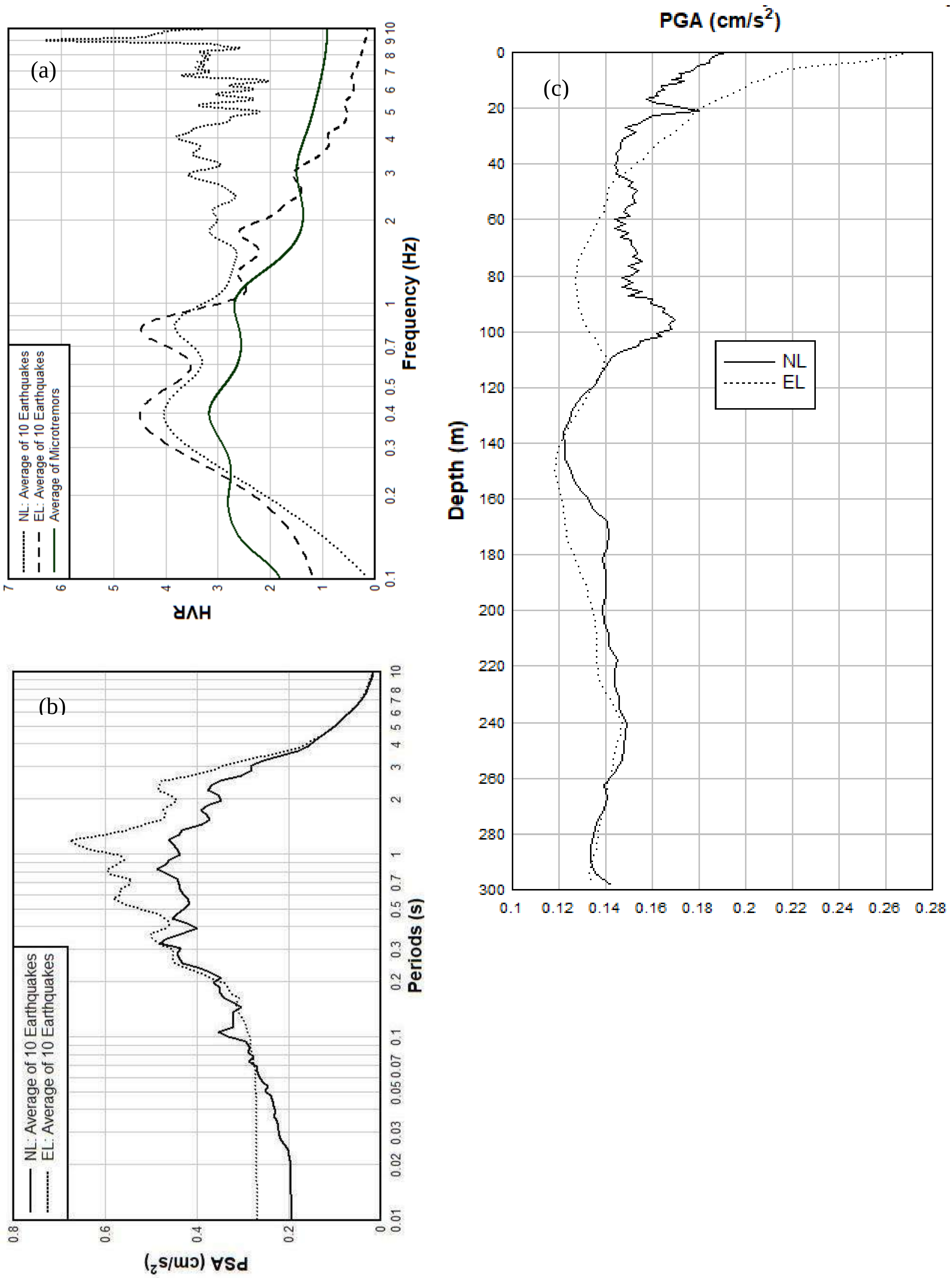


Figure 4.8 (a) Horizontal to Vertical Spectral Ratio (HVR), (b) Response Spectra and (c) Maximum peak ground acceleration (PGA) for the site-BH045

4.2.9 Site Response Analysis for BH049

The location is at Khilgaon Primary School, Pubail, Gazipur. The co-ordinate of the location is lat: 23° 55' 49.9944"N and long: 90° 28' 27.7752"E and the performed SPT borehole depth is 43.5m and the performed seismic downhole test depth is 42.0m.

Spectral Ratio Analysis

The comparison of spectral ratio analysis using SPT and shear wave velocity data by DEEPSOIL program and the Horizontal to Vertical Spectral Ratio (HVR) obtained from the microtremors using Geopsy program is shown in Figure 4.9a. Both equivalent linear and nonlinear methods have been applied in the case of DEEPSOIL analysis. For estimation of ground response site amplification factors at sub surface layers are often used as one of the parameters. The amplification factor is the maximum amplitude of the HVR curve.

The amplification factor obtained from the microtremors is 4.2 at 0.39 Hz, the amplification factor obtained from nonlinear method is 4.0 at 1.05 Hz and the amplification factor obtained from equivalent linear method is 4.31 at 0.92 Hz.

Response Spectra

Response spectra obtained from DEEPSOIL program in both equivalent linear and nonlinear method is presented in the following Figure 4.9b. The peak spectral acceleration (PSA) obtained using the nonlinear method is 0.66g and PSA obtained using equivalent linear method is 0.91g for the specific site.

Maximum Peak Ground Acceleration (PGA)

Maximum Peak Ground Acceleration (PGA) at different depths for this site is shown in the Figure 4.9c at surface, which is obtained from equivalent linear and nonlinear analysis. The averages of PGA values at surface are observed 0.29g for equivalent linear analysis and 0.20g for nonlinear analysis.

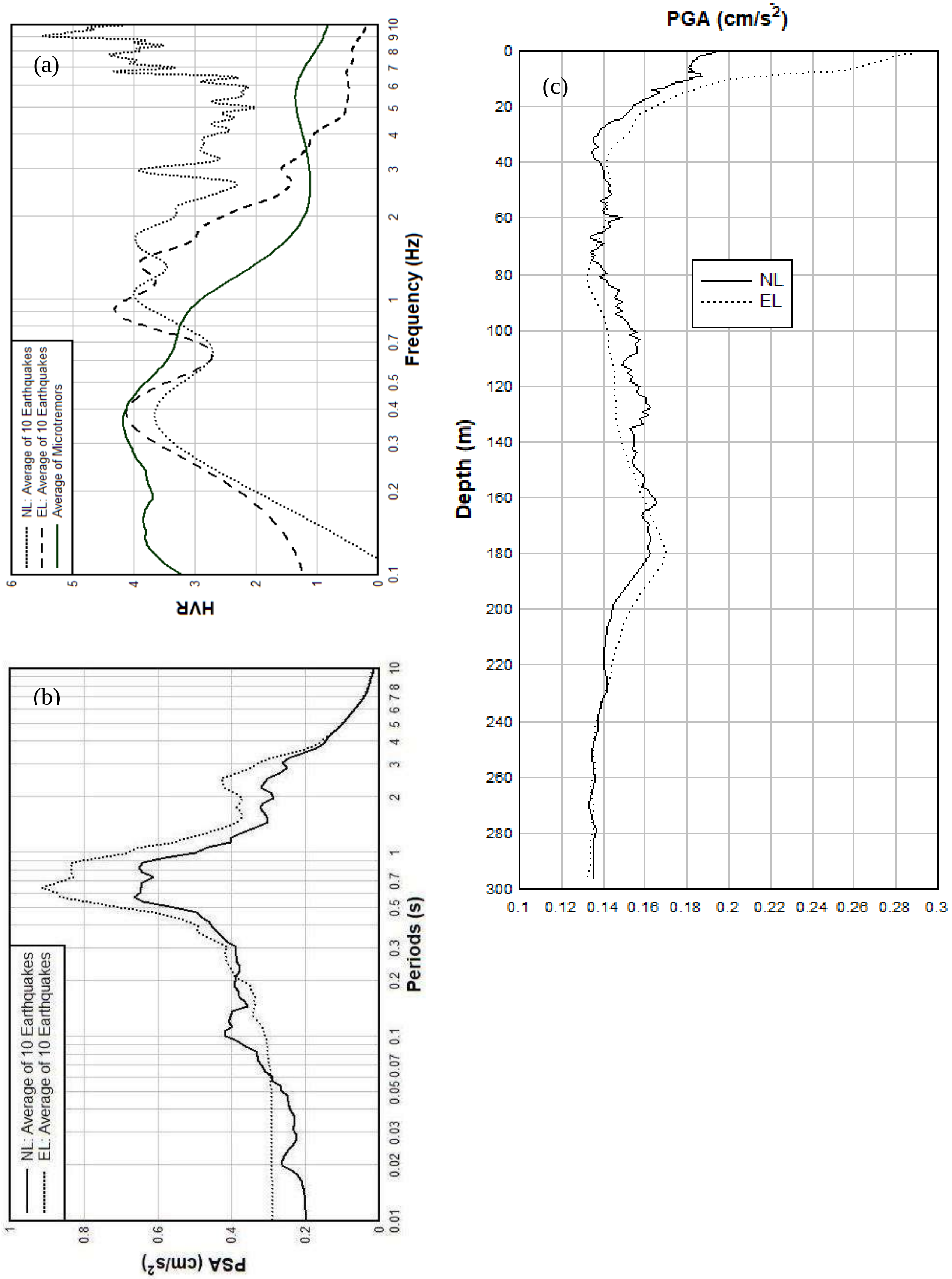


Figure 4.9 (a) Horizontal to Vertical Spectral Ratio (HVR), (b) Response Spectra and (c) Maximum peak ground acceleration (PGA) for the site-BH049

4.2.10 Site Response Analysis for BH061

The location is at Nyebbari, Uttar Salna, Gazipur, Dhaka. The co-ordinate of the location is lat: 24° 3' 19.0368"N and long: 90° 22' 44.5404"E and the performed borehole depth of SPT is 34.5m and the performed seismic downhole test depth is 34.0m.

Spectral Ratio Analysis

The comparison of spectral ratio analysis using SPT and shear wave velocity data by DEEPSOIL program and the Horizontal to Vertical Spectral Ratio (HVR) obtained from the microtremors using Geopsy program is shown in Figure 4.10a. Both equivalent linear and nonlinear methods have been applied in the case of DEEPSOIL analysis. For estimation of ground response site amplification factors at sub surface layers are often used as one of the parameters. The amplification factor is the maximum amplitude of the HVR curve.

Hence the amplification factor obtained from the microtremors is 2.96 at 0.35 Hz, the amplification factor obtained from nonlinear method is 3.47 at 0.43 Hz and the amplification factor obtained from equivalent linear method is 3.99 at 0.43 Hz.

Response Spectra

Response spectra obtained from DEEPSOIL program in both equivalent linear and nonlinear method is presented in the following Figure 4.10b. The peak spectral acceleration (PSA) obtained using the nonlinear method is 0.60g and PSA obtained using equivalent linear method is 0.63g for the specific site.

Maximum Peak Ground Acceleration (PGA)

Maximum Peak Ground Acceleration (PGA) at different depths for this site is shown in the Figure 4.10c at surface, which is obtained from equivalent linear and nonlinear analysis. The averages of PGA values at surface are observed 0.27g for equivalent linear analysis and 0.20g for nonlinear analysis.

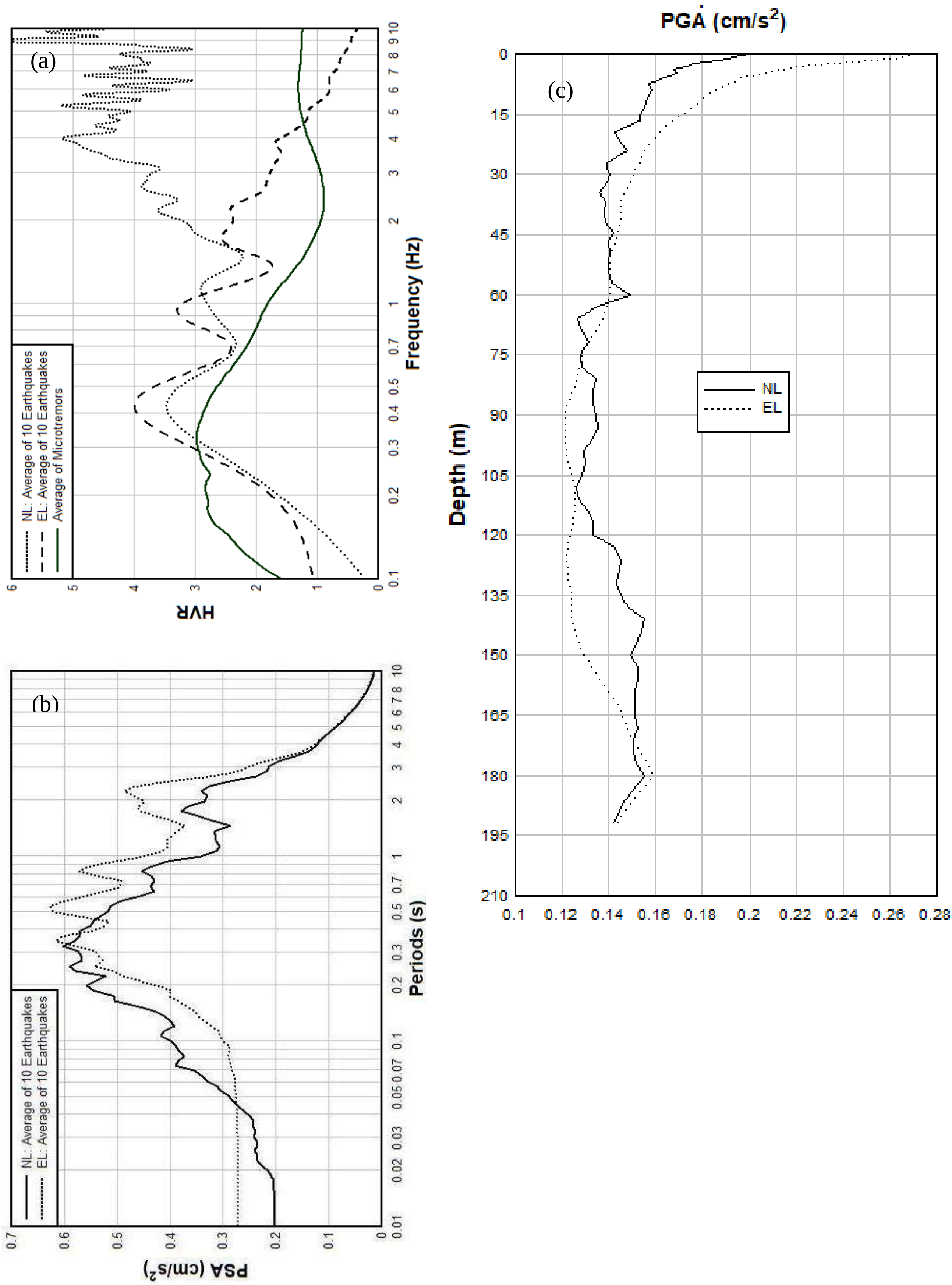


Figure 4.10 (a) Horizontal to Vertical Spectral Ratio (HVR), (b) Response Spectra and (c) Maximum peak ground acceleration (PGA) for the site-BH061

4.2.11 Site Response Analysis for BH071

The location is at Govt Hazi Ibrahim School and College, Bandar, Narayanganj. The co-ordinate of the location is lat: 23° 35' 32.8272"N and long: 90° 31' 14.2494"E and the performed SPT borehole depth is 54.0m and the performed seismic downhole test depth is 52.0m.

Spectral Ratio Analysis

The comparison of spectral ratio analysis using SPT and shear wave velocity data by DEEPSOIL program and the Horizontal to Vertical Spectral Ratio (HVR) obtained from the microtremors using Geopsy program is shown in Figure 4.11a. Both equivalent linear and nonlinear methods have been applied in the case of DEEPSOIL analysis. For estimation of ground response site amplification factors at sub surface layers are often used as one of the parameters. The amplification factor is the maximum amplitude of the HVR curve.

Hence the amplification factor obtained from the microtremors is 5.98 at 0.31 Hz, the amplification factor obtained from nonlinear method is 4.23 at 0.41 Hz and the amplification factor obtained from equivalent linear method is 4.56 at 0.40 Hz.

Response Spectra

Response spectra obtained from DEEPSOIL program in both equivalent linear and nonlinear method is presented in the following Figure 4.11b. The peak spectral acceleration (PSA) obtained using the nonlinear method is 0.55g and PSA obtained using equivalent linear method is 0.65g for the specific site.

Maximum Peak Ground Acceleration (PGA)

Maximum Peak Ground Acceleration (PGA) at different depths for this site is shown in Figure 4.11c at surface, which is obtained from equivalent linear and nonlinear analysis. The averages of PGA values at surface are observed 0.29g for equivalent linear analysis and 0.20g for nonlinear analysis.

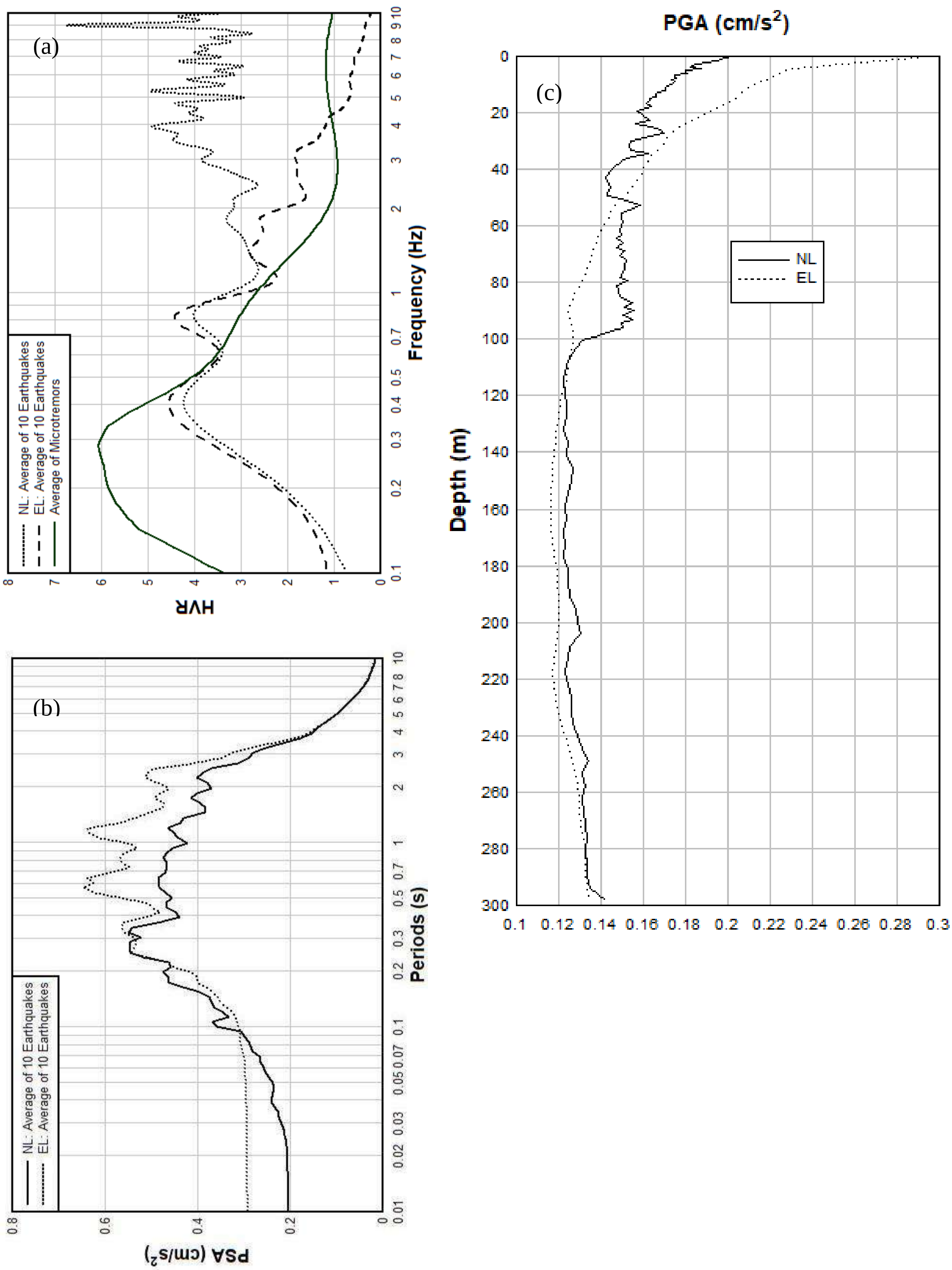


Figure 4.11 (a) Horizontal to Vertical Spectral Ratio (HVR), (b) Response Spectra and (c) Maximum peak ground acceleration (PGA) for the site-BH071

4.2.12 Site Response Analysis for BH074

The location is at Purbo Gopalnagar Govt. Primary School, Purbo Gopalnagar, Fatullah, Narayanganj. The co-ordinate of the location is lat: 23° 36' 52.9992"N and long: 90° 27' 54.6978"E and the performed borehole depth of SPT is 85.5m and the seismic downhole test cannot be done here due to blockage of borehole.

Spectral Ratio Analysis

The comparison of spectral ratio analysis using SPT and shear wave velocity data by DEEPSOIL program and the Horizontal to Vertical Spectral Ratio (HVR) obtained from the microtremors using Geopsy program is shown in Figure 4.12a. Both equivalent linear and nonlinear methods have been applied in the case of DEEPSOIL analysis. For estimation of ground response site amplification factors at sub surface layers are often used as one of the parameters. The amplification factor is the maximum amplitude of the HVR curve.

Hence the amplification factor obtained from the microtremors is 4.22 at 0.23 Hz, the amplification factor obtained from nonlinear method is 4.140 at 0.44 Hz and the amplification factor obtained from equivalent linear method is 4.71 at 0.40 Hz.

Response Spectra

Response spectra obtained from DEEPSOIL program in both equivalent linear and nonlinear method is presented in the following Figure 4.12b. The peak spectral acceleration (PSA) obtained using the nonlinear method is 0.57g and PSA obtained using equivalent linear method is 0.75g for the specific site.

Maximum Peak Ground Acceleration (PGA)

Maximum Peak Ground Acceleration (PGA) at different depths for this site is shown in Figure 4.12c at surface, which is obtained from equivalent linear and nonlinear analysis. The averages of PGA values at surface are observed 0.31g for equivalent linear analysis and 0.21g for nonlinear analysis.

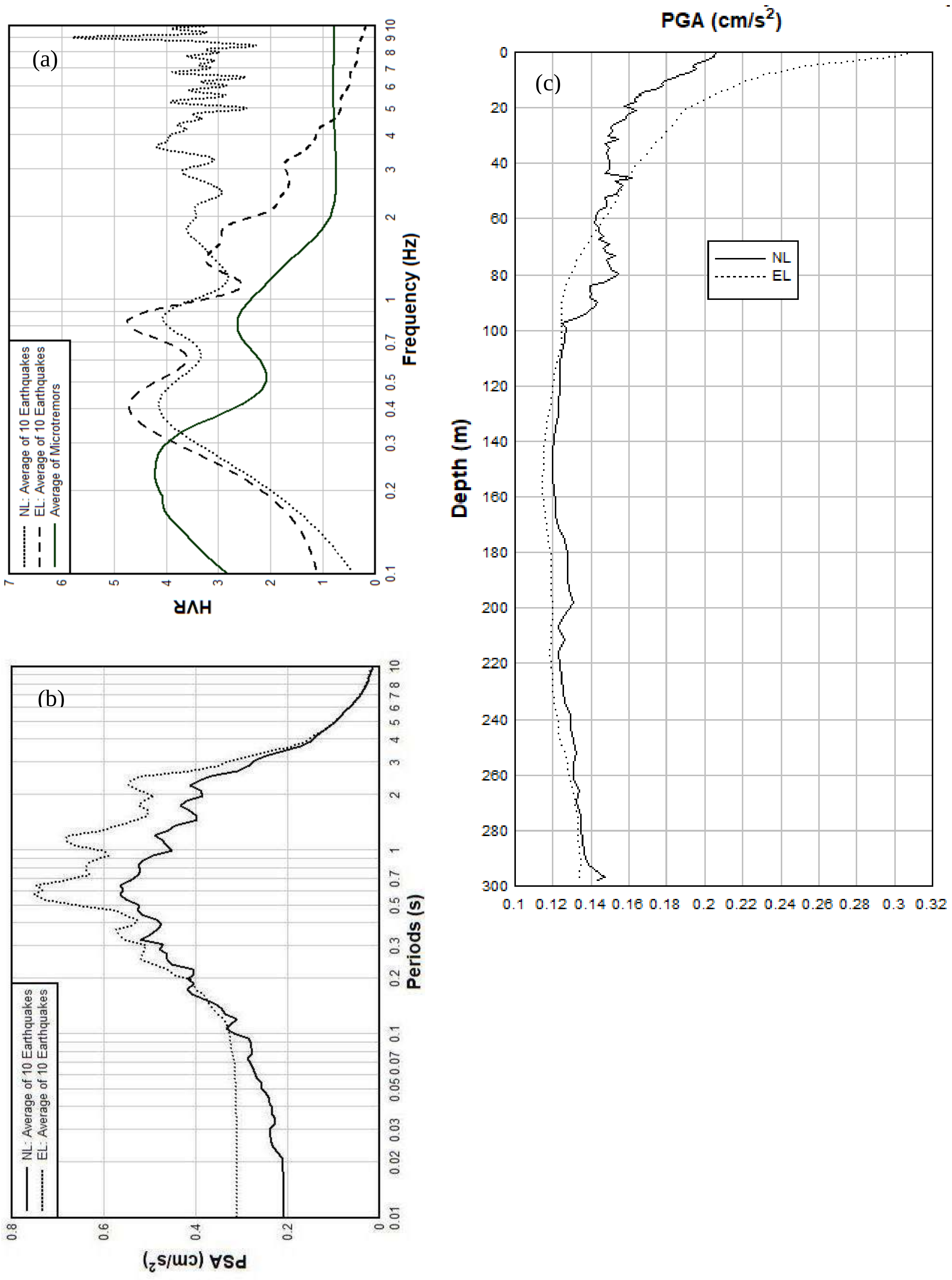


Figure 4.12 (a) Horizontal to Vertical Spectral Ratio (HVR), (b) Response Spectra and (c) Maximum peak ground acceleration (PGA) for the site-BH074

4.2.13 Site Response Analysis for BH085

The location is T Hossain Garden, Bandar, Narayanganj. The co-ordinate of the location is lat: 23° 37' 50.5266"N and long: 90° 31' 33.8046"E and the performed borehole depth of SPT is 31.5m and the performed seismic downhole test depth is 30.0m.

Spectral Ratio Analysis

The comparison of spectral ratio analysis using SPT and shear wave velocity data by DEEPSOIL program and the Horizontal to Vertical Spectral Ratio (HVR) obtained from the microtremors using Geopsy program is shown in Figure 4.13a. Both equivalent linear and nonlinear methods have been applied in the case of DEEPSOIL analysis. For estimation of ground response site amplification factors at sub surface layers are often used as one of the parameters. The amplification factor is the maximum amplitude of the HVR curve.

Hence, the amplification factor obtained from the microtremors is 4.28 at 0.34Hz, the amplification factor obtained from nonlinear method is 4.00 at 0.87Hz and amplification factor obtained from equivalent linear method is 5.72 at 0.804Hz.

Response Spectra

Response spectra obtained from DEEPSOIL program in both equivalent linear and nonlinear method is presented in the following Figure 4.13b The peak spectral acceleration (PSA) obtained using the nonlinear method is 0.68g and PSA obtained using equivalent linear method is 0.98g for the specific site.

Maximum Peak Ground Acceleration (PGA)

Maximum Peak Ground Acceleration (PGA) at different depths for this site is shown in the Figure 4.13c at surface, which is obtained from equivalent linear and nonlinear analysis. The averages of PGA values at surface are observed 0.39g for equivalent linear analysis and 0.22g for nonlinear analysis.

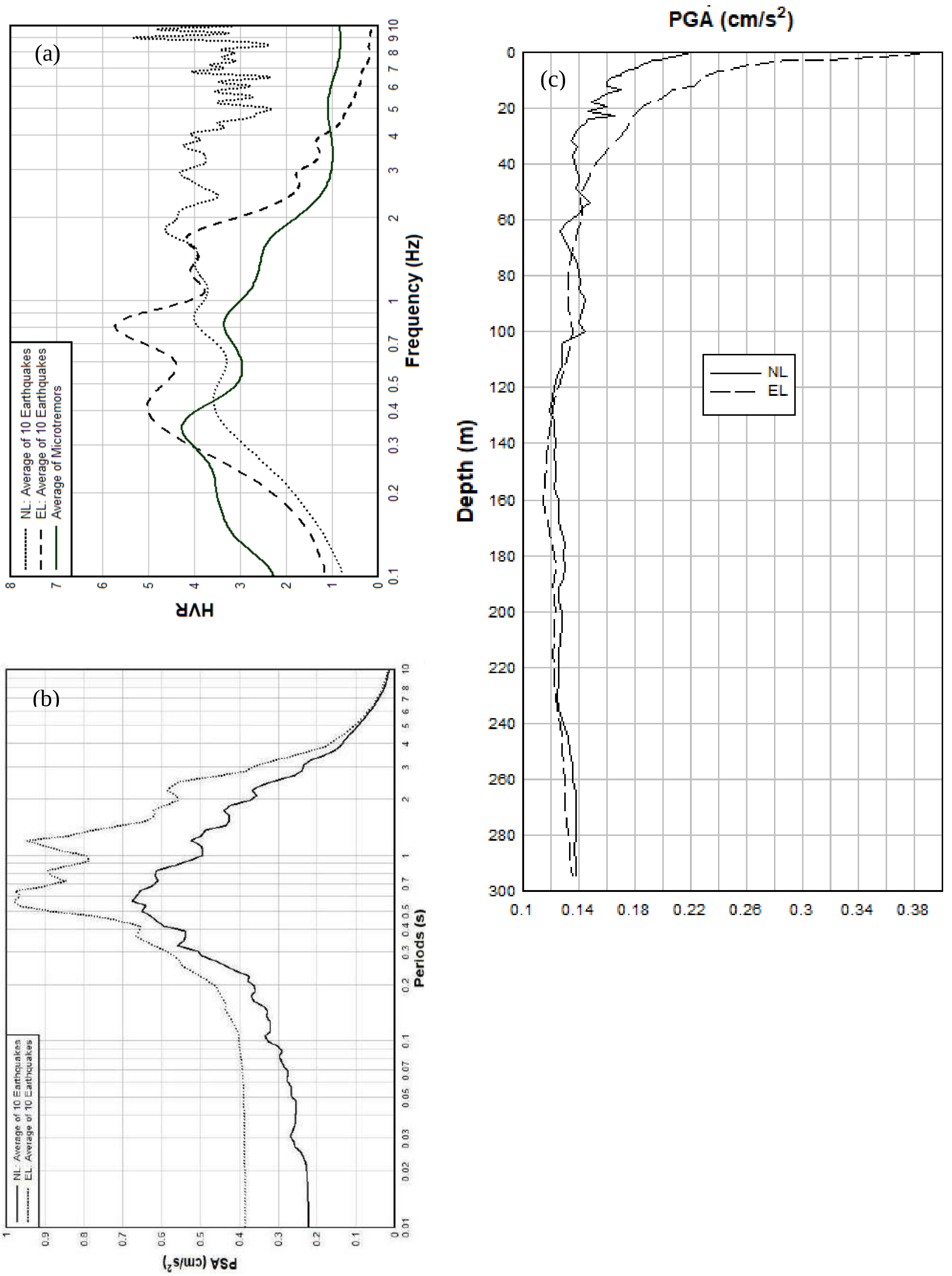


Figure 4.13 (a) Horizontal to Vertical Spectral Ratio (HVR), (b) Response Spectra and (c) Maximum peak ground acceleration (PGA) for the site-BH085

4.2.14 Site Response Analysis for BH088

The location is at 55 No Mograpara Govt. Primary School Sonagaon, Sonargaon, Narayanganj. The co-ordinate of the location is lat: 23° 38' 4.1994"N and long: 90° 35' 18.5994"E and the performed borehole depth of SPT is 40.5m and the performed seismic downhole test depth is 39.0m.

Spectral Ratio Analysis

The comparison of spectral ratio analysis using SPT and shear wave velocity data by DEEPSOIL program and the Horizontal to Vertical Spectral Ratio (HVR) obtained from the microtremors using Geopsy program is shown in Figure 4.14a. Both equivalent linear and nonlinear methods have been applied in the case of DEEPSOIL analysis. For estimation of ground response site amplification factors at sub surface layers are often used as one of the parameters. The amplification factor is the maximum amplitude of the HVR curve.

Hence, the amplification factor obtained from the microtremors is 4.08 at 0.82 Hz, the amplification factor obtained from nonlinear method is 4.66 at 0.80 Hz and the amplification factor obtained from equivalent linear method is 5.22 at 0.77Hz.

Response Spectra

Response spectra obtained from DEEPSOIL program in both equivalent linear and nonlinear method is presented in the following Figure 4.14b. The peak spectral acceleration (PSA) obtained using the nonlinear method is 0.62g and PSA obtained using equivalent linear method is 0.83g for the specific site.

Maximum Peak Ground Acceleration (PGA)

Maximum Peak Ground Acceleration (PGA) at different depths for this site is shown in the Figure 4.14c at surface, which is obtained from equivalent linear and nonlinear analysis. The averages of PGA values at surface are observed 0.34g for equivalent linear analysis and 0.23g for nonlinear analysis.

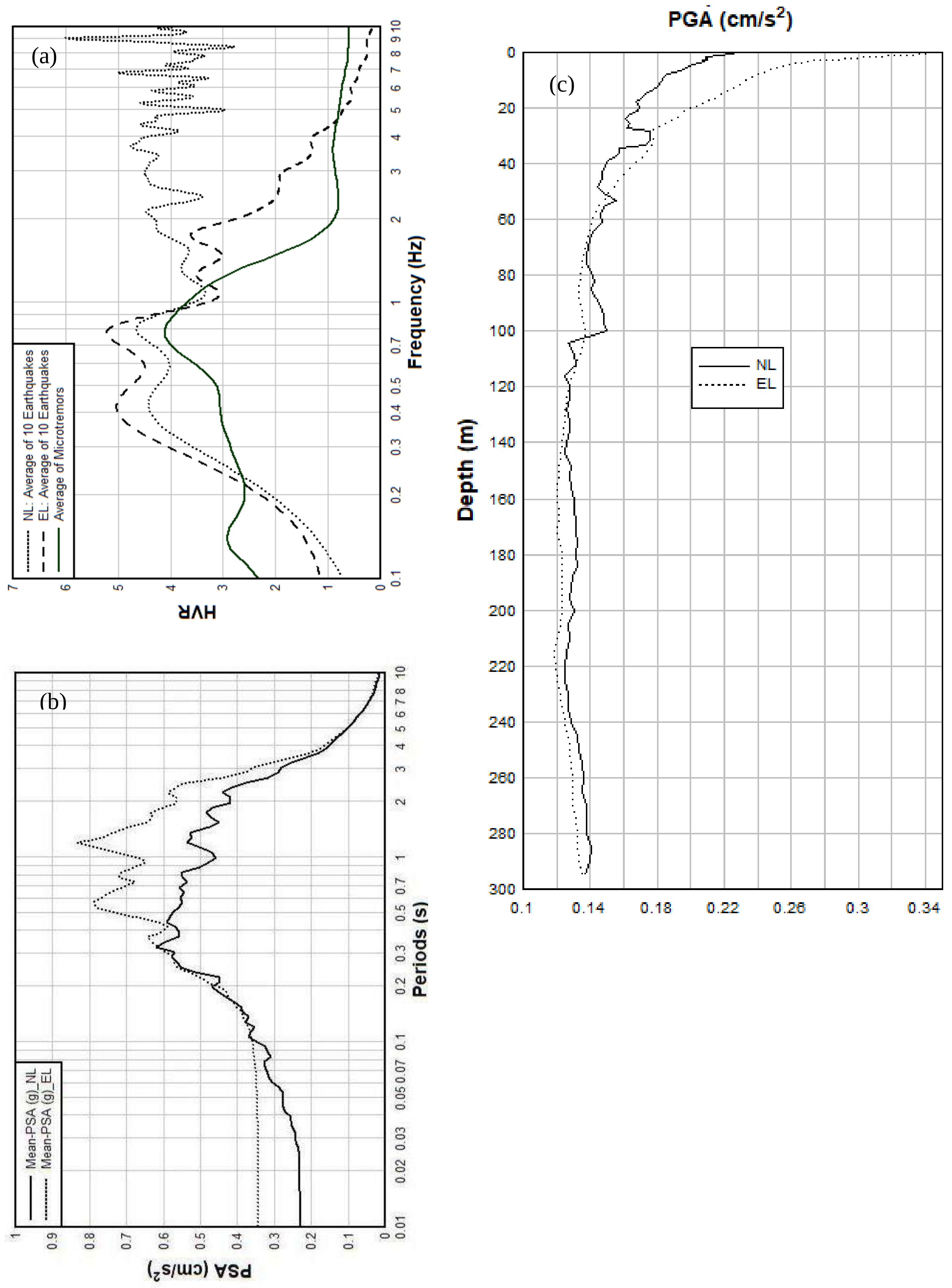


Figure 4.14 (a) Horizontal to Vertical Spectral Ratio (HVR), (b) Response Spectra and (c) Maximum peak ground acceleration (PGA) for the site-BH088

4.2.15 Site Response Analysis for BH107

The location is Sonamia Market S.O Road Balurmath, Sumilpara, Narayanganj. The co-ordinate of the location is lat: 23° 40' 4.9614"N and long: 90° 31' 7.104"E and the performed borehole depth of SPT is 40.5m and the performed seismic downhole test depth is 38.0m.

Spectral Ratio Analysis

The comparison of spectral ratio analysis using SPT and shear wave velocity data by DEEPSOIL program and the Horizontal to Vertical Spectral Ratio (HVR) obtained from the microtremors using Geopsy program is shown in Figure 4.15a. Both equivalent linear and nonlinear methods have been applied in the case of DEEPSOIL analysis. For estimation of ground response site amplification factors at sub surface layers are often used as one of the parameters. The amplification factor is the maximum amplitude of the HVR curve.

The amplification factor obtained from the microtremors is 3.19 at 0.72 Hz, the amplification factor obtained from nonlinear method is 4.78 at 0.81 Hz and the amplification factor obtained from equivalent linear method is 5.75 at 0.78 Hz.

Response Spectra

Response spectra obtained from DEEPSOIL program in both equivalent linear and nonlinear method is presented in the following Figure 4.15b. The peak spectral acceleration (PSA) obtained using the nonlinear method is 0.60g and PSA obtained using equivalent linear method is 0.93g for the specific site.

Maximum Peak Ground Acceleration (PGA)

Maximum Peak Ground Acceleration (PGA) at different depths for this site is shown in the Figure 4.15c at surface, which is obtained from equivalent linear and nonlinear analysis. The averages of PGA values at surface are observed 0.36g for equivalent linear analysis and 0.22g for nonlinear analysis.

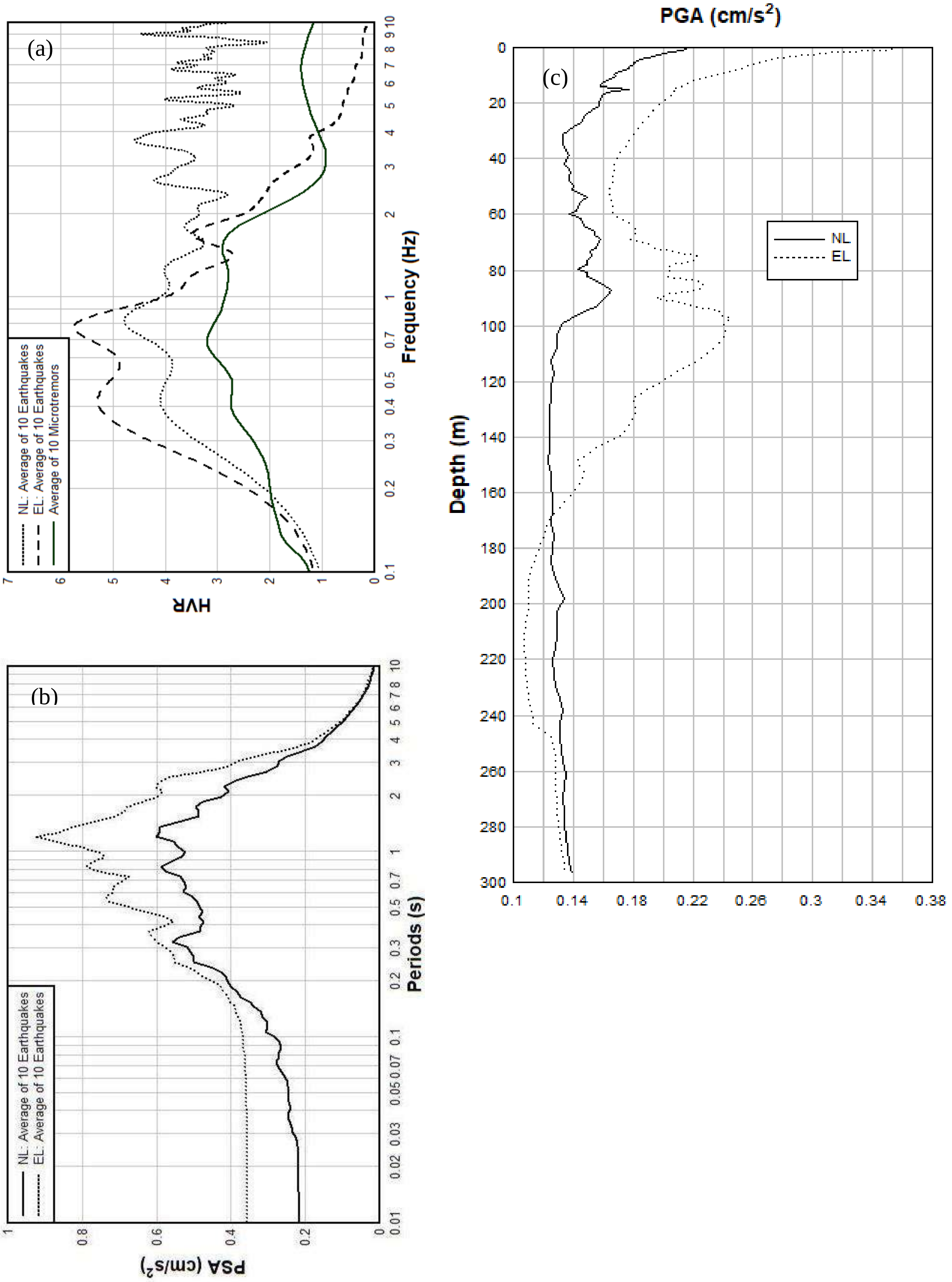


Figure 4.15 (a) Horizontal to Vertical Spectral Ratio (HVR), (b) Response Spectra and (c) Maximum peak ground acceleration (PGA) for the site-BH107

4.2.16 Site Response Analysis for BH112

The location is 122 No Goalkhali Poshchim Govt. Primary School, Keraniganj, Dhaka. The co-ordinate of the location is lat: 23° 41' 4.0668"N and long: 90° 19' 26.5794"E and the performed borehole depth of SPT is 52.5m and the performed seismic downhole test depth is 52.0m.

Spectral Ratio Analysis

The comparison of spectral ratio analysis using SPT and shear wave velocity data by DEEPSOIL program and the Horizontal to Vertical Spectral Ratio (HVR) obtained from the microtremors using Geopsy program is shown in Figure 4.16a. Both equivalent linear and nonlinear methods have been applied in the case of DEEPSOIL analysis. For estimation of ground response site amplification factors at sub surface layers are often used as one of the parameters. The amplification factor is the maximum amplitude of the HVR curve.

The amplification factor obtained from the microtremors is 4.21 at 0.98 Hz, the amplification factor obtained from nonlinear method is 4.28 at 0.93 Hz and the amplification factor obtained from equivalent linear method is 5.38 at 0.88 Hz.

Response Spectra

Response spectra obtained from DEEPSOIL program in both equivalent linear and nonlinear method is presented in the following Figure 4.16b. The peak spectral acceleration (PSA) obtained using the nonlinear method is 0.66g and PSA obtained using equivalent linear method is 0.85g for the specific site.

Maximum Peak Ground Acceleration (PGA)

Maximum Peak Ground Acceleration (PGA) at different depths for this site is shown in the Figure 4.16c at surface, which is obtained from equivalent linear and nonlinear analysis. The averages of PGA values at surface are observed 0.33g for equivalent linear analysis and 0.23g for nonlinear analysis.

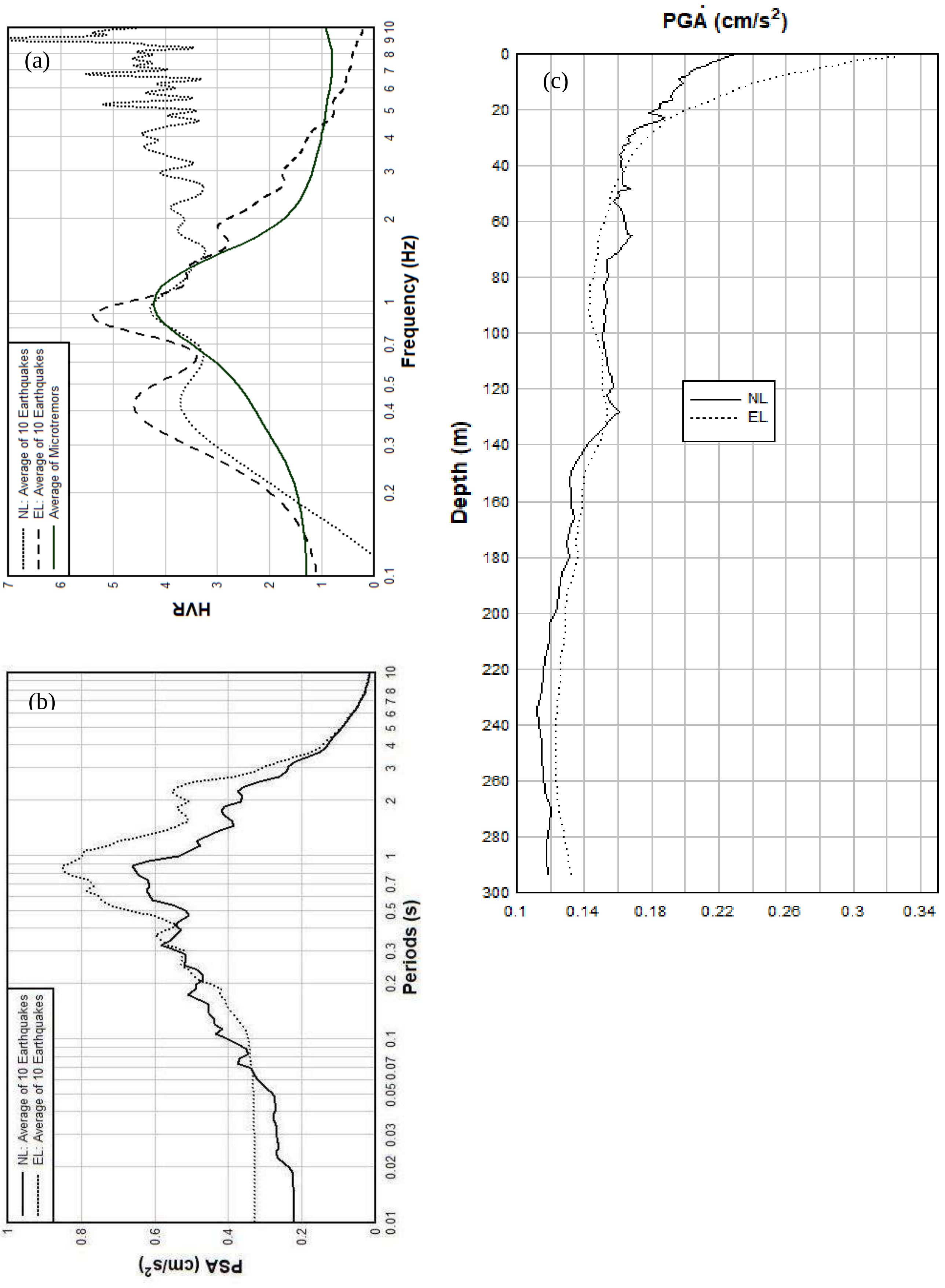


Figure 4.16 (a) Horizontal to Vertical Spectral Ratio (HVR), (b) Response Spectra and (c) Maximum peak ground acceleration (PGA) for the site-BH112

4.2.17 Site Response Analysis for BH116

The location is at Doleshwar Government Primary School, Keraniganj, Dhaka. The co-ordinate of the location is lat: 23° 40' 14.8758"N and long: 90° 26' 21.753"E and the performed borehole depth of SPT is 45.0m and the performed seismic downhole test depth is 44.0m.

Spectral Ratio Analysis

The comparison of spectral ratio analysis using SPT and shear wave velocity data by DEEPSOIL program and the Horizontal to Vertical Spectral Ratio (HVR) obtained from the microtremors using Geopsy program is shown in Figure 4.17a. Both equivalent linear and nonlinear methods have been applied in the case of DEEPSOIL analysis. For estimation of ground response site amplification factors at sub surface layers are often used as one of the parameters. The amplification factor is the maximum amplitude of the HVR curve.

Hence, the amplification factor obtained from the microtremors is 3.21 at 0.75 Hz, the amplification factor obtained from nonlinear method is 4.24 at 0.84 Hz and the amplification factor obtained from equivalent linear method is 5.10 at 0.80 Hz.

Response Spectra

Response spectra obtained from DEEPSOIL program in both equivalent linear and nonlinear method is presented in the following Figure 4.17b. The peak spectral acceleration (PSA) obtained using the nonlinear method is 0.52 g and PSA obtained using equivalent linear method is 0.79g for the specific site.

Maximum Peak Ground Acceleration (PGA)

Maximum Peak Ground Acceleration (PGA) at different depths for this site is shown in the Figure 4.17c at surface, which is obtained from equivalent linear and nonlinear analysis. The averages of PGA values at surface are observed 0.32g for equivalent linear analysis and 0.21g for nonlinear analysis.

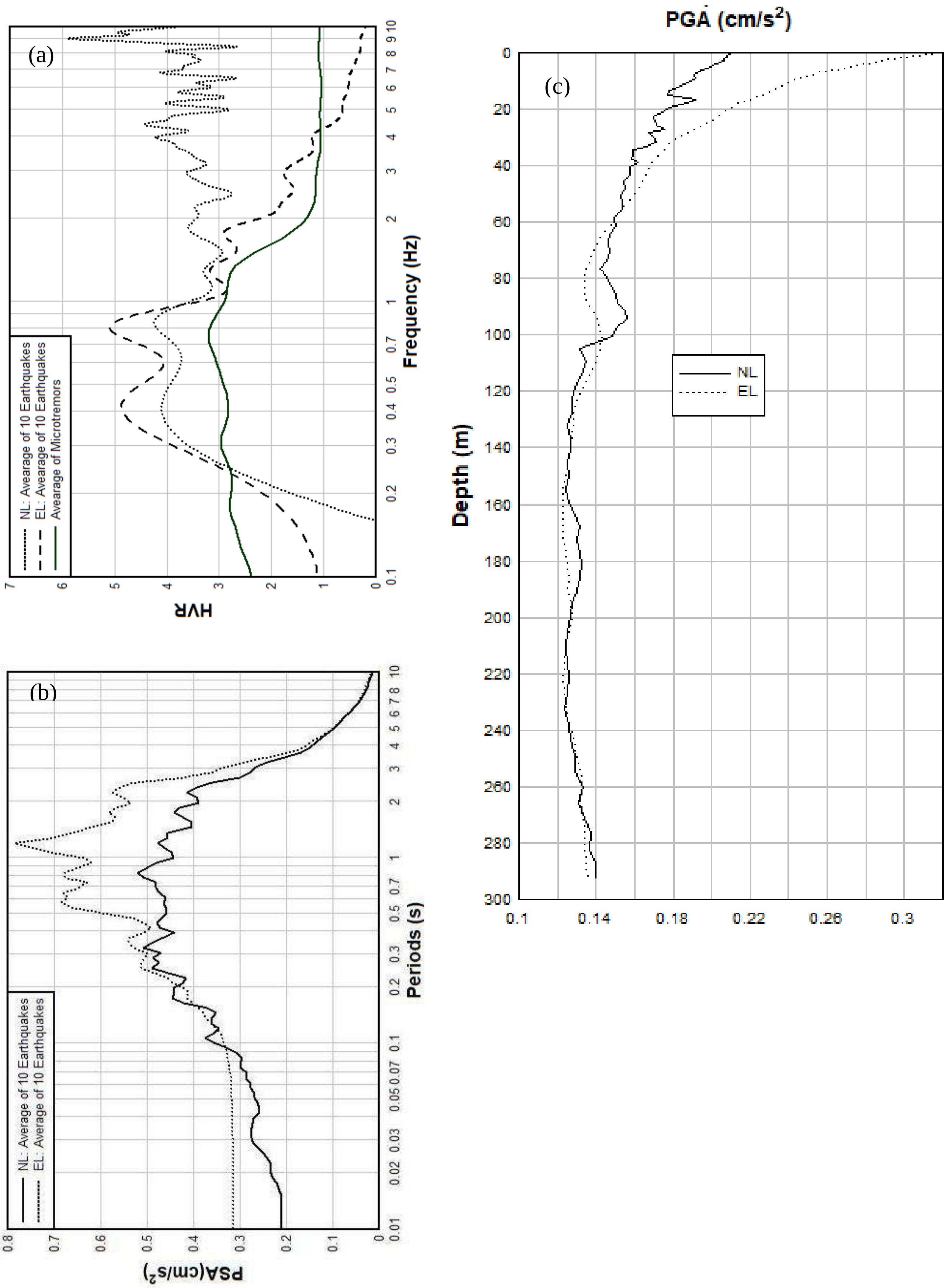


Figure 4.17 (a) Horizontal to Vertical Spectral Ratio (HVR), (b) Response Spectra and (c) Maximum peak ground acceleration (PGA) for the site-BH116

4.2.18 Site Response Analysis for BH139

The location is at Kharakandi Govt. Primary School, Keraniganj, Dhaka. The co-ordinate of the location is lat: 23° 43' 19.2066"N and long: 90° 16' 28.7574"E and the performed SPT borehole depth is 51.0m and the performed seismic downhole test depth is 51.0m.

Spectral Ratio Analysis

The comparison of spectral ratio analysis using SPT and shear wave velocity data by DEEPSOIL program and the Horizontal to Vertical Spectral Ratio (HVR) obtained from the microtremors using Geopsy program is shown in Figure 4.18a. Both equivalent linear and nonlinear methods have been applied in the case of DEEPSOIL analysis. For estimation of ground response site amplification factors at sub surface layers are often used as one of the parameters. The amplification factor is the maximum amplitude of the HVR curve.

Hence the amplification factor obtained from the microtremors is 3.61 at 0.76 Hz, the amplification factor obtained from nonlinear method is 4.10 at 0.79 Hz and the amplification factor obtained from equivalent linear method is 4.45 at 0.39 Hz.

Response Spectra

Response spectra obtained from DEEPSOIL program in both equivalent linear and nonlinear method is presented in the following Figure 4.18b. The peak spectral acceleration (PSA) obtained using the nonlinear method is 0.53g and PSA obtained using equivalent linear method is 0.67g for the specific site.

Maximum Peak Ground Acceleration (PGA)

Maximum Peak Ground Acceleration (PGA) at different depths for this site is shown in the Figure 4.18c at surface, which is obtained from equivalent linear and nonlinear analysis. The averages of PGA values at surface are observed 0.24g for equivalent linear analysis and 0.19g for nonlinear analysis.

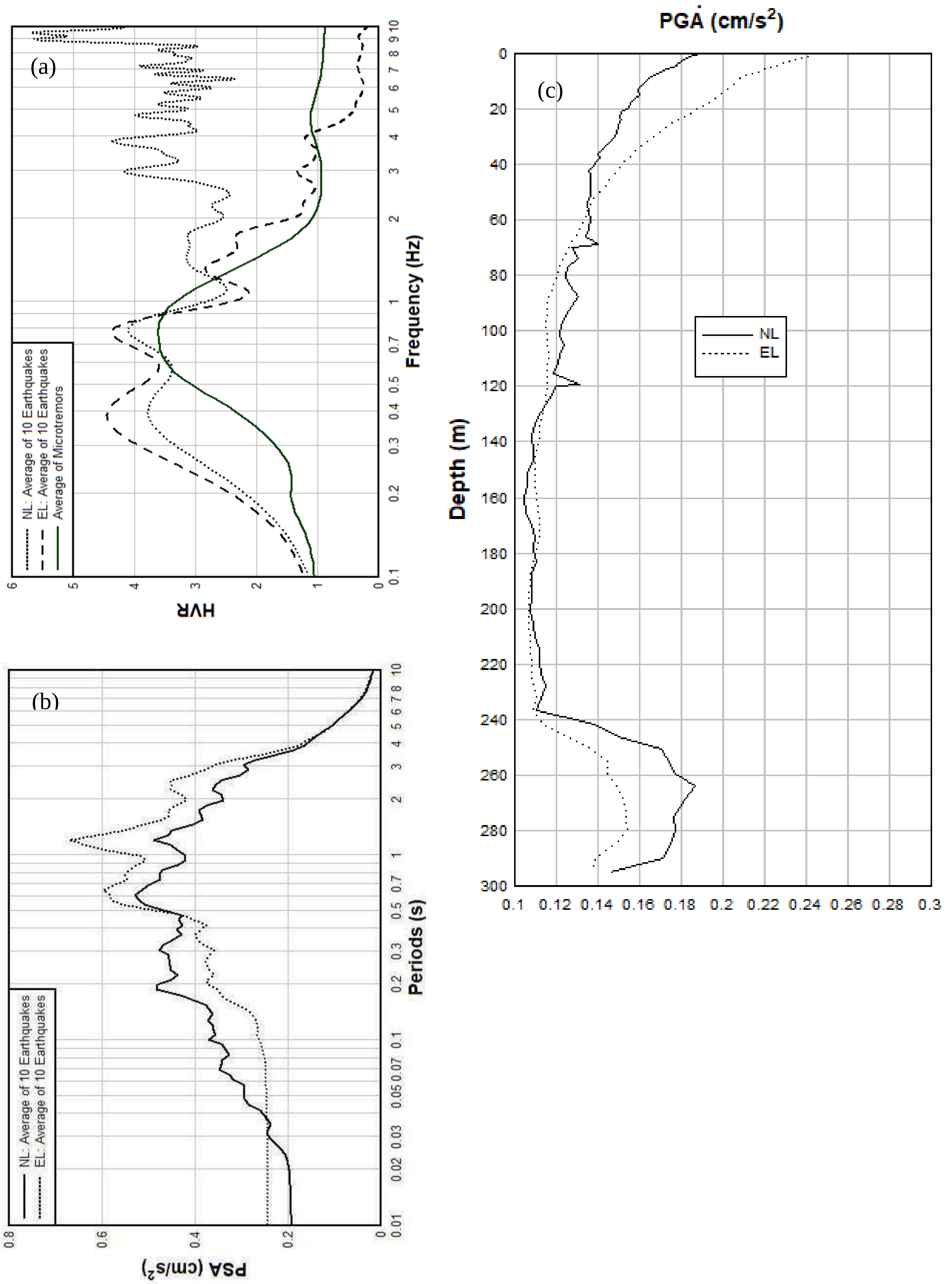


Figure 4.18 (a) Horizontal to Vertical Spectral Ratio (HVR), (b) Response Spectra and (c) Maximum peak ground acceleration (PGA) for the site-BH139

4.2.19 Site Response Analysis for BH146

The location is at Samad Nagar, Jatrabari, Dhaka. The co-ordinate of the location is lat: 23° 42' 49.2012"N and long: 90° 26' 44.0982"E and the performed borehole depth of SPT is 30.0m and the performed seismic downhole test depth is 32.0m.

Spectral Ratio Analysis

The comparison of spectral ratio analysis using SPT and shear wave velocity data by DEEPSOIL program and the Horizontal to Vertical Spectral Ratio (HVR) obtained from the microtremors using Geopsy program is shown in Figure 4.19a. Both equivalent linear and nonlinear methods have been applied in the case of DEEPSOIL analysis. For estimation of ground response site amplification factors at sub surface layers are often used as one of the parameters. The amplification factor is the maximum amplitude of the HVR curve.

Hence the amplification factor obtained from the microtremors is 3.13 at 1.39 Hz, the amplification factor obtained from nonlinear method is 4.08 at 0.41 Hz and the amplification factor obtained from equivalent linear method is 4.36 at 0.41 Hz.

Response Spectra

Response spectra obtained from DEEPSOIL program in both equivalent linear and nonlinear method is presented in the following Figure 4.19b. The peak spectral acceleration (PSA) obtained using the nonlinear method is 0.75g and PSA obtained using equivalent linear method is 0.70g for the specific site.

Maximum Peak Ground Acceleration (PGA)

Maximum Peak Ground Acceleration (PGA) at different depths for this site is shown in the Figure 4.19c at surface, which is obtained from equivalent linear and nonlinear analysis. The averages of PGA values at surface are observed 0.29g for equivalent linear analysis and 0.21g for nonlinear analysis.

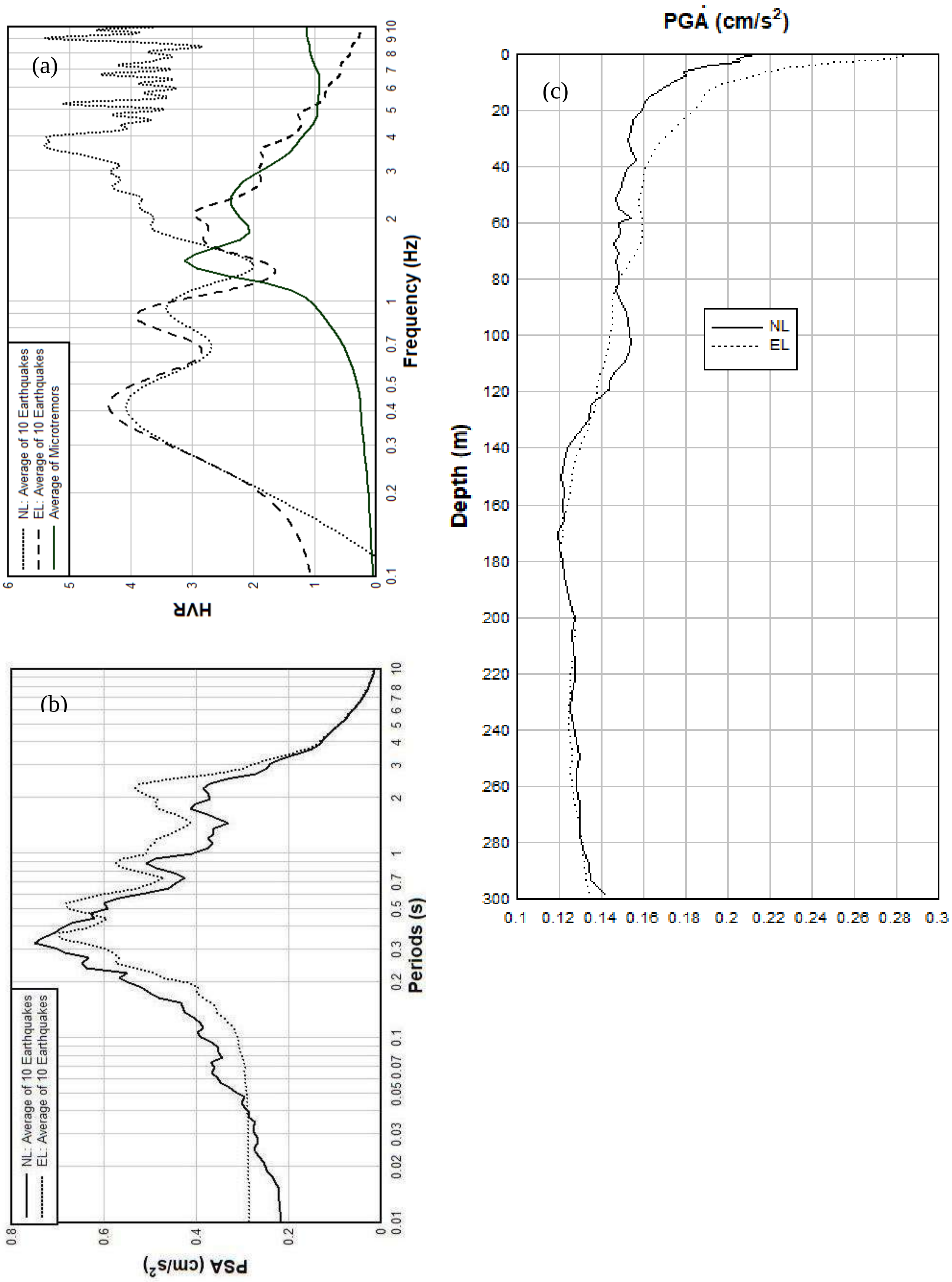


Figure 4.19 (a) Horizontal to Vertical Spectral Ratio (HVR), (b) Response Spectra and (c) Maximum peak ground acceleration (PGA) for the site-BH146

4.2.20 Site Response Analysis for BH150

The location is at Sonali paper mills Ltd Tarabo, Narayanganj. The co-ordinate of the location is lat: 23° 43' 2.352"N and long: 90° 30' 46.0332"E and the performed borehole depth of SPT is 45.0m and the performed seismic downhole test depth is 45.0m.

Spectral Ratio Analysis

The comparison of spectral ratio analysis using SPT and shear wave velocity data by DEEPSOIL program and the Horizontal to Vertical Spectral Ratio (HVR) obtained from the microtremors using Geopsy program is shown in Figure 4.20a. Both equivalent linear and nonlinear methods have been applied in the case of DEEPSOIL analysis. For estimation of ground response site amplification factors at sub surface layers are often used as one of the parameters. The amplification factor is the maximum amplitude of the HVR curve.

The amplification factor obtained from the microtremors is 4.02 at 0.88 Hz, the amplification factor obtained from nonlinear method is 4.17 at 0.76 Hz and the amplification factor obtained from equivalent linear method is 4.78 at 0.73 Hz.

Response Spectra

Response spectra obtained from DEEPSOIL program in both equivalent linear and nonlinear method is presented in the following Figure 4.20b. The peak spectral acceleration (PSA) obtained using the nonlinear method is 0.57g and PSA obtained using equivalent linear method is 0.73g for the specific site.

Maximum Peak Ground Acceleration (PGA)

Maximum Peak Ground Acceleration (PGA) at different depths for this site is shown in the Figure 4.20c at surface, which is obtained from equivalent linear and nonlinear analysis. The averages of PGA values at surface are observed 0.29g for equivalent linear analysis and 0.21g for nonlinear analysis.

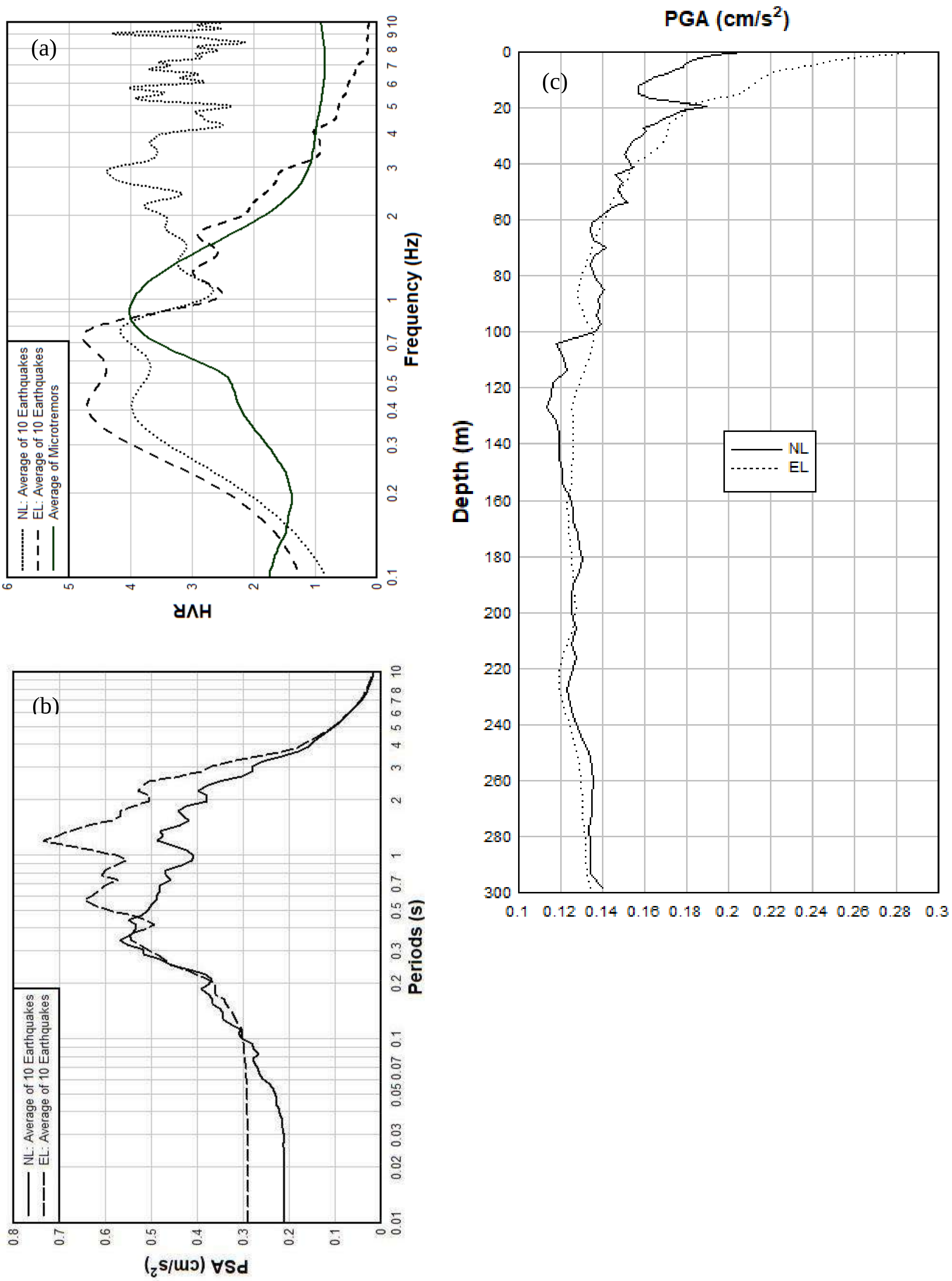


Figure 4.20 (a) Horizontal to Vertical Spectral Ratio (HVR), (b) Response Spectra and (c) Maximum peak ground acceleration (PGA) for the site-BH150

4.2.21 Site Response Analysis for BH153

The location is Sommalon Math, Noyapur Bazar, Sadipur, Sonargaon, Narayanganj. The co-ordinate of the location is lat: 23° 43' 19.2108"N and long: 90° 34' 33.6714"E and the performed borehole depth of SPT is 40.5m and the performed seismic downhole test depth is 40.0m.

Spectral Ratio Analysis

The comparison of spectral ratio analysis using SPT and shear wave velocity data by DEEPSOIL program and the Horizontal to Vertical Spectral Ratio (HVR) obtained from the microtremors using Geopsy program is shown in Figure 4.21a. Both equivalent linear and nonlinear methods have been applied in the case of DEEPSOIL analysis. For estimation of ground response site amplification factors at sub surface layers are often used as one of the parameters. The amplification factor is the maximum amplitude of the HVR curve.

Hence the amplification factor obtained from the microtremors is 4.24 at 0.68 Hz, the amplification factor obtained from nonlinear method is 4.14 at 0.41 Hz and the amplification factor obtained from equivalent linear method is 4.36 at 0.40 Hz.

Response Spectra

Response spectra obtained from DEEPSOIL program in both equivalent linear and nonlinear method is presented in the following Figure 4.21b. The peak spectral acceleration (PSA) obtained using the nonlinear method is 0.57g and PSA obtained using equivalent linear method is 0.58g for the specific site.

Maximum Peak Ground Acceleration (PGA)

Maximum Peak Ground Acceleration (PGA) at different depths for this site is shown in the Figure 4.21c at surface, which is obtained from equivalent linear and nonlinear analysis. The averages of PGA values at surface are observed 0.24g for equivalent linear analysis and 0.20g for nonlinear analysis.

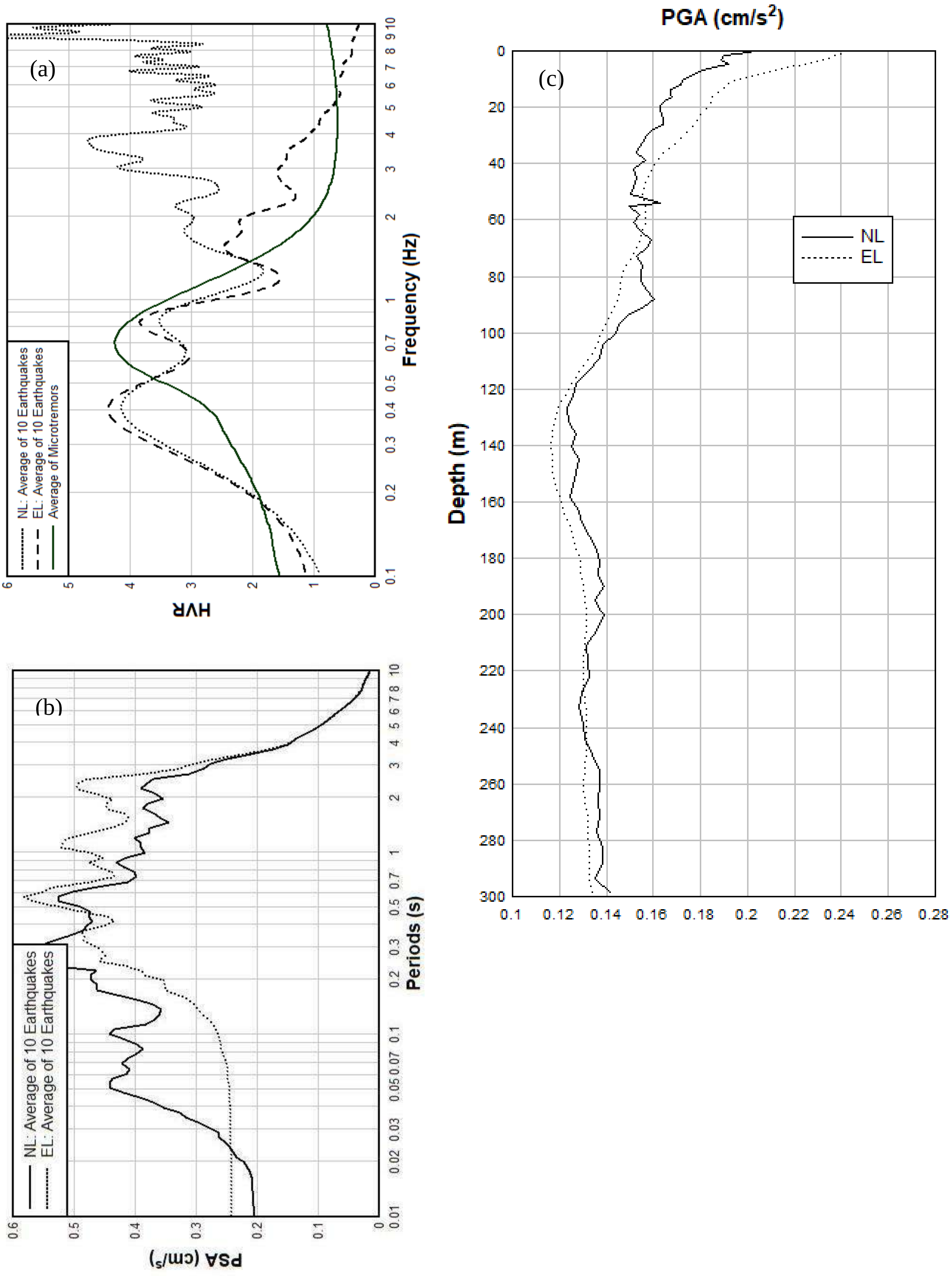


Figure 4.21 (a) Horizontal to Vertical Spectral Ratio (HVR), (b) Response Spectra and (c) Maximum peak ground acceleration (PGA) for the site-BH153

4.2.22 Site Response Analysis for BH160

The location is at Modderchor Govt. Primary School, Keraniganj, Dhaka. The co-ordinate of the location is lat: 23° 43' 55.959"N and long: 90° 20' 50.1612"E and the performed borehole depth of SPT is 45.5m and the performed seismic downhole test depth is 54.0m.

Spectral Ratio Analysis

The comparison of spectral ratio analysis using SPT and shear wave velocity data by DEEPSOIL program and the Horizontal to Vertical Spectral Ratio (HVR) obtained from the microtremors using Geopsy program is shown in Figure 4.22a. Both equivalent linear and nonlinear methods have been applied in the case of DEEPSOIL analysis. For estimation of ground response site amplification factors at sub surface layers are often used as one of the parameters. The amplification factor is the maximum amplitude of the HVR curve.

Hence the amplification factor obtained from the microtremors is 2.90 at 0.56Hz, the amplification factor obtained from nonlinear method is 4.16 at 0.39Hz and the amplification factor obtained from equivalent linear method is 4.92 at 0.47Hz.

Response Spectra

Response spectra obtained from DEEPSOIL program in both equivalent linear and nonlinear method is presented in the following Figure 4.22b. The peak spectral acceleration (PSA) obtained using the nonlinear method is 0.70g and PSA obtained using equivalent linear method is 0.77g for the specific site.

Maximum Peak Ground Acceleration (PGA)

Maximum Peak Ground Acceleration (PGA) at different depths for this site is shown in the Figure 4.22c at surface, which is obtained from equivalent linear and nonlinear analysis. The averages of PGA values at surface are observed 0.32g for equivalent linear analysis and 0.22g for nonlinear analysis.

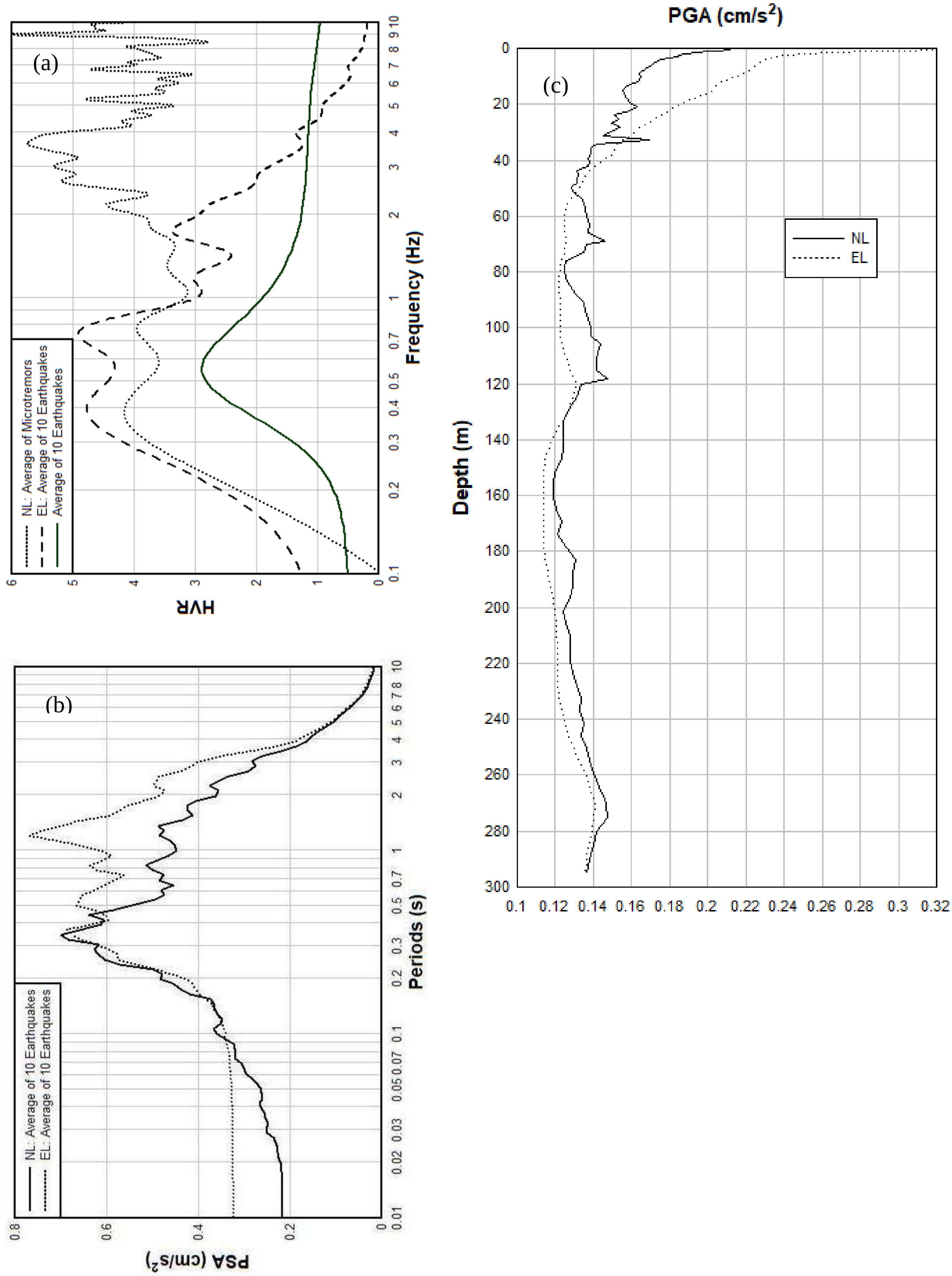


Figure 4.22 (a) Horizontal to Vertical Spectral Ratio (HVR), (b) Response Spectra and (c) Maximum peak ground acceleration (PGA) for the site-BH160

4.2.23 Site Response Analysis for BH163

The location is at Kakrail Mosque (Tablig Jamat), Dhaka. The co-ordinate of the location is lat: 23° 44' 13.3146"N and long: 90° 24' 13.8852"E and the performed borehole depth of SPT is 37.5m and the performed seismic downhole test depth is 37.0m.

Spectral Ratio Analysis

The comparison of spectral ratio analysis using SPT and shear wave velocity data by DEEPSOIL program and the Horizontal to Vertical Spectral Ratio (HVR) obtained from the microtremors using Geopsy program is shown in Figure 4.23a. Both equivalent linear and nonlinear methods have been applied in the case of DEEPSOIL analysis. For estimation of ground response site amplification factors at sub surface layers are often used as one of the parameters. The amplification factor is the maximum amplitude of the HVR curve.

Hence the amplification factor obtained from the microtremors is 2.03 at 0.76 Hz, the amplification factor obtained from nonlinear method is 4.37 at 0.92 Hz and the amplification factor obtained from equivalent linear method is 5.52 at 0.89 Hz.

Response Spectra

Response spectra obtained from DEEPSOIL program in both equivalent linear and nonlinear method is presented in the following Figure 4.23b. The peak spectral acceleration (PSA) obtained using the nonlinear method is 0.68g and PSA obtained using equivalent linear method is 0.88g for the specific site.

Maximum Peak Ground Acceleration (PGA)

Maximum Peak Ground Acceleration (PGA) at different depths for this site is shown in the Figure 4.23c at surface, which is obtained from equivalent linear and nonlinear analysis. The averages of PGA values at surface are observed 0.34g for equivalent linear analysis and 0.23g for nonlinear analysis.

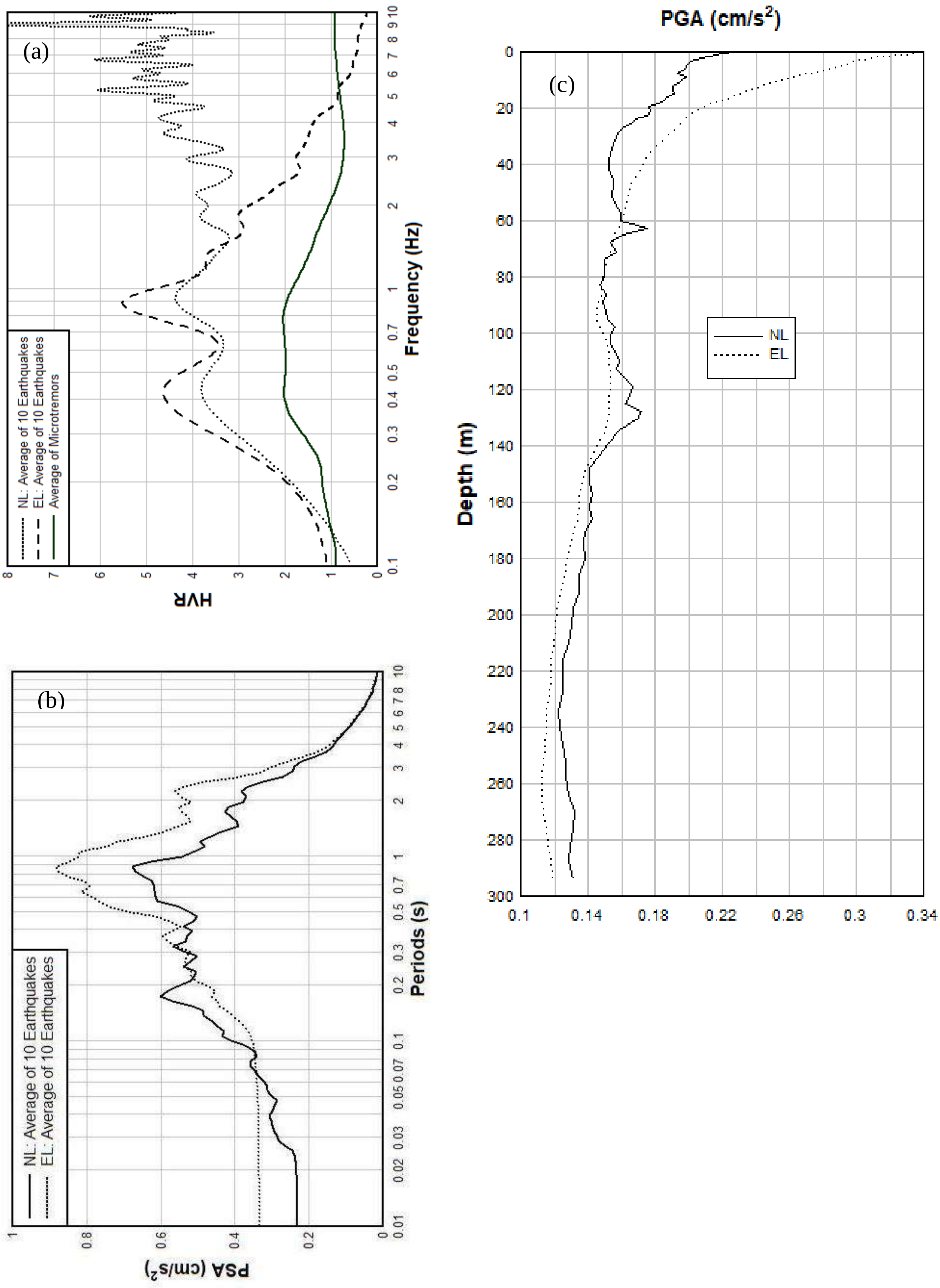


Figure 4.23 (a) Horizontal to Vertical Spectral Ratio (HVR), (b) Response Spectra and (c) Maximum peak ground acceleration (PGA) for the site-BH163

4.2.24 Site Response Analysis for BH185

The location is at Baitunnur lalmia mosque,golakandail Rupganj Narayanganj. The co-ordinate of the location is lat: 23° 45' 40.683"N and long: 90° 33' 20.3328"E and the performed borehole depth of SPT is 34.5m and the performed seismic downhole test depth is 36.0m.

Spectral Ratio Analysis

The comparison of spectral ratio analysis using SPT and shear wave velocity data by DEEPSOIL program and the Horizontal to Vertical Spectral Ratio (HVR) obtained from the microtremors using Geopsy program is shown in Figure 4.24a. Both equivalent linear and nonlinear methods have been applied in the case of DEEPSOIL analysis. For estimation of ground response site amplification factors at sub surface layers are often used as one of the parameters. The amplification factor is the maximum amplitude of the HVR curve.

Hence the amplification factor obtained from the microtremors is 4.21 at 0.88 Hz, the amplification factor obtained from nonlinear method is 3.92 at 0.77 Hz and the amplification factor obtained from equivalent linear method is 4.95 at 0.74 Hz.

Response Spectra

Response spectra obtained from DEEPSOIL program in both equivalent linear and nonlinear method is presented in the following Figure 4.24b. The peak spectral acceleration (PSA) obtained using the nonlinear method is 0.49g and PSA obtained using equivalent linear method is 0.78g for the specific site.

Maximum Peak Ground Acceleration (PGA)

Maximum Peak Ground Acceleration (PGA) at different depths for this site is shown in the Figure 4.24c at surface, which is obtained from equivalent linear and nonlinear analysis. The averages of PGA values at surface are observed 0.28g for equivalent linear analysis and 0.20g for nonlinear analysis.

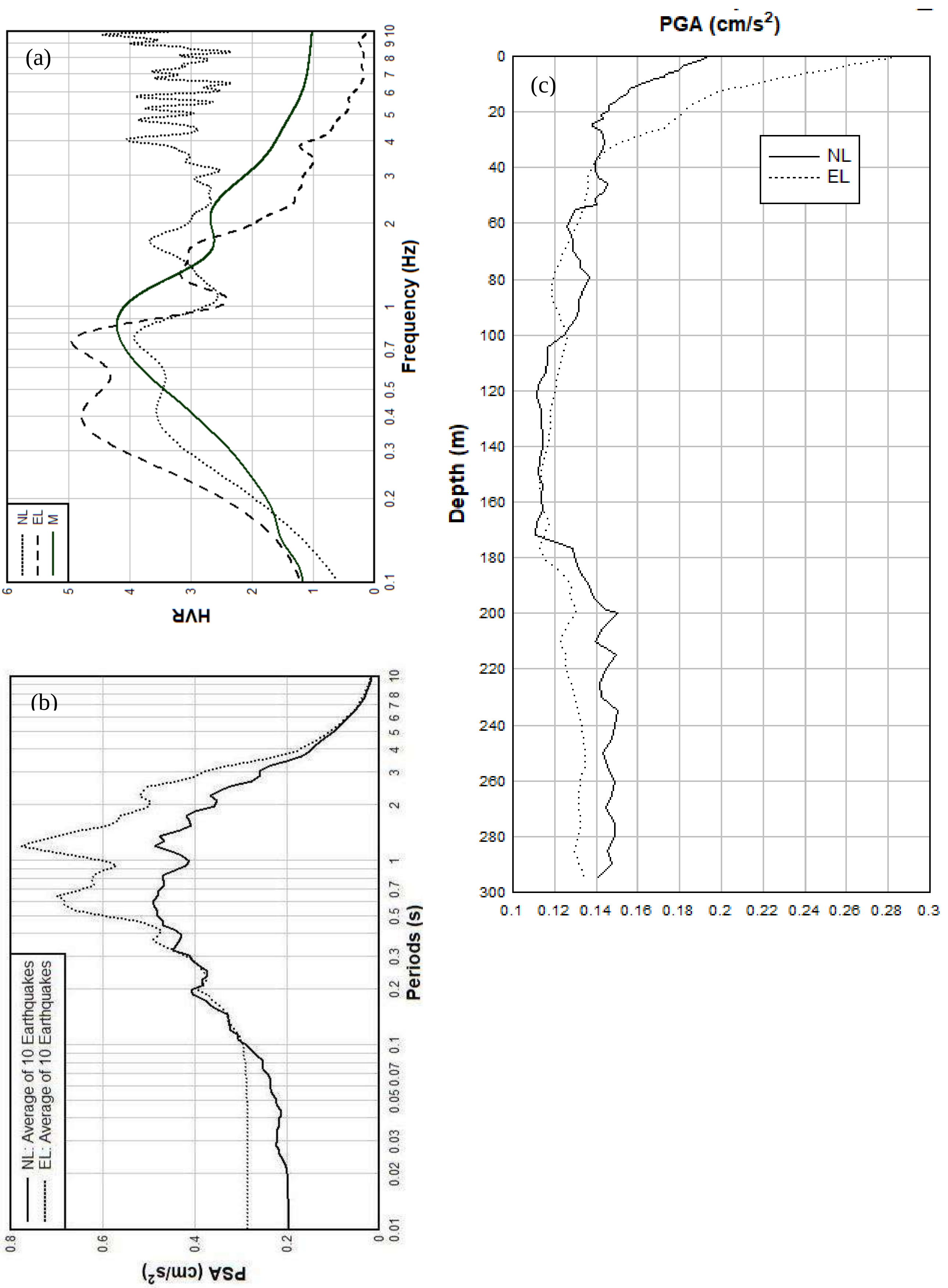


Figure 4.24 (a) Horizontal to Vertical Spectral Ratio (HVR), (b) Response Spectra and (c) Maximum peak ground acceleration (PGA) for the site-BH185

4.2.25 Site Response Analysis for BH189

The location is at 11 No Mograkanda Govt. School, Savar, Dhaka. The co-ordinate of the location is lat: 23° 46' 19.9842"N and long: 90° 18' 33.7716"E and the performed borehole depth of SPT is 51.0 and the performed seismic downhole test depth is 51.0m.

Spectral Ratio Analysis

The comparison of spectral ratio analysis using SPT and shear wave velocity data by DEEPSOIL program and the Horizontal to Vertical Spectral Ratio (HVR) obtained from the microtremors using Geopsy program is shown in Figure 4.25a. Both equivalent linear and nonlinear methods have been applied in the case of DEEPSOIL analysis. For estimation of ground response site amplification factors at sub surface layers are often used as one of the parameters. The amplification factor is the maximum amplitude of the HVR curve.

Hence the amplification factor obtained from the microtremors is 4.24 at 0.71 Hz, the amplification factor obtained from nonlinear method is 3.87 at 0.78 Hz and the amplification factor obtained from equivalent linear method is 4.41 at 0.38 Hz.

Response Spectra

Response spectra obtained from DEEPSOIL program in both equivalent linear and nonlinear method is presented in the following Figure 4.25b. The peak spectral acceleration (PSA) obtained using the nonlinear method is 0.55g and PSA obtained using equivalent linear method is 0.72g for the specific site.

Maximum Peak Ground Acceleration (PGA)

Maximum Peak Ground Acceleration (PGA) at different depths for this site is shown in the Figure 4.25c at surface, which is obtained from equivalent linear and nonlinear analysis. The averages of PGA values at surface are observed 0.28g for equivalent linear analysis and 0.20g for nonlinear analysis.

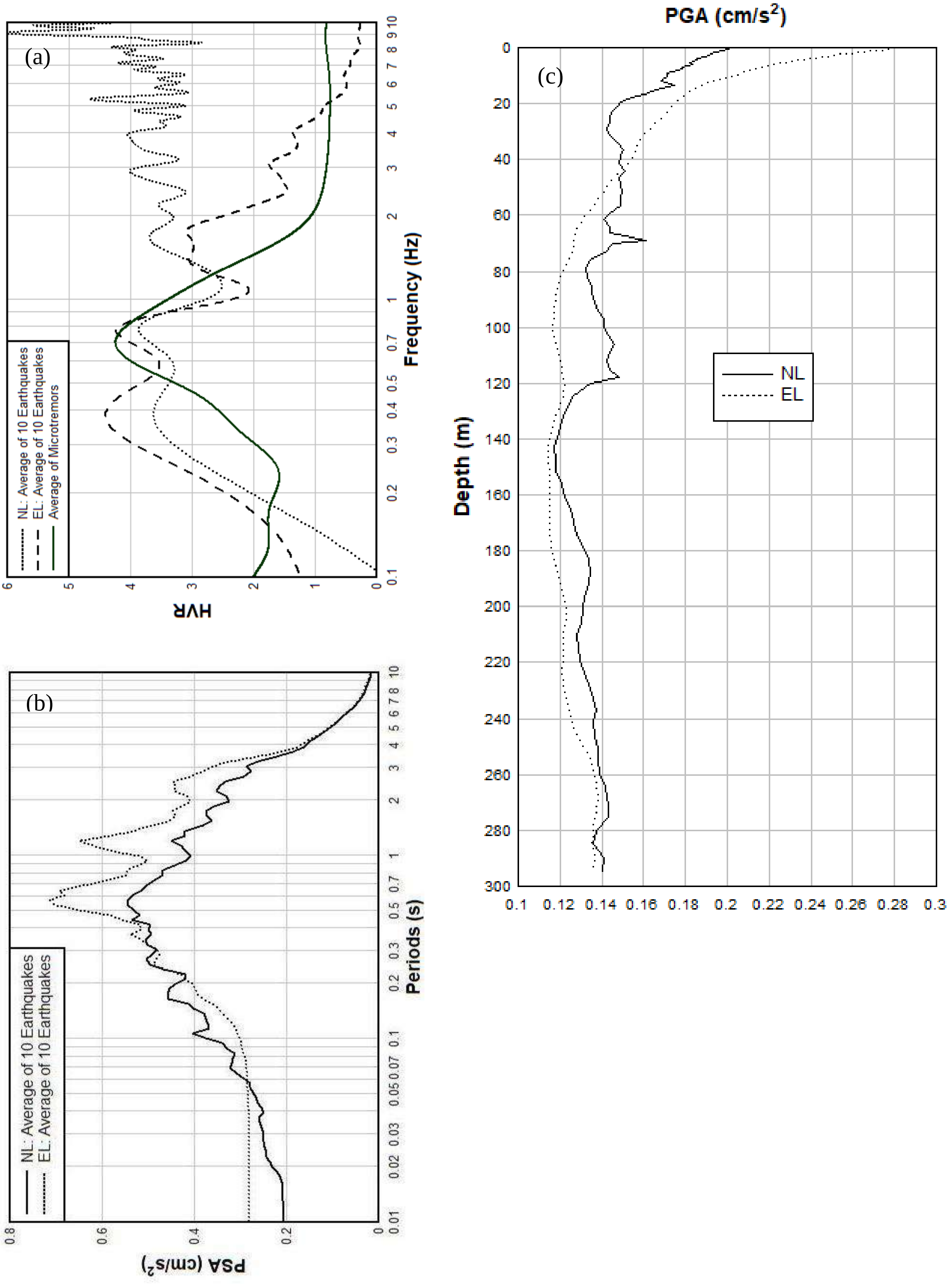


Figure 4.25 (a) Horizontal to Vertical Spectral Ratio (HVR), (b) Response Spectra and (c) Maximum peak ground acceleration (PGA) for the site-BH189

4.2.26 Site Response Analysis for BH195

The location is at Ichakhali, Kaiup para, Rupganj, Narayanganj. The co-ordinate of the location is lat: 23° 46' 25.7916''N and long: 90° 30' 33.7638''E and the performed borehole depth of SPT is 33.0 and the performed seismic downhole test depth is 33.0m

Spectral Ratio Analysis

The comparison of spectral ratio analysis using SPT and shear wave velocity data by DEEPSOIL program and the Horizontal to Vertical Spectral Ratio (HVR) obtained from the microtremors using Geopsy program is shown in Figure 4.26a. Both equivalent linear and nonlinear methods have been applied in the case of DEEPSOIL analysis. For estimation of ground response site amplification factors at sub surface layers are often used as one of the parameters. The amplification factor is the maximum amplitude of the HVR curve.

Hence the amplification factor obtained from the microtremors is 3.69 at 0.86 Hz, the amplification factor obtained from nonlinear method is 5.50 at 0.86 Hz and the amplification factor obtained from equivalent linear method is 6.66 at 0.82 Hz.

Response Spectra

Response spectra obtained from DEEPSOIL program in both equivalent linear and nonlinear method is presented in the following Figure 4.26b. The peak spectral acceleration (PSA) obtained using the nonlinear method is 0.67g and PSA obtained using equivalent linear method is 0.99g for the specific site.

Maximum Peak Ground Acceleration (PGA)

Maximum Peak Ground Acceleration (PGA) at different depths for this site is shown in the Figure 4.26c at surface, which is obtained from equivalent linear and nonlinear analysis. The averages of PGA values at surface are observed 0.43g for equivalent linear analysis and 0.24g for nonlinear analysis.

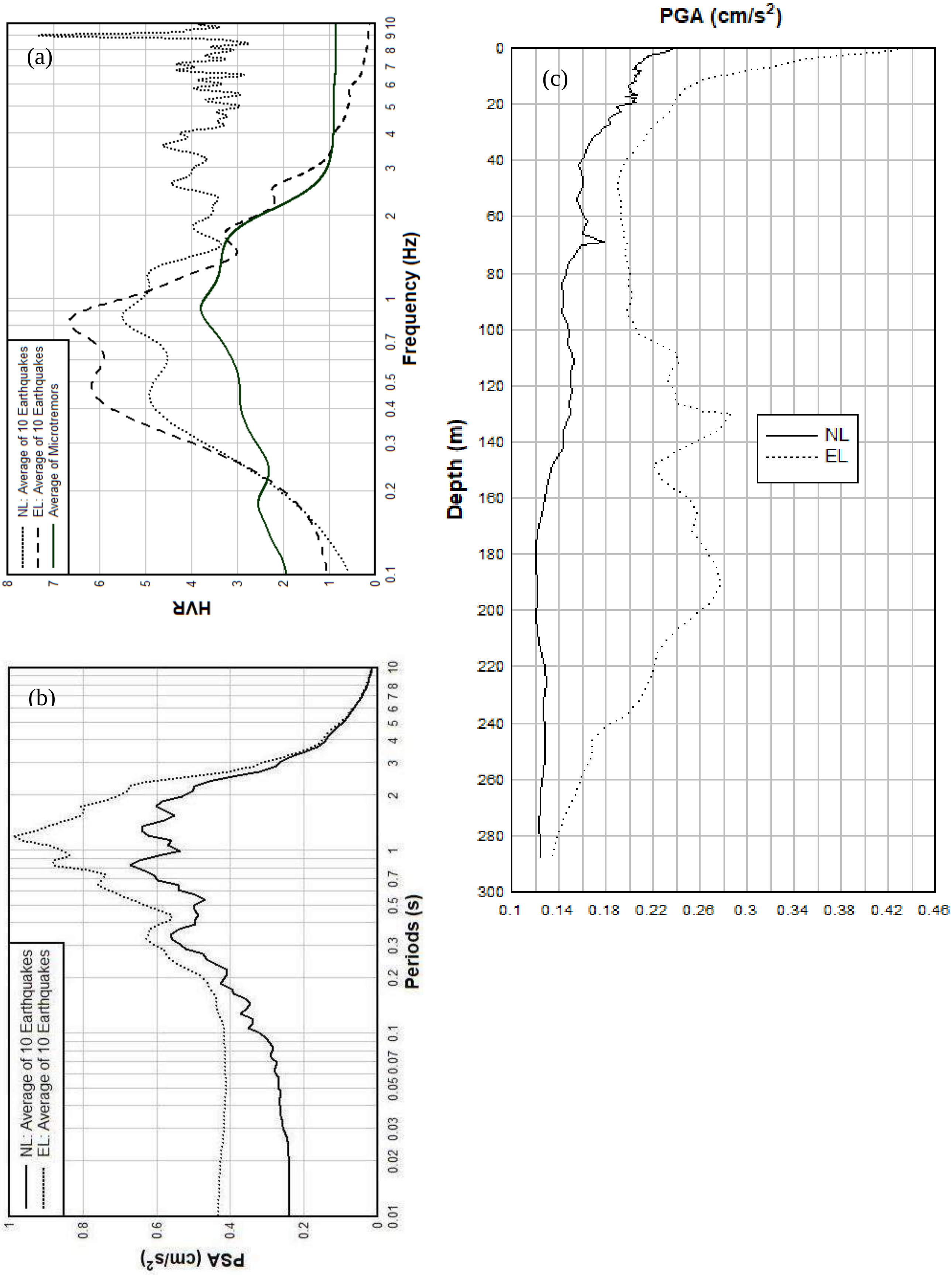


Figure 4.26 (a) Horizontal to Vertical Spectral Ratio (HVR), (b) Response Spectra and (c) Maximum peak ground acceleration (PGA) for the site-BH195

4.2.27 Site Response Analysis for BH199

The location is at Rupayan Sity, Hamiyetpur, Savar, Dhaka. The co-ordinate of the location is lat: 23° 47' 25.8426"N and long: 90° 14' 58.1496"E and the performed borehole depth of SPT is 50.0 and the performed seismic downhole test depth is 49.0m.

Spectral Ratio Analysis

The comparison of spectral ratio analysis using SPT and shear wave velocity data by DEEPSOIL program and the Horizontal to Vertical Spectral Ratio (HVR) obtained from the microtremors using Geopsy program is shown in Figure 4.27a. Both equivalent linear and nonlinear methods have been applied in the case of DEEPSOIL analysis. For estimation of ground response site amplification factors at sub surface layers are often used as one of the parameters. The amplification factor is the maximum amplitude of the HVR curve.

The maximum HVR value obtained from the microtremors is 4.17 at 0.38 Hz, the maximum HVR value obtained from nonlinear method is 4.73 at 0.92 Hz and the maximum HVR value obtained from equivalent linear method is 5.51 at 0.85 Hz.

Response Spectra

Response spectra obtained from DEEPSOIL program in both equivalent linear and nonlinear method is presented in the following Figure 4.27b. The peak spectral acceleration (PSA) obtained using the nonlinear method is 0.76g and PSA obtained using equivalent linear method is 0.95g for the specific site.

Maximum Peak Ground Acceleration (PGA)

Maximum Peak Ground Acceleration (PGA) at different depths for this site is shown in the Figure 4.27c at surface, which is obtained from equivalent linear and nonlinear analysis. The averages of PGA values at surface are observed 0.33g for equivalent linear analysis and 0.23g for nonlinear analysis.

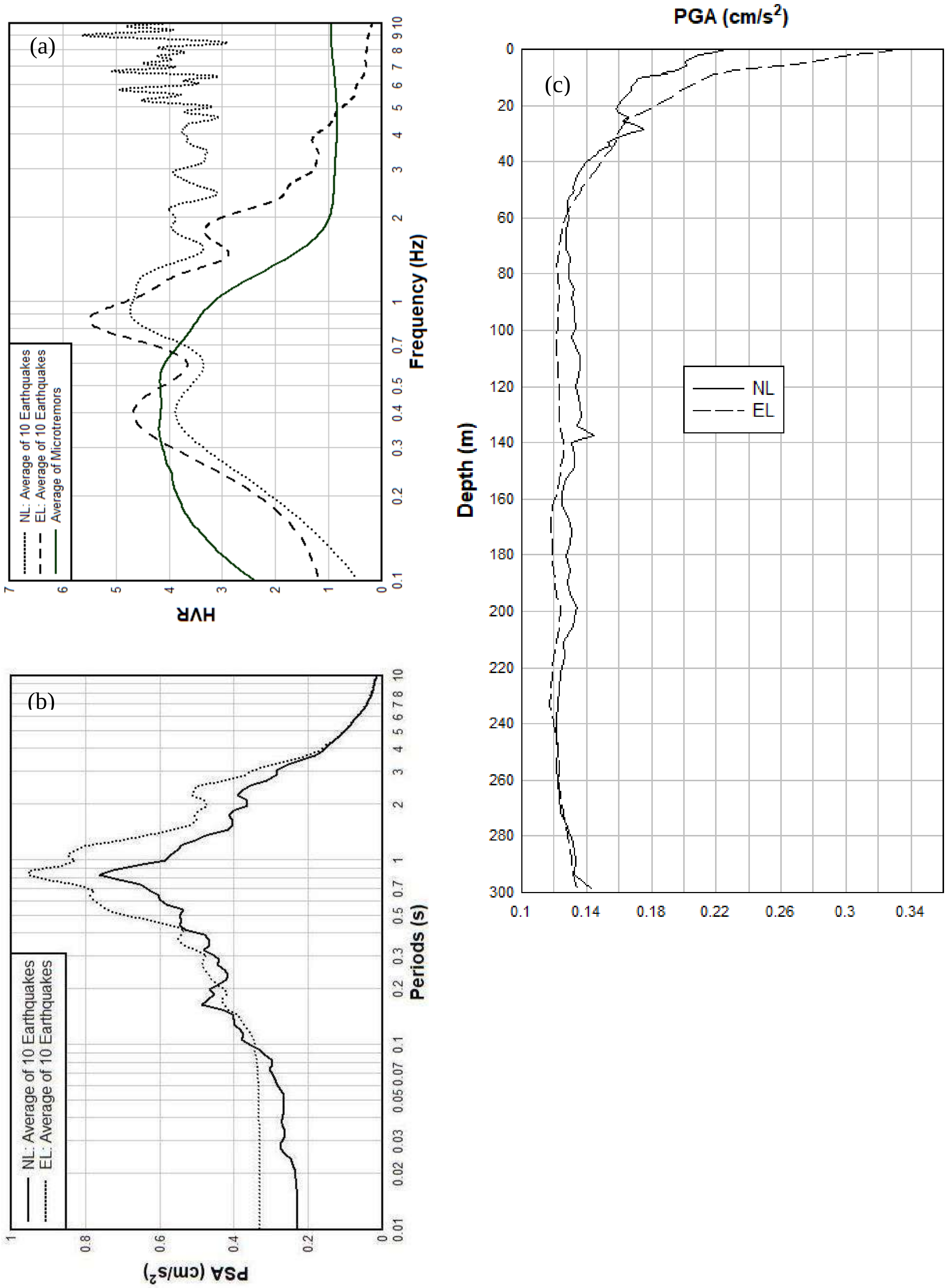


Figure 4.27 (a) Horizontal to Vertical Spectral Ratio (HVR), (b) Response Spectra and (c) Maximum peak ground acceleration (PGA) for the site-BH199

4.2.28 Site Response Analysis for BH203

The location is at Golertek playground Darussalam, Mirpur, Dhaka. The co-ordinate of the location is lat: 23° 47' 33.0144''N and long: 90° 20' 36.2502''E and the performed borehole depth of SPT is 30.0 and the performed seismic downhole test depth is 30.0m.

Spectral Ratio Analysis

The comparison of spectral ratio analysis using SPT and shear wave velocity data by DEEPSOIL program and the Horizontal to Vertical Spectral Ratio (HVR) obtained from the microtremors using Geopsy program is shown in Figure 4.28a. Both equivalent linear and nonlinear methods have been applied in the case of DEEPSOIL analysis. For estimation of ground response site amplification factors at sub surface layers are often used as one of the parameters. The amplification factor is the maximum amplitude of the HVR curve.

Hence the amplification factor obtained from the microtremors is 2.34 at 0.99 Hz, the amplification factor obtained from nonlinear method is 4.77 at 0.87 Hz and the amplification factor obtained from equivalent linear method is 5.72 at 0.83 Hz.

Response Spectra

Response spectra obtained from DEEPSOIL program in both equivalent linear and nonlinear method is presented in the following Figure 4.28b. The peak spectral acceleration (PSA) obtained using the nonlinear method is 0.69g and PSA obtained using equivalent linear method is 0.90g for the specific site.

Maximum Peak Ground Acceleration (PGA)

Maximum Peak Ground Acceleration (PGA) at different depths for this site is shown in the Figure 4.28c at surface, which is obtained from equivalent linear and nonlinear analysis. The averages of PGA values at surface are observed 0.32g for equivalent linear analysis and 0.22g for nonlinear analysis.

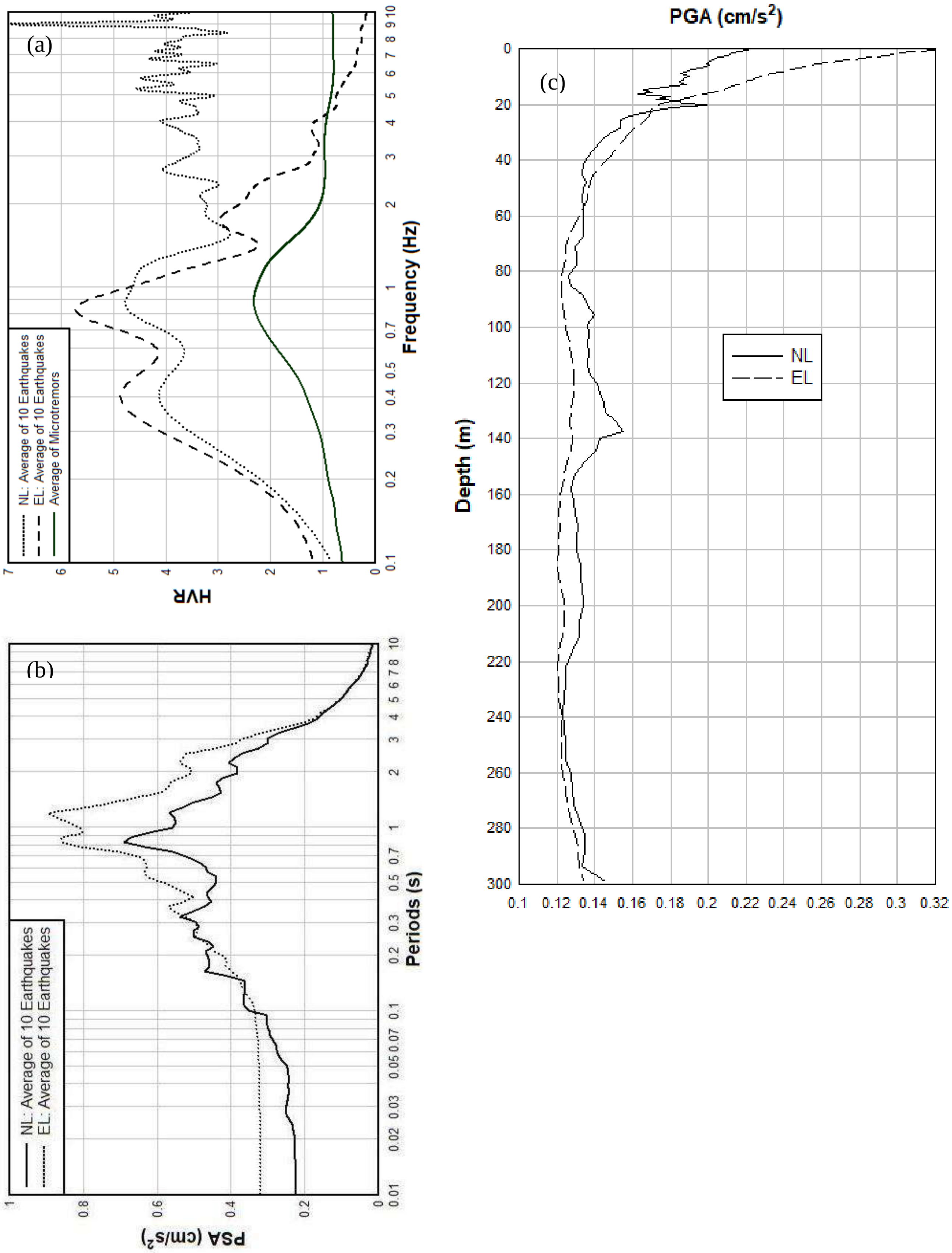


Figure 4.28 (a) Horizontal to Vertical Spectral Ratio (HVR), (b) Response Spectra and (c) Maximum peak ground acceleration (PGA) for the site-BH203

4.2.29 Site Response Analysis for BH209

The location is at Rowshan Ara girls high school, Beraid, Badda, Dhaka. The co-ordinate of the location is lat: 23° 47' 59.409"N and long: 90° 28' 30.5646"E and the performed borehole depth of SPT is 30.0 and the performed seismic downhole test depth is 30.0m.

Spectral Ratio Analysis

The comparison of spectral ratio analysis using SPT and shear wave velocity data by DEEPSOIL program and the Horizontal to Vertical Spectral Ratio (HVR) obtained from the microtremors using Geopsy program is shown in Figure 4.29a. Both equivalent linear and nonlinear methods have been applied in the case of DEEPSOIL analysis. For estimation of ground response site amplification factors at sub surface layers are often used as one of the parameters. The amplification factor is the maximum amplitude of the HVR curve.

Hence the amplification factor obtained from the microtremors is 2.31 at 0.90 Hz, the amplification factor obtained from nonlinear method is 3.88 at 0.91 Hz and amplification factor obtained from equivalent linear method is 5.01 at 0.89 Hz.

Response Spectra

Response spectra obtained from DEEPSOIL program in both equivalent linear and nonlinear method is presented in the following Figure 4.29b. The peak spectral acceleration (PSA) obtained using the nonlinear method is 0.57g and PSA obtained using equivalent linear method is 0.72g for the specific site.

Maximum Peak Ground Acceleration (PGA)

Maximum Peak Ground Acceleration (PGA) at different depths for this site is shown in the Figure 4.29c at surface, which is obtained from equivalent linear and nonlinear analysis. The averages of PGA values at surface are observed 0.31g for equivalent linear analysis and 0.22g for nonlinear analysis.

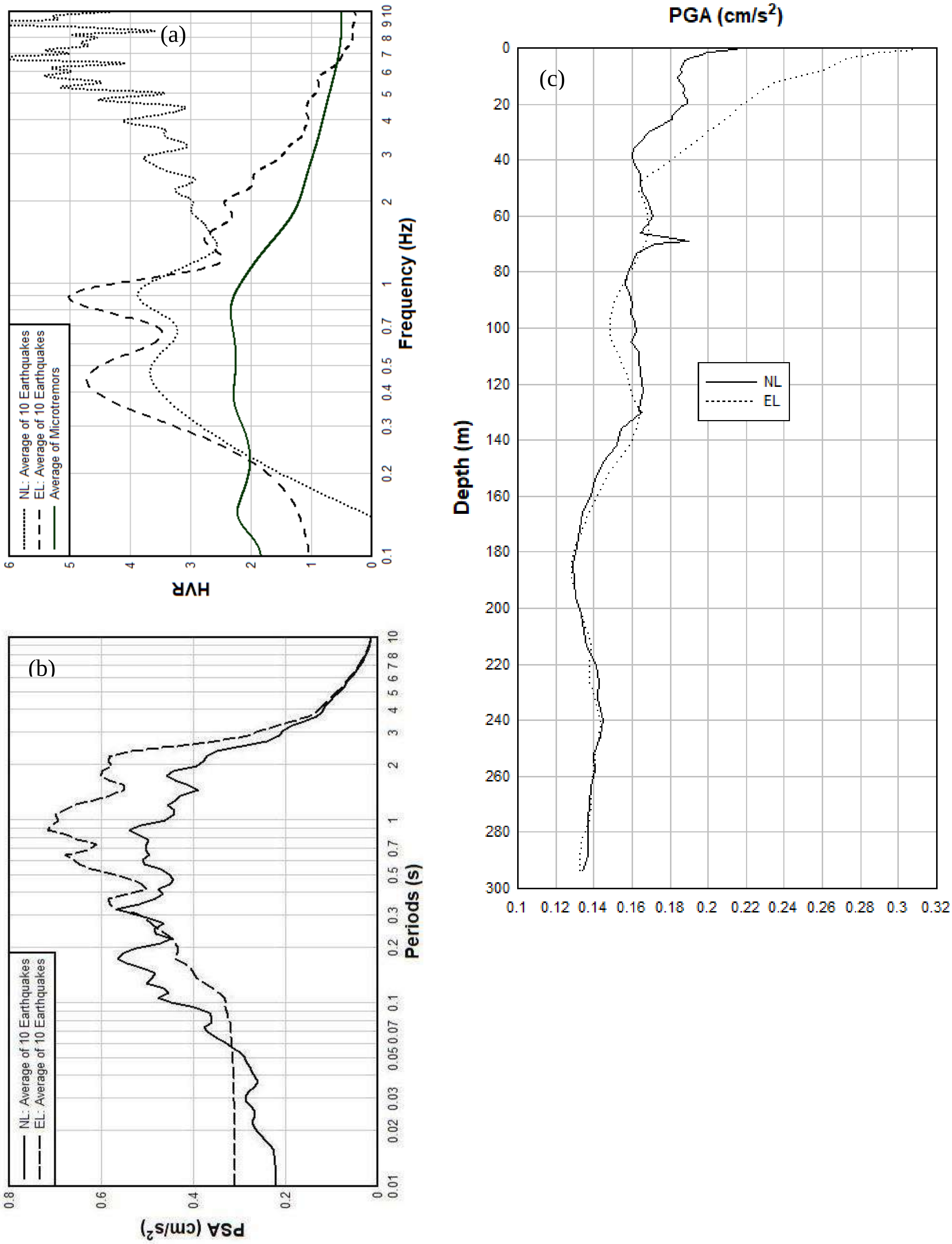


Figure 4.29 (a) Horizontal to Vertical Spectral Ratio (HVR), (b) Response Spectra and (c) Maximum peak ground acceleration (PGA) for the site-BH209

4.2.30 Site Response Analysis for BH213

The location is at Moirabo, Bhulta, Rupganj, Narayanganj. The co-ordinate of the location is lat: 23° 47' 39.858"N and long: 90° 32' 46.197"E and the performed borehole depth of SPT is 34.5 and the performed seismic downhole test depth is 33.0m.

Spectral Ratio Analysis

The comparison of spectral ratio analysis using SPT and shear wave velocity data by DEEPSOIL program and the Horizontal to Vertical Spectral Ratio (HVR) obtained from the microtremors using Geopsy program is shown in Figure 4.30a. Both equivalent linear and nonlinear methods have been applied in the case of DEEPSOIL analysis. For estimation of ground response site amplification factors at sub surface layers are often used as one of the parameters. The amplification factor is the maximum amplitude of the HVR curve.

Hence the amplification factor obtained from the microtremors is 3.31 at 0.73 Hz, the amplification factor obtained from nonlinear method is 4.27 at 1.22 Hz and the amplification factor obtained from equivalent linear method is 4.41 at 0.48 Hz.

Response Spectra

Response spectra obtained from DEEPSOIL program in both equivalent linear and nonlinear method is presented in the following Figure 4.30b. The peak spectral acceleration (PSA) obtained using the nonlinear method is 0.74g and PSA obtained using equivalent linear method is 0.81g for the specific site.

Maximum Peak Ground Acceleration (PGA)

Maximum Peak Ground Acceleration (PGA) at different depths for this site is shown in Figure 4.30c at surface, which is obtained from equivalent linear and nonlinear analysis. The averages of PGA values at surface are observed 0.31g for equivalent linear analysis and 0.25g for nonlinear analysis.

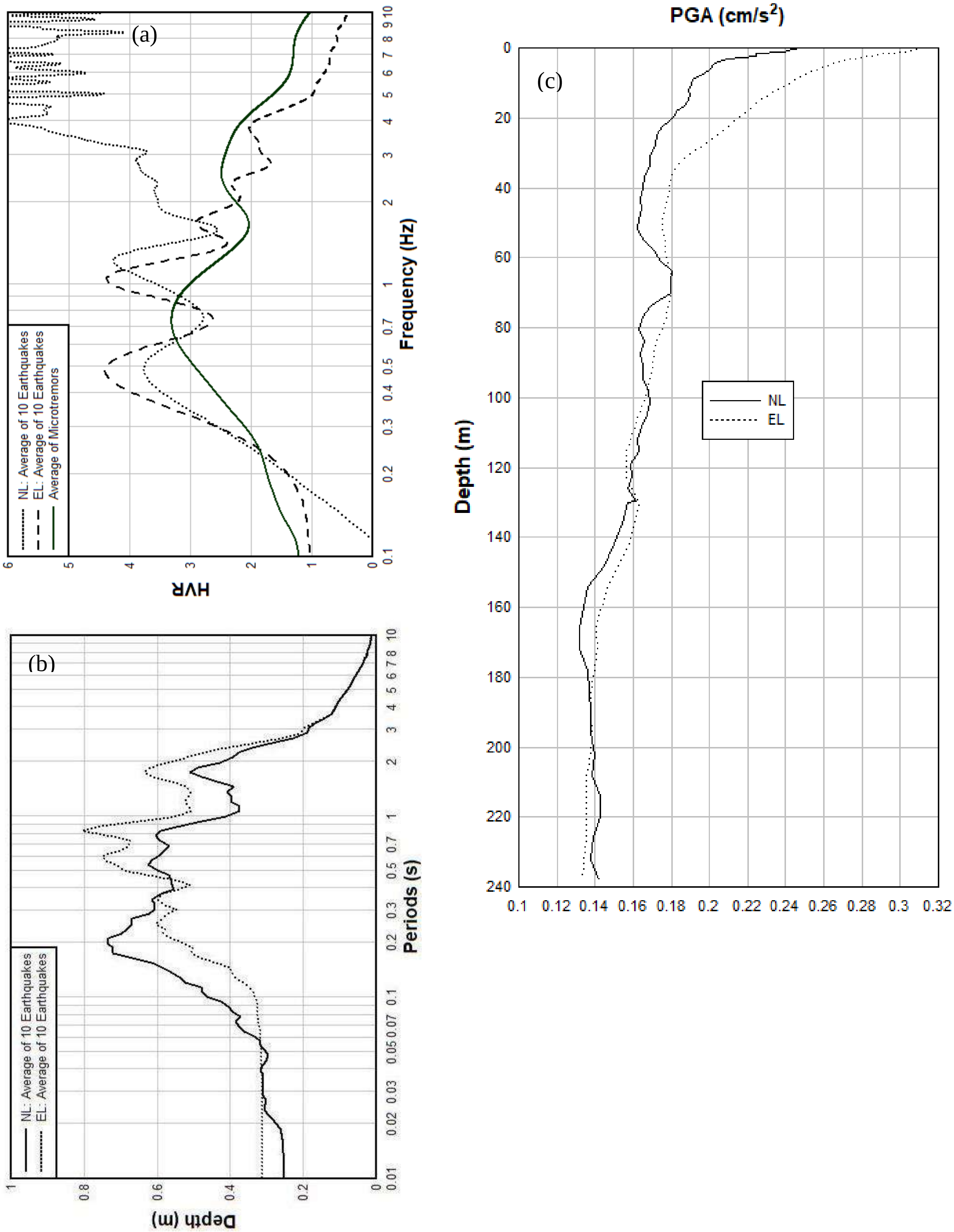


Figure 4.30 (a) Horizontal to Vertical Spectral Ratio (HVR), (b) Response Spectra and (c) Maximum peak ground acceleration (PGA) for the site-BH213

4.2.31 Site Response Analysis for BH230

The location is at Awal Market, Sadupur, Kazipara, Bongayo, Savar, Dhaka. The co-ordinate of the location is lat: 23° 49' 23.6496"N and long: 90° 17' 14.409"E and the performed borehole depth of SPT is 72.0 and the performed seismic downhole test depth is 70.0m.

Spectral Ratio Analysis

The comparison of spectral ratio analysis using SPT and shear wave velocity data by DEEPSOIL program and the Horizontal to Vertical Spectral Ratio (HVR) obtained from the microtremors using Geopsy program is shown in Figure 4.31a. Both equivalent linear and nonlinear methods have been applied in the case of DEEPSOIL analysis. For estimation of ground response site amplification factors at sub surface layers are often used as one of the parameters. The amplification factor is the maximum amplitude of the HVR curve.

The maximum HVR value obtained from the microtremors is 5.56 at 0.27 Hz, the maximum HVR value obtained from nonlinear method is 3.71 at 0.97 Hz and the maximum HVR value obtained from equivalent linear method is 4.30 at 0.88 Hz.

Response Spectra

Response spectra obtained from DEEPSOIL program in both equivalent linear and nonlinear method is presented in the following Figure 4.31b. The peak spectral acceleration (PSA) obtained using the nonlinear method is 0.59g and PSA obtained using equivalent linear method is 0.73g for the specific site.

Maximum Peak Ground Acceleration (PGA)

Maximum Peak Ground Acceleration (PGA) at different depths for this site is shown in Figure 4.31c at surface, which is obtained from equivalent linear and nonlinear analysis. The averages of PGA values at surface are observed 0.25g for equivalent linear analysis and 0.20g for nonlinear analysis.

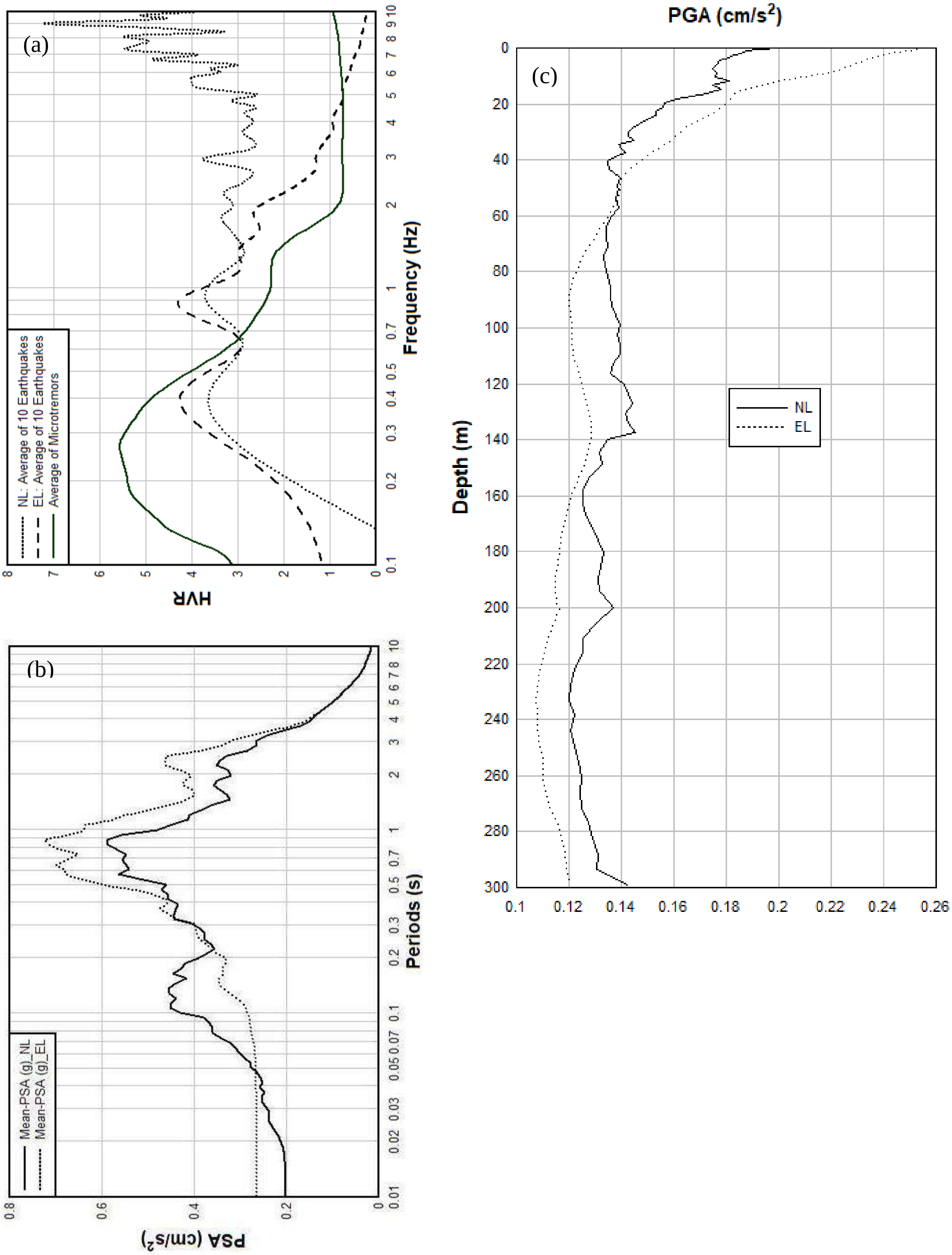


Figure 4.31 (a) Horizontal to Vertical Spectral Ratio (HVR), (b) Response Spectra and (c) Maximum peak ground acceleration (PGA) for the site-BH230

4.2.32 Site Response Analysis for BH236

The location is at Bagber, Rupganj, Narayanganj. The co-ordinate of the location is lat: 23° 49' 36.807"N and long: 90° 30' 47.9298"E and the performed borehole depth of SPT is 37.5 and the performed seismic downhole test depth is 37.0m.

Spectral Ratio Analysis

The comparison of spectral ratio analysis using SPT and shear wave velocity data by DEEPSOIL program and the Horizontal to Vertical Spectral Ratio (HVR) obtained from the microtremors using Geopsy program is shown in Figure 4.32a. Both equivalent linear and nonlinear methods have been applied in the case of DEEPSOIL analysis. For estimation of ground response site amplification factors at sub surface layers are often used as one of the parameters. The amplification factor is the maximum amplitude of the HVR curve.

Hence the amplification factor obtained from the microtremors is 2.82 at 0.51Hz, the amplification factor obtained from nonlinear method is 3.82 at 0.41Hz and the amplification factor obtained from equivalent linear method is 4.45 at 0.93 Hz.

Response Spectra

Response spectra obtained from DEEPSOIL program in both equivalent linear and nonlinear method is presented in the following Figure 4.32b. The peak spectral acceleration (PSA) obtained using the nonlinear method is 0.80g and PSA obtained using equivalent linear method is 0.85g for the specific site.

Maximum Peak Ground Acceleration (PGA)

Maximum Peak Ground Acceleration (PGA) at different depths for this site is shown in Figure 4.32c at surface, which is obtained from equivalent linear and nonlinear analysis. The averages of PGA values at surface are observed 0.35g for equivalent linear analysis and 0.25g for nonlinear analysis.

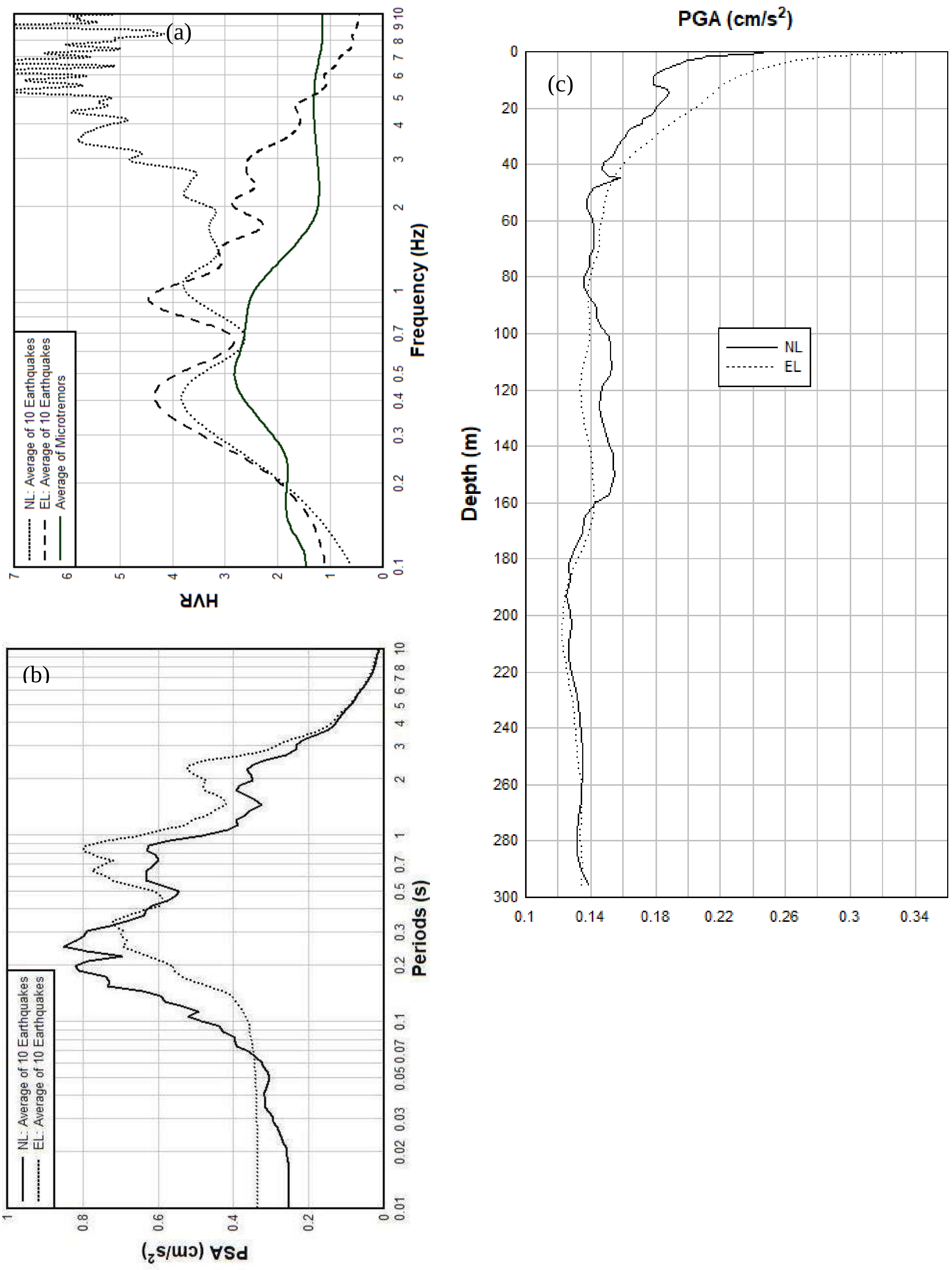


Figure 4.32 (a) Horizontal to Vertical Spectral Ratio (HVR), (b) Response Spectra and (c) Maximum peak ground acceleration (PGA) for the site-BH236

4.2.33 Site Response Analysis for BH245

The location is at Barua (shilon para), Khilkhet, Dhaka. The co-ordinate of the location is lat: 23° 50' 35.2818"N and long: 90° 27' 12.0018"E and the performed borehole depth of SPT is 30.0 and the performed seismic downhole test depth is 30.0m.

Spectral Ratio Analysis

The comparison of spectral ratio analysis using SPT and shear wave velocity data by DEEPSOIL program and the Horizontal to Vertical Spectral Ratio (HVR) obtained from the microtremors using Geopsy program is shown in Figure 4.33a. Both equivalent linear and nonlinear methods have been applied in the case of DEEPSOIL analysis. For estimation of ground response site amplification factors at sub surface layers are often used as one of the parameters. The amplification factor is the maximum amplitude of the HVR curve.

Hence, the amplification factor obtained from the microtremors is 2.10 at 0.76 Hz, the amplification factor obtained from nonlinear method is 4.02 at 1.05 Hz and amplification factor obtained from equivalent linear method is 4.63 at 0.92 Hz.

Response Spectra

Response spectra obtained from DEEPSOIL program in both equivalent linear and nonlinear method is presented in the following Figure 4.33b. The peak spectral acceleration (PSA) obtained using the nonlinear method is 0.65g and PSA obtained using equivalent linear method is 0.85g for the specific site.

Maximum Peak Ground Acceleration (PGA)

Maximum Peak Ground Acceleration (PGA) at different depths for this site is shown in Figure 4.33c at surface, which is obtained from equivalent linear and nonlinear analysis. The averages of PGA values at surface are observed 0.32g for equivalent linear analysis and 0.22g for nonlinear analysis.

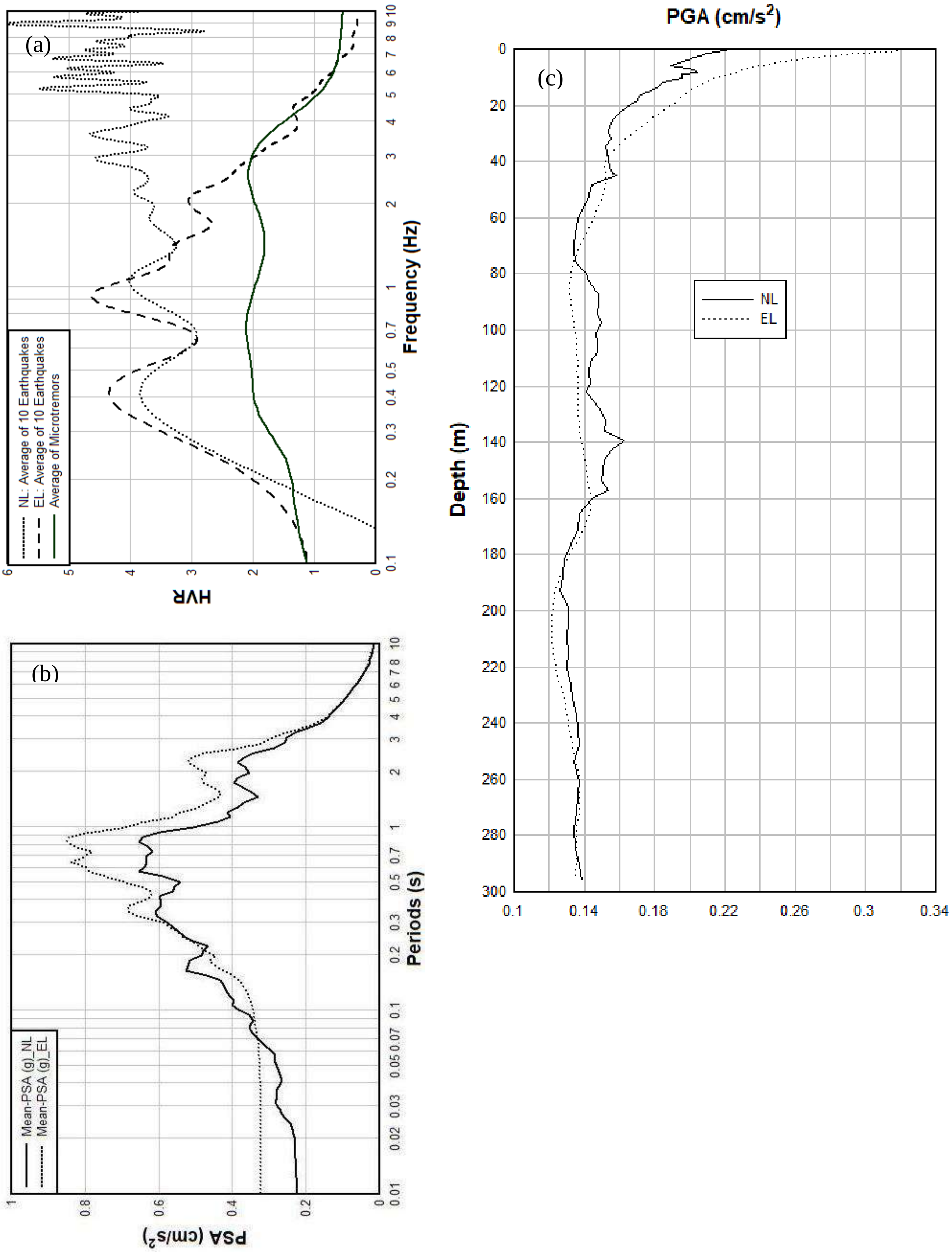


Figure 4.33 (a) Horizontal to Vertical Spectral Ratio (HVR), (b) Response Spectra and (c) Maximum peak ground acceleration (PGA) for the site-BH245

4.2.34 Site Response Analysis for BH253

The location is at Kakabo, Birulia, Savar, Dhaka. The co-ordinate of the location is lat: 23° 51' 35.1108"N and long: 90° 19' 27.948"E and the performed borehole depth of SPT is 51.0 and the performed seismic downhole test depth is 51.0m.

Spectral Ratio Analysis

The comparison of spectral ratio analysis using SPT and shear wave velocity data by DEEPSOIL program and the Horizontal to Vertical Spectral Ratio (HVR) obtained from the microtremors using Geopsy program is shown in Figure 4.34a. Both equivalent linear and nonlinear methods have been applied in the case of DEEPSOIL analysis. For estimation of ground response site amplification factors at sub surface layers are often used as one of the parameters. The amplification factor is the maximum amplitude of the HVR curve.

Hence, the amplification factor obtained from the microtremors is 2.43 at 0.49 Hz, the amplification factor obtained from nonlinear method is 3.23 at 0.41 Hz and the amplification factor obtained from equivalent linear method is 4.54 at 0.40 Hz.

Response Spectra

Response spectra obtained from DEEPSOIL program in both equivalent linear and nonlinear method is presented in the following Figure 4.34b. The peak spectral acceleration (PSA) obtained using the nonlinear method is 0.65g and PSA obtained using equivalent linear method is 0.80g for the specific site.

Maximum Peak Ground Acceleration (PGA)

Maximum Peak Ground Acceleration (PGA) at different depths for this site is shown in Figure 4.34c at surface, which is obtained from equivalent linear and nonlinear analysis. The averages of PGA values at surface are observed 0.30g for equivalent linear analysis and 0.21g for nonlinear analysis.

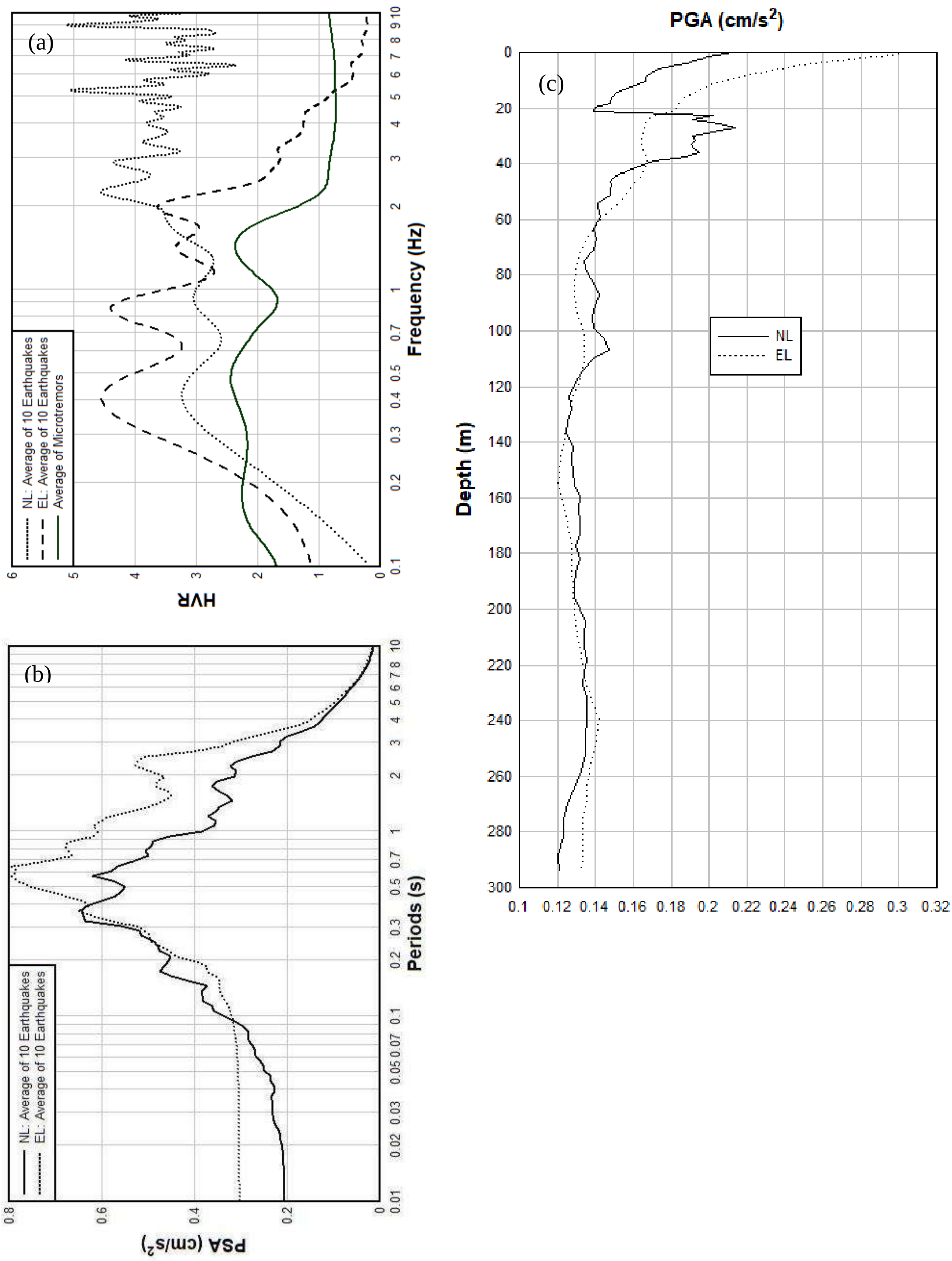


Figure 4.34 (a) Horizontal to Vertical Spectral Ratio (HVR), (b) Response Spectra and (c) Maximum peak ground acceleration (PGA) for the site-BH253

4.2.35 Site Response Analysis for BH263

The location is at Rajuk Land Area, Zinda Park, Gazipur. The co-ordinate of the location is lat: 23° 51' 48.477"N and long: 90° 31' 1.401"E and the performed borehole depth of SPT is 30.0 and the performed seismic downhole test depth is 30.0m.

Spectral Ratio Analysis

The comparison of spectral ratio analysis using SPT and shear wave velocity data by DEEPSOIL program and the Horizontal to Vertical Spectral Ratio (HVR) obtained from the microtremors using Geopsy program is shown in Figure 4.35a. Both equivalent linear and nonlinear methods have been applied in the case of DEEPSOIL analysis. For estimation of ground response site amplification factors at sub surface layers are often used as one of the parameters. The amplification factor is the maximum amplitude of the HVR curve.

Hence, the amplification factor obtained from the microtremors is 3.66 at 0.85 Hz, the amplification factor obtained from nonlinear method is 4.22 at 0.41 Hz and the amplification factor obtained from equivalent linear method is 4.56 at 0.88Hz.

Response Spectra

Response spectra obtained from DEEPSOIL program in both equivalent linear and nonlinear method is presented in the following Figure 4.35b. The peak spectral acceleration (PSA) obtained using the nonlinear method is 0.62g and PSA obtained using equivalent linear method is 0.76g for the specific site.

Maximum Peak Ground Acceleration (PGA)

Maximum Peak Ground Acceleration (PGA) at different depths for this site is shown in Figure 4.35c at surface, which is obtained from equivalent linear and nonlinear analysis. The averages of PGA values at surface are observed 0.28g for equivalent linear analysis and 0.21g for nonlinear analysis.

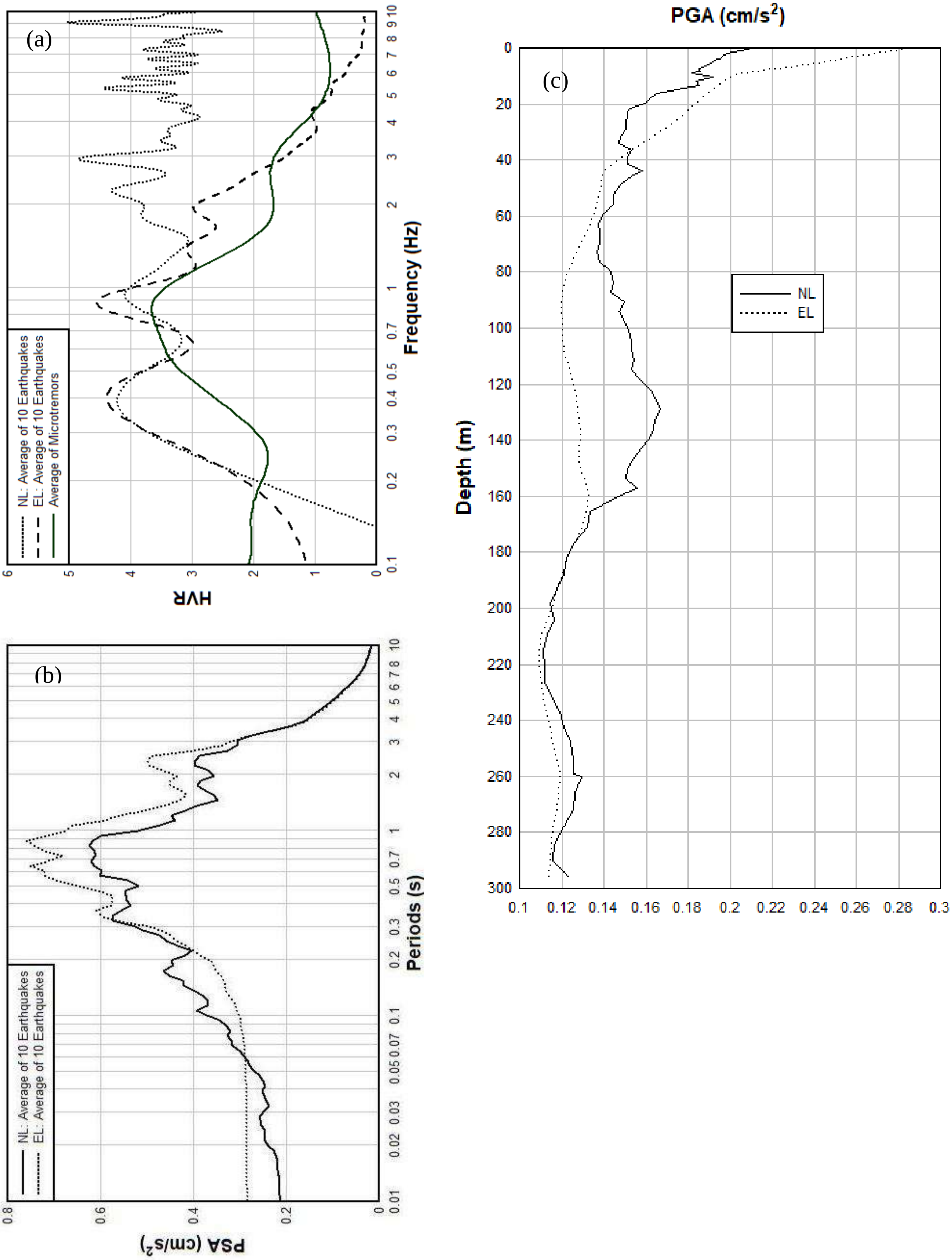


Figure 4.35 (a) Horizontal to Vertical Spectral Ratio (HVR), (b) Response Spectra and (c) Maximum peak ground acceleration (PGA) for the site-BH263

4.2.36 Site Response Analysis for BH275

The location is at Teromukh bridge uttarkhan Dhaka. The co-ordinate of the location is lat: 23° 52' 59.559"N and long: 90° 27' 26.0172"E and the performed borehole depth of SPT is 37.5 and the performed seismic downhole test depth is 39.0m.

Spectral Ratio Analysis

The comparison of spectral ratio analysis using SPT and shear wave velocity data by DEEPSOIL program and the Horizontal to Vertical Spectral Ratio (HVR) obtained from the microtremors using Geopsy program is shown in Figure 4.36a. Both equivalent linear and nonlinear methods have been applied in the case of DEEPSOIL analysis. For estimation of ground response site amplification factors at sub surface layers are often used as one of the parameters. The amplification factor is the maximum amplitude of the HVR curve.

Hence, the amplification factor obtained from the microtremors is 2.16 at 0.76 Hz, the amplification factor obtained from nonlinear method is 3.523at 0.41 Hz and the amplification factor obtained from equivalent linear method is 3.98 at 0.42 Hz.

Response Spectra

Response spectra obtained from DEEPSOIL program in both equivalent linear and nonlinear method is presented in the following Figure 4.36b. The peak spectral acceleration (PSA) obtained using the nonlinear method is 0.52g and PSA obtained using equivalent linear method is 0.53g for the specific site.

Maximum Peak Ground Acceleration (PGA)

Maximum Peak Ground Acceleration (PGA) at different depths for this site is shown in Figure 4.36c at surface, which is obtained from equivalent linear and nonlinear analysis. The averages of PGA values at surface are observed 0.22g for equivalent linear analysis and 0.18g for nonlinear analysis.

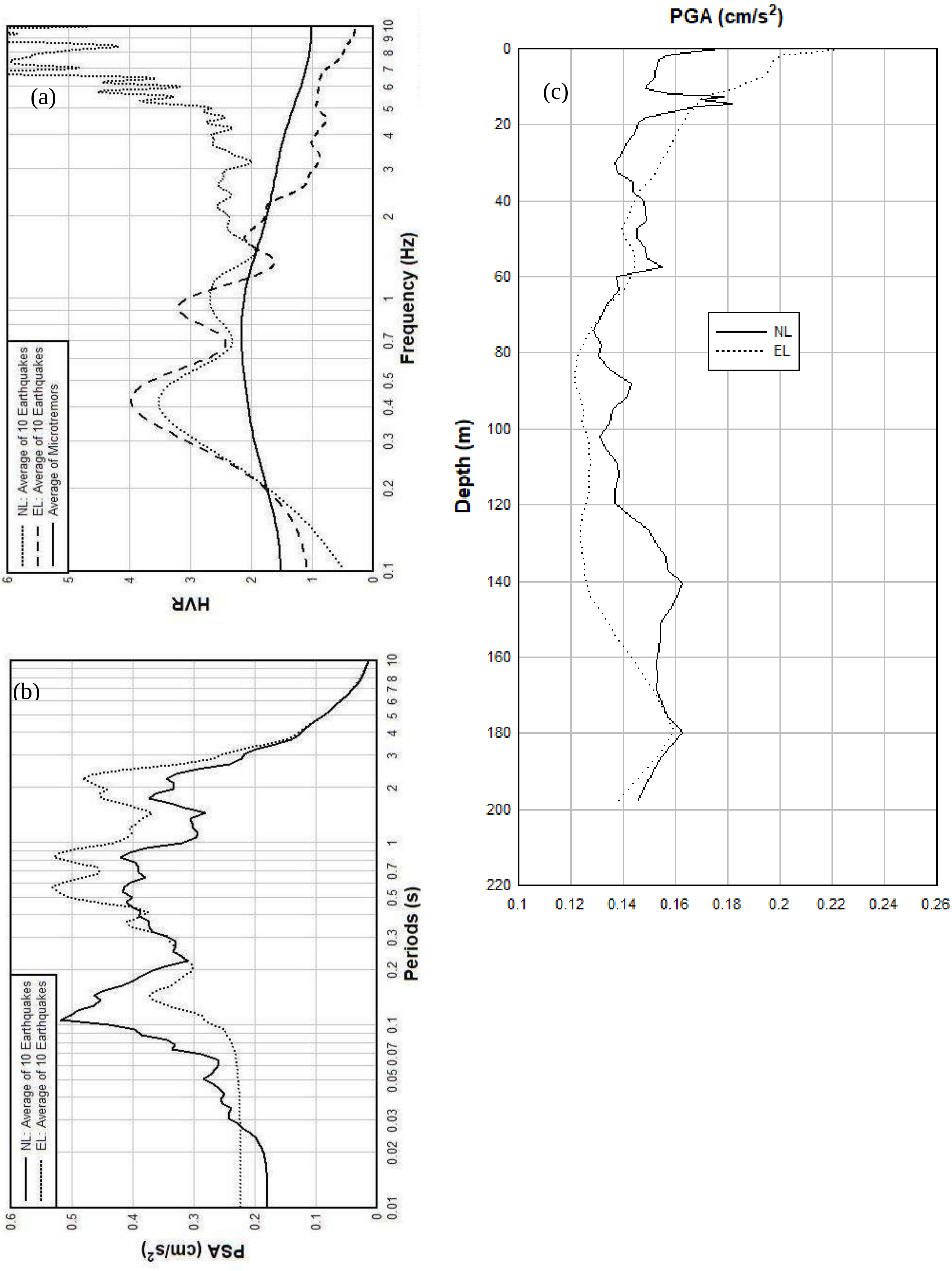


Figure 4.36 (a) Horizontal to Vertical Spectral Ratio (HVR), (b) Response Spectra and (c) Maximum peak ground acceleration (PGA) for the site-BH275

4.2.37 Site Response Analysis for BH286

The location is at Ashulia, Savar, Dhaka. The co-ordinate of the location is lat: 23° 53' 43.6518"N and long: 90° 20' 15.7194"E and the performed borehole depth of SPT is 43.5 and the performed seismic downhole test depth is 43.0m.

Spectral Ratio Analysis

The comparison of spectral ratio analysis using SPT and shear wave velocity data by DEEPSOIL program and the Horizontal to Vertical Spectral Ratio (HVR) obtained from the microtremors using Geopsy program is shown in Figure 4.37a. Both equivalent linear and nonlinear methods have been applied in the case of DEEPSOIL analysis. For estimation of ground response site amplification factors at sub surface layers are often used as one of the parameters. The amplification factor is the maximum amplitude of the HVR curve.

Hence, the amplification factor obtained from the microtremors is 1.29 at 1.46 Hz, the amplification factor obtained from nonlinear method is 5.16 at 0.44 Hz and amplification factor obtained from equivalent linear method is 8.50 at 0.41 Hz.

Response Spectra

Response spectra obtained from DEEPSOIL program in both equivalent linear and nonlinear method is presented in the following Figure 4.37b. The peak spectral acceleration (PSA) obtained using the nonlinear method is 0.54g and PSA obtained using equivalent linear method is 1.03 for the specific site.

Maximum Peak Ground Acceleration (PGA)

Maximum Peak Ground Acceleration (PGA) at different depths for this site is shown in 4.37 Figurec at surface, which is obtained from equivalent linear and nonlinear analysis. The averages of PGA values at surface are observed 0.30g for equivalent linear analysis and 0.19g for nonlinear analysis.

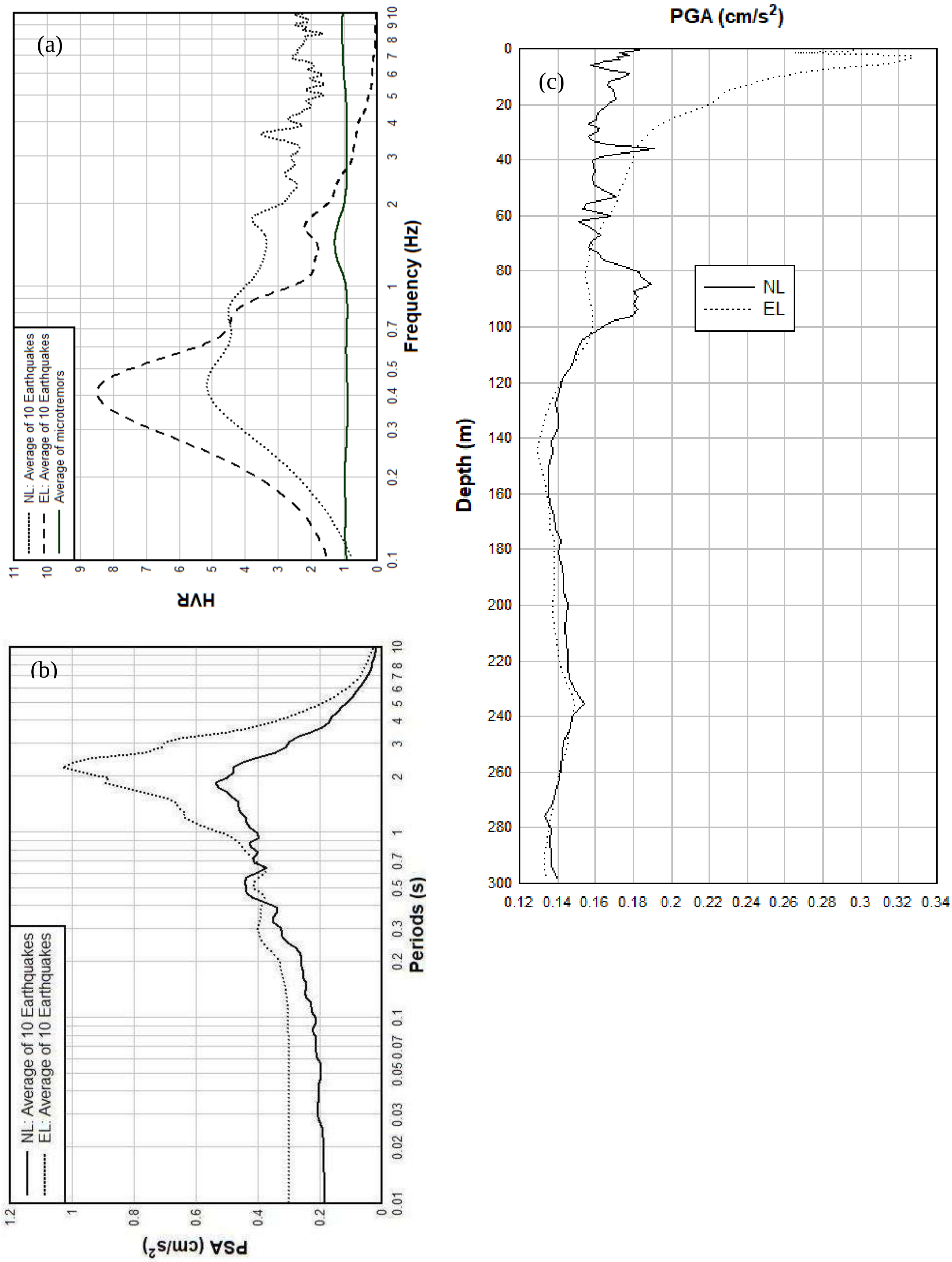


Figure 4.37 (a) Horizontal to Vertical Spectral Ratio (HVR), (b) Response Spectra and (c) Maximum peak ground acceleration (PGA) for the site-BH286

4.2.38 Site Response Analysis for BH289

The location is at BTCL Tongi, Gazipur. The co-ordinate of the location is lat: 23° 53' 49.6242"N and long: 90° 23' 53.5086"E and the performed borehole depth of SPT is 52.5 and the performed seismic downhole test depth is 52.0m.

Spectral Ratio Analysis

The comparison of spectral ratio analysis using SPT and shear wave velocity data by DEEPSOIL program and the Horizontal to Vertical Spectral Ratio (HVR) obtained from the microtremors using Geopsy program is shown in Figure 4.38a. Both equivalent linear and nonlinear methods have been applied in the case of DEEPSOIL analysis. For estimation of ground response site amplification factors at sub surface layers are often used as one of the parameters. The amplification factor is the maximum amplitude of the HVR curve.

Hence, the amplification factor obtained from the microtremors is 3.21 at 0.53 Hz, the amplification factor obtained from nonlinear method is 3.71 at 0.42Hz and the amplification factor obtained from equivalent linear method is 3.96 at 0.43 Hz.

Response Spectra

Response spectra obtained from DEEPSOIL program in both equivalent linear and nonlinear method is presented in the following Figure 4.38b. The peak spectral acceleration (PSA) obtained using the nonlinear method is 0.65g and PSA obtained using equivalent linear method is 0.61g for the specific site.

Maximum Peak Ground Acceleration (PGA)

Maximum Peak Ground Acceleration (PGA) at different depths for this site is shown in Figure 4.38c at surface, which is obtained from equivalent linear and nonlinear analysis. The averages of PGA values at surface are observed 0.26g for equivalent linear analysis and 0.20g for nonlinear analysis.

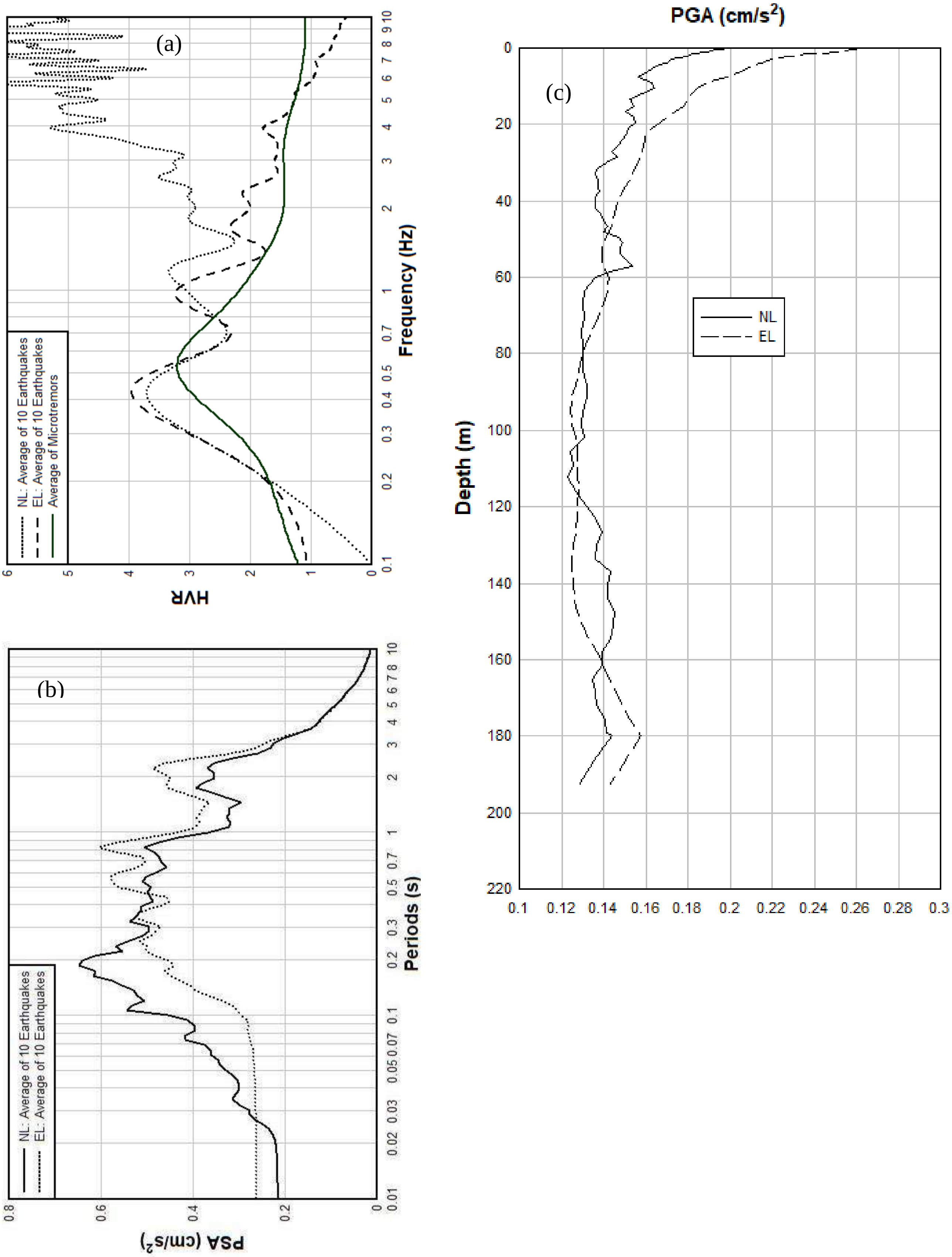


Figure 4.38 (a) Horizontal to Vertical Spectral Ratio (HVR), (b) Response Spectra and (c) Maximum peak ground acceleration (PGA) for the site-BH289

4.2.39 Site Response Analysis for BH293

The location is at Bhasania Primary School, Gazipur. The co-ordinate of the location is lat: 23° 53' 59.8914"N and long: 90° 29' 49.3866"E and the performed borehole depth of SPT is 30.0 and the performed seismic downhole test depth is 30.0m.

Spectral Ratio Analysis

The comparison of spectral ratio analysis using SPT and shear wave velocity data by DEEPSOIL program and the Horizontal to Vertical Spectral Ratio (HVR) obtained from the microtremors using Geopsy program is shown in Figure 4.39a. Both equivalent linear and nonlinear methods have been applied in the case of DEEPSOIL analysis. For estimation of ground response site amplification factors at sub surface layers are often used as one of the parameters. The amplification factor is the maximum amplitude of the HVR curve.

Hence, the amplification factor obtained from the microtremors is 2.34 at 0.79 Hz, the amplification factor obtained from nonlinear method is 4.21 at 0.40 Hz and the amplification factor obtained from equivalent linear method is 4.21 at 0.1 Hz.

Response Spectra

Response spectra obtained from DEEPSOIL program in both equivalent linear and nonlinear method is presented in the following Figure 4.39b. The peak spectral acceleration (PSA) obtained using the nonlinear method is 0.70g and PSA obtained using equivalent linear method is 0.72g for the specific site.

Maximum Peak Ground Acceleration (PGA)

Maximum Peak Ground Acceleration (PGA) at different depths for this site is shown in Figure 4.39c at surface, which is obtained from equivalent linear and nonlinear analysis. The averages of PGA values at surface are observed 0.30g for equivalent linear analysis and 0.23g for nonlinear analysis.

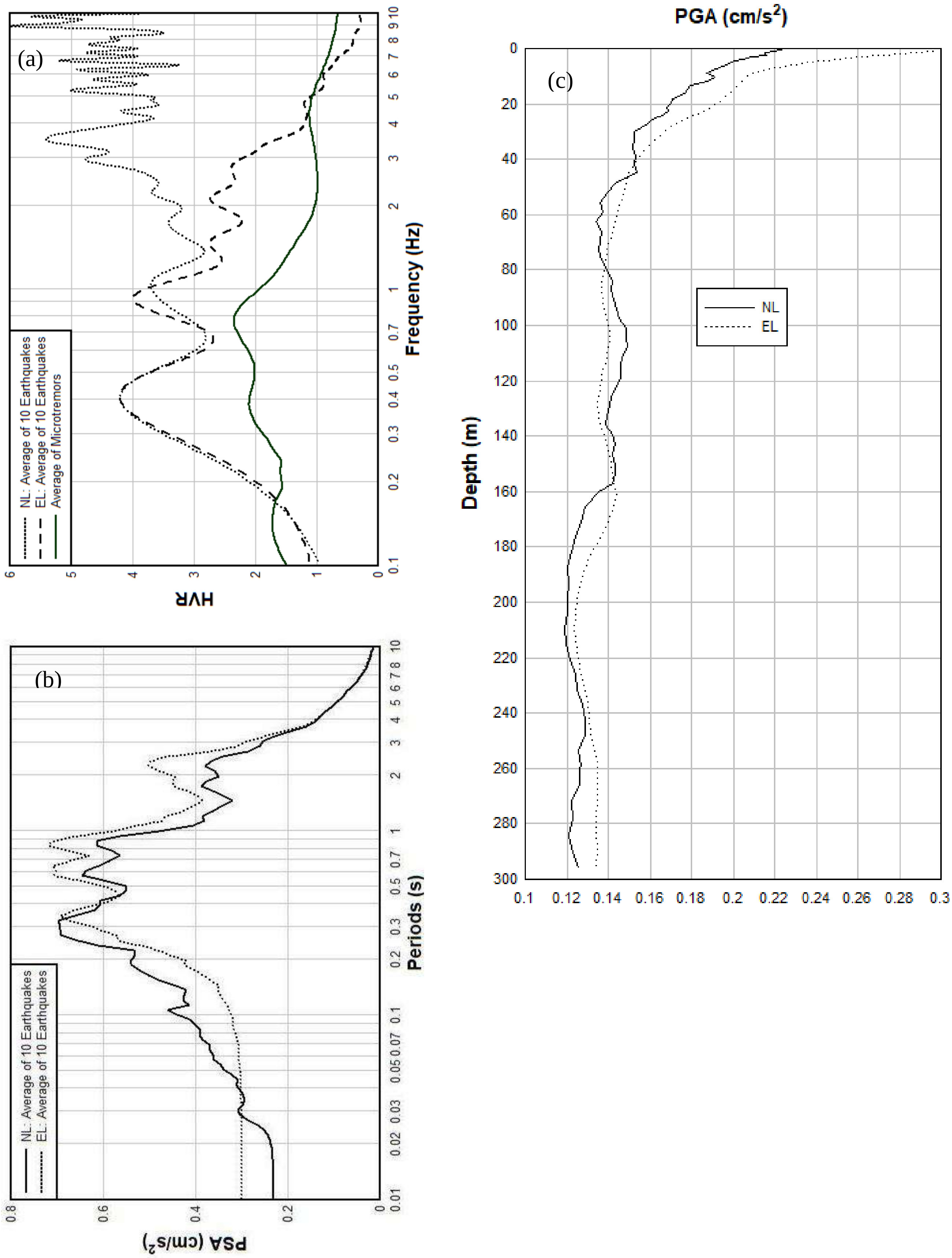


Figure 4.39 (a) Horizontal to Vertical Spectral Ratio (HVR), (b) Response Spectra and (c) Maximum peak ground acceleration (PGA) for the site-BH293

4.2.40 Site Response Analysis for BH298

The location is at Madhobi Sheltech Project, Plot No. 63, Katgora, Ashulia. The co-ordinate of the location is lat: 23° 54' 54.3198"N and long: 90° 18' 6.0696"E and the performed borehole depth of SPT is 57.0 and the performed seismic downhole test depth is 55.0m.

Spectral Ratio Analysis

The comparison of spectral ratio analysis using SPT and shear wave velocity data by DEEPSOIL program and the Horizontal to Vertical Spectral Ratio (HVR) obtained from the microtremors using Geopsy program is shown in Figure 4.40a. Both equivalent linear and nonlinear methods have been applied in the case of DEEPSOIL analysis. For estimation of ground response site amplification factors at sub surface layers are often used as one of the parameters. The amplification factor is the maximum amplitude of the HVR curve.

Hence, the amplification factor obtained from the microtremors is 5.13 at 0.75 Hz, the amplification factor obtained from nonlinear method is 5.29 at 0.70 Hz and the amplification factor obtained from equivalent linear method is 6.17 at 0.52 Hz.

Response Spectra

Response spectra obtained from DEEPSOIL program in both equivalent linear and nonlinear method is presented in the following Figure 4.40b. The peak spectral acceleration (PSA) obtained using the nonlinear method is 0.59g and PSA obtained using equivalent linear method is 0.94g for the specific site.

Maximum Peak Ground Acceleration (PGA)

Maximum Peak Ground Acceleration (PGA) at different depths for this site is shown in Figure 3.40c at surface, which is obtained from equivalent linear and nonlinear analysis. The averages of PGA values at surface are observed 0.38g for equivalent linear analysis and 0.22g for nonlinear analysis.

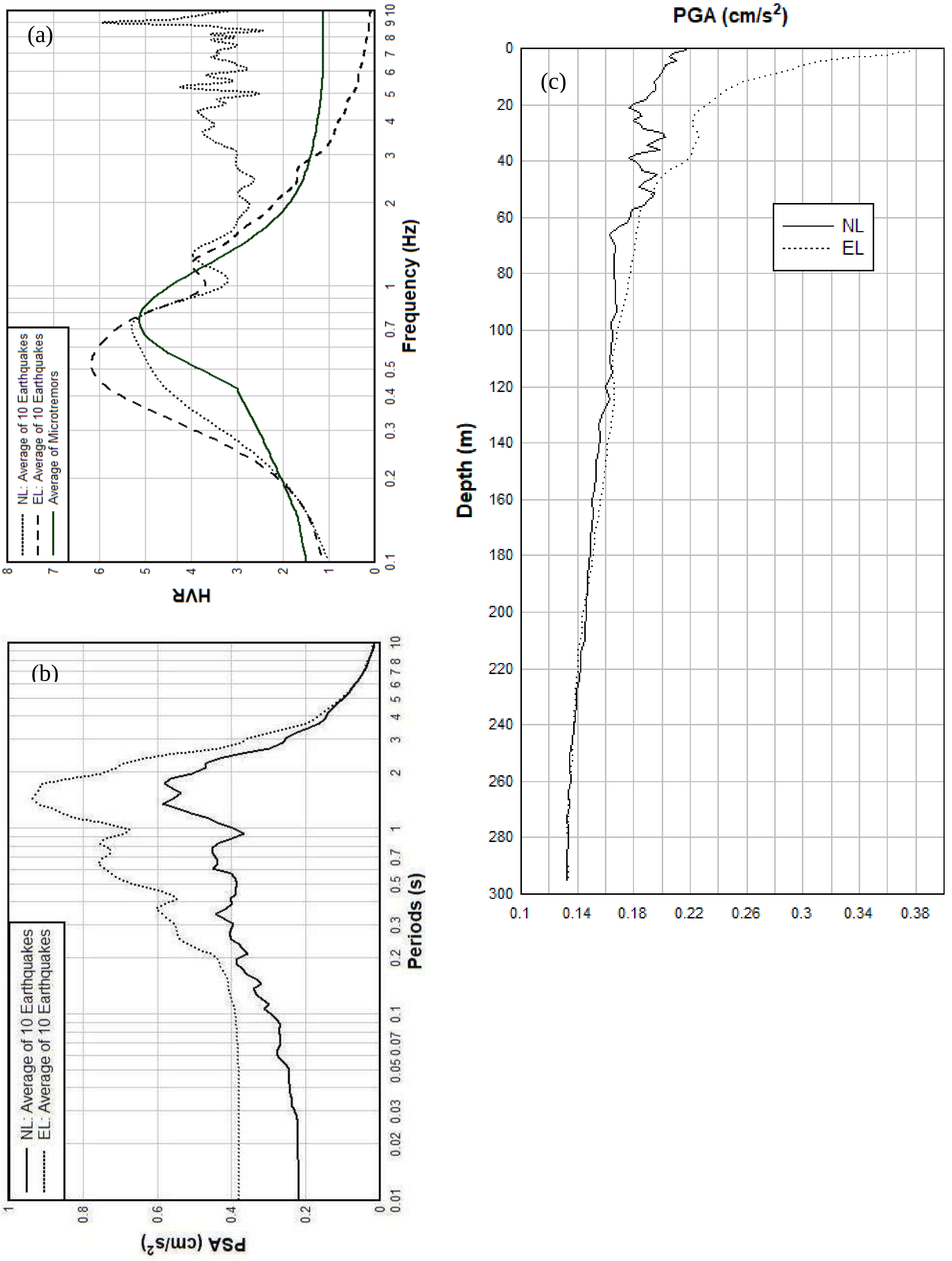


Figure 4.40 (a) Horizontal to Vertical Spectral Ratio (HVR), (b) Response Spectra and (c) Maximum peak ground acceleration (PGA) for the site-BH298

4.2.41 Site Response Analysis for BH311

The location is at Victoria Hondachiam Interbita School, Kaliganj, Dhaka. The co-ordinate of the location is lat: 23° 54' 55.7604"N and long: 90° 33' 20.2356"E and the performed borehole depth of SPT is 31.5 and the performed seismic downhole test depth is 31.0m.

Spectral Ratio Analysis

The comparison of spectral ratio analysis using SPT and shear wave velocity data by DEEPSOIL program and the Horizontal to Vertical Spectral Ratio (HVR) obtained from the microtremors using Geopsy program is shown in Figure 4.41a. Both equivalent linear and nonlinear methods have been applied in the case of DEEPSOIL analysis. For estimation of ground response site amplification factors at sub surface layers are often used as one of the parameters. The amplification factor is the maximum amplitude of the HVR curve.

Hence, the amplification factor obtained from the microtremors is 4.20 at 1.08 Hz, the amplification factor obtained from nonlinear method is 4.99 at 1.12 Hz and the amplification factor obtained from equivalent linear method is 5.69 at 0.95 Hz.

Response Spectra

Response spectra obtained from DEEPSOIL program in both equivalent linear and nonlinear method is presented in the following Figure 4.41b. The peak spectral acceleration (PSA) obtained using the nonlinear method is 0.79g and PSA obtained using equivalent linear method is 1.12g for the specific site.

Maximum Peak Ground Acceleration (PGA)

Maximum Peak Ground Acceleration (PGA) at different depths for this site is shown in Figure 4.41c at surface, which is obtained from equivalent linear and nonlinear analysis. The averages of PGA values at surface are observed 0.34g for equivalent linear analysis and 0.23g for nonlinear analysis.

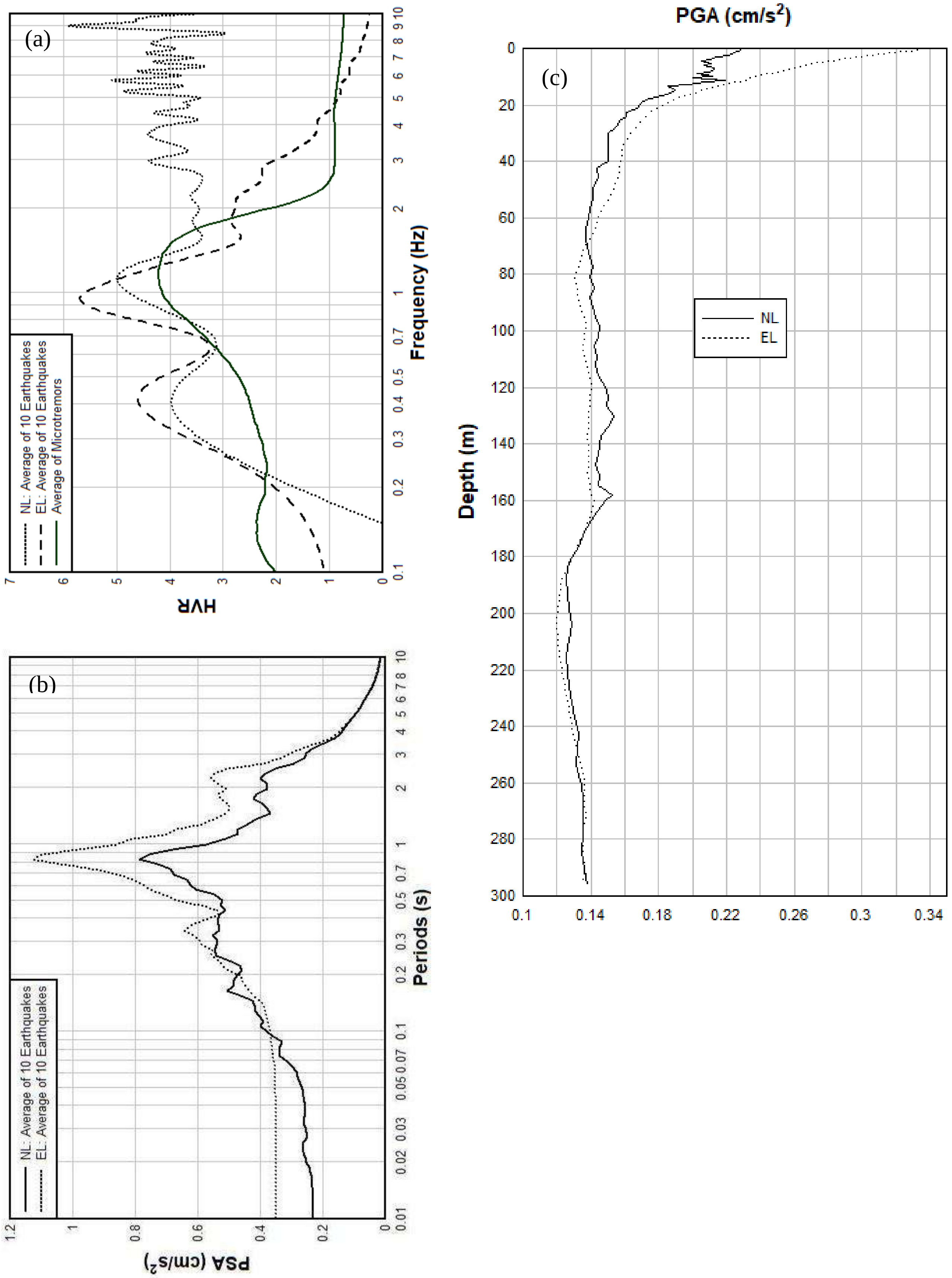


Figure 4.41 (a) Horizontal to Vertical Spectral Ratio (HVR), (b) Response Spectra and (c) Maximum peak ground acceleration (PGA) for the site-BH311

4.2.42 Site Response Analysis for BH320

The location is at Kunia Moddho para Jame mosjid ,Gazipur. The co-ordinate of the location is lat: 23° 55' 51.996"N and long: 90° 23' 3.7422"E and the performed borehole depth of SPT is 37.5 and the performed seismic downhole test depth is 39.0m.

Spectral Ratio Analysis

The comparison of spectral ratio analysis using SPT and shear wave velocity data by DEEPSOIL program and the Horizontal to Vertical Spectral Ratio (HVR) obtained from the microtremors using Geopsy program is shown in Figure 4.42a. Both equivalent linear and nonlinear methods have been applied in the case of DEEPSOIL analysis. For estimation of ground response site amplification factors at sub surface layers are often used as one of the parameters. The amplification factor is the maximum amplitude of the HVR curve.

Hence, the amplification factor obtained from the microtremors is 2.75 at 0.91 Hz, the amplification factor obtained from nonlinear method is 3.40 at 0.42 Hz and the amplification factor obtained from equivalent linear method is 4.00 at 0.43 Hz.

Response Spectra

Response spectra obtained from DEEPSOIL program in both equivalent linear and nonlinear method is presented in the following Figure4.42b. The peak spectral acceleration (PSA) obtained using the nonlinear method is 0.59g and PSA obtained using equivalent linear method is 0.65g for the specific site.

Maximum Peak Ground Acceleration (PGA)

Maximum Peak Ground Acceleration (PGA) at different depths for this site is shown in Figure 4.42c at surface, which is obtained from equivalent linear and nonlinear analysis. The averages of PGA values at surface are observed 0.26g for equivalent linear analysis and 0.20g for nonlinear analysis.

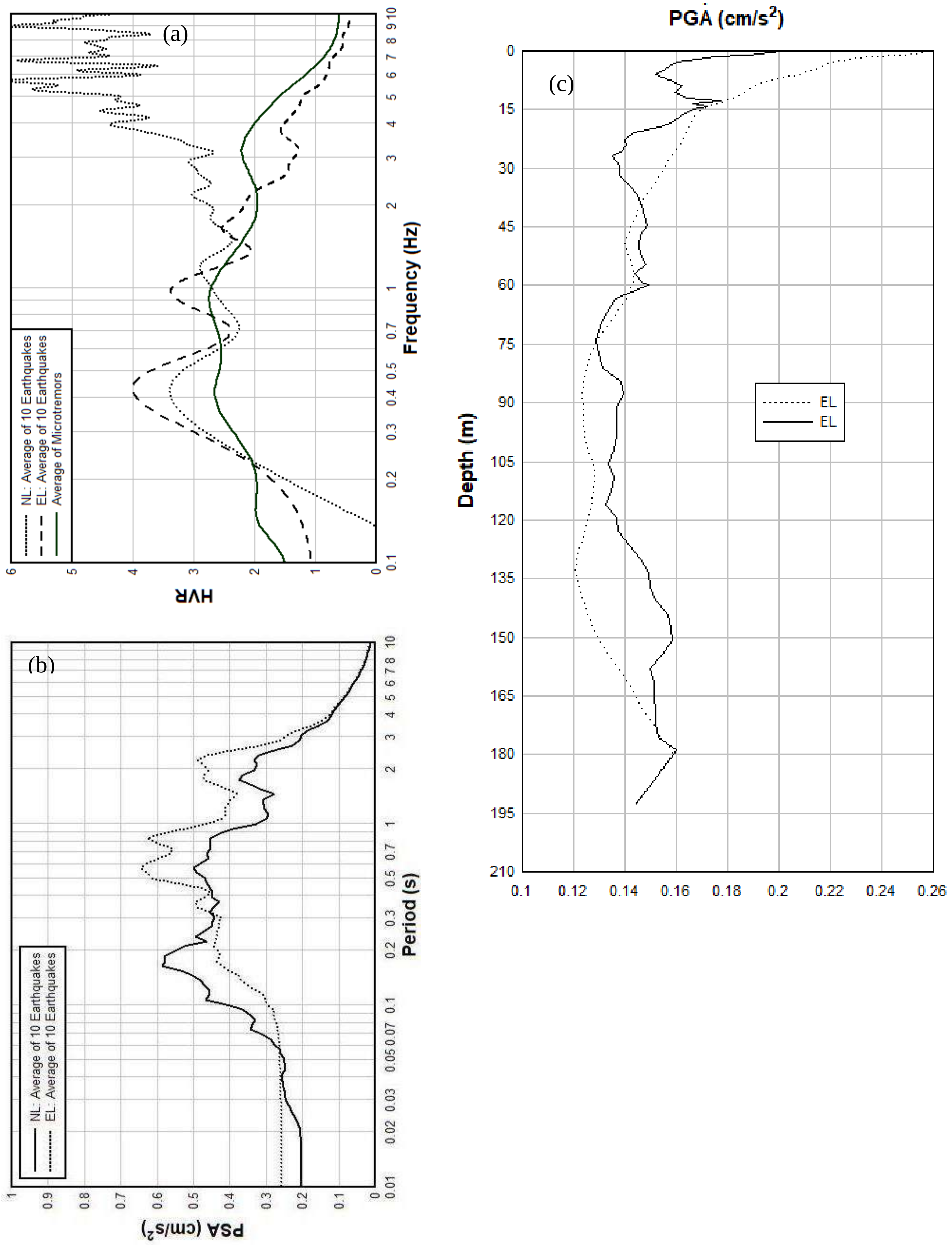


Figure 4.42 (a) Horizontal to Vertical Spectral Ratio (HVR), (b) Response Spectra and (c) Maximum peak ground acceleration (PGA) for the site-BH320

4.2.43 Site Response Analysis for BH323

The location is at Kudaba, Pubail, Gazipur. The co-ordinate of the location is lat: 23° 55' 55.9416"N and long: 90° 26' 16.731"E and the performed borehole depth of SPT is 52.5 and the performed seismic downhole test depth is 52.0m.

Spectral Ratio Analysis

The comparison of spectral ratio analysis using SPT and shear wave velocity data by DEEPSOIL program and the Horizontal to Vertical Spectral Ratio (HVR) obtained from the microtremors using Geopsy program is shown in Figure 4.43a. Both equivalent linear and nonlinear methods have been applied in the case of DEEPSOIL analysis. For estimation of ground response site amplification factors at sub surface layers are often used as one of the parameters. The amplification factor is the maximum amplitude of the HVR curve.

Hence, the amplification factor obtained from the microtremors is 3.12 at 0.73Hz, the amplification factor obtained from nonlinear method is 3.74 at 0.41 Hz and the amplification factor obtained from equivalent linear method is 4.05 at 0.43 Hz.

Response Spectra

Response spectra obtained from DEEPSOIL program in both equivalent linear and nonlinear method is presented in the following Figure 4.43b. The peak spectral acceleration (PSA) obtained using the nonlinear method is 0.41g and PSA obtained using equivalent linear method is 0.53g for the specific site.

Maximum Peak Ground Acceleration (PGA)

Maximum Peak Ground Acceleration (PGA) at different depths for this site is shown in Figure 4.43c at surface, which is obtained from equivalent linear and nonlinear analysis. The averages of PGA values at surface are observed 0.22g for equivalent linear analysis and 0.18g for nonlinear analysis.

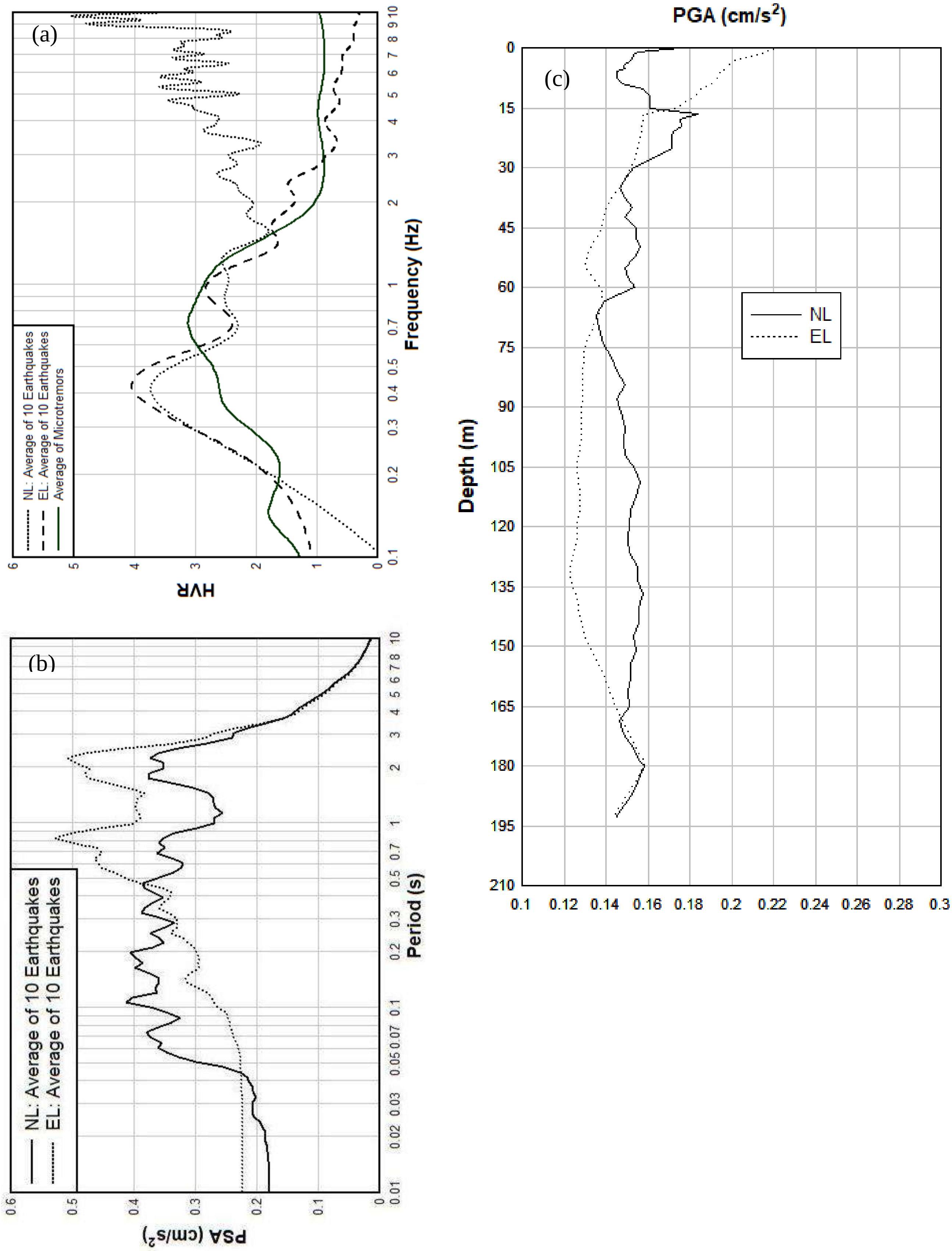


Figure 4.43 (a) Horizontal to Vertical Spectral Ratio (HVR), (b) Response Spectra and (c) Maximum peak ground acceleration (PGA) for the site-BH323

4.2.44 Site Response Analysis for BH329

The location is at Tajpur, Model High School, Ashulia, Savar, Dhaka. The co-ordinate of the location is lat: 23° 56' 54.9738"N and long: 90° 19' 21.3954"E and the performed borehole depth of SPT is 46.5 and the performed seismic downhole test depth is 45.0m.

Spectral Ratio Analysis

The comparison of spectral ratio analysis using SPT and shear wave velocity data by DEEPSOIL program and the Horizontal to Vertical Spectral Ratio (HVR) obtained from the microtremors using Geopsy program is shown in Figure 4.44a. Both equivalent linear and nonlinear methods have been applied in the case of DEEPSOIL analysis. For estimation of ground response site amplification factors at sub surface layers are often used as one of the parameters. The amplification factor is the maximum amplitude of the HVR curve.

Hence, the amplification factor obtained from the microtremors is 3.01 at 0.79 Hz, the amplification factor obtained from nonlinear method is 3.61 at 0.40 Hz and amplification factor obtained from equivalent linear method is 4.45 at 0.38 Hz.

Response Spectra

Response spectra obtained from DEEPSOIL program in both equivalent linear and nonlinear method is presented in the following Figure 4.44b. The peak spectral acceleration (PSA) obtained using the nonlinear method is 0.45g and PSA obtained using equivalent linear method is 0.64g for the specific site.

Maximum Peak Ground Acceleration (PGA)

Maximum Peak Ground Acceleration (PGA) at different depths for this site is shown in Figure 4.44c at surface, which is obtained from equivalent linear and nonlinear analysis. The averages of PGA values at surface are observed 0.22g for equivalent linear analysis and 0.19g for nonlinear analysis.

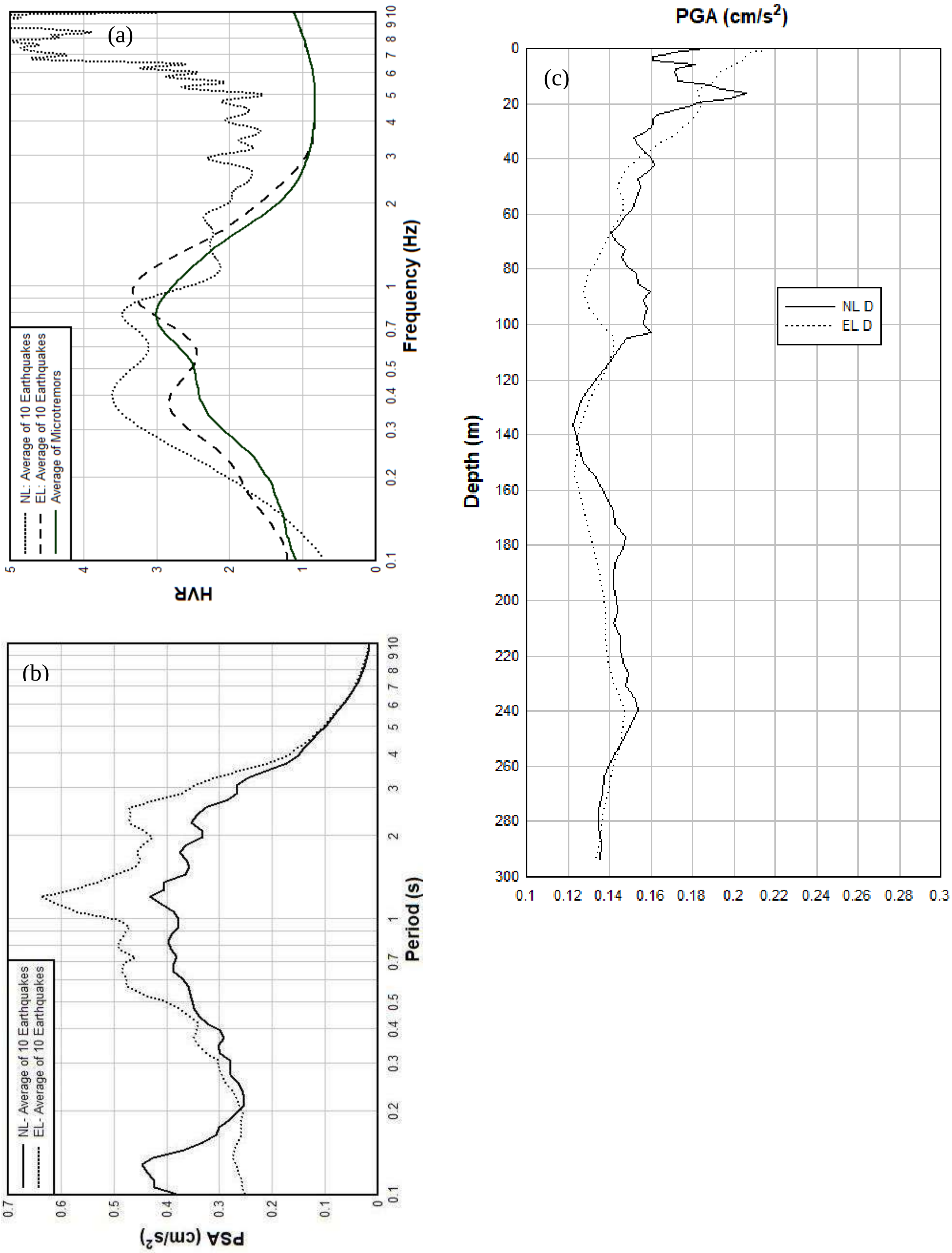


Figure 4.44 (a) Horizontal to Vertical Spectral Ratio (HVR), (b) Response Spectra and (c) Maximum peak ground acceleration (PGA) for the site-BH329

4.2.45 Site Response Analysis for BH341

The location is at Stand Housing, Dehra, Ashulia, Savar, Dhaka. The co-ordinate of the location is lat: 23° 58' 0.1158"N and long: 90° 15' 37.7892"E and the performed borehole depth of SPT is 43.5 and the performed seismic downhole test depth is 43.0m.

Spectral Ratio Analysis

The comparison of spectral ratio analysis using SPT and shear wave velocity data by DEEPSOIL program and the Horizontal to Vertical Spectral Ratio (HVR) obtained from the microtremors using Geopsy program is shown in Figure 4.45a. Both equivalent linear and nonlinear methods have been applied in the case of DEEPSOIL analysis. For estimation of ground response site amplification factors at sub surface layers are often used as one of the parameters. The amplification factor is the maximum amplitude of the HVR curve.

Hence, the amplification factor obtained from the microtremors is 3.87 at 0.85 Hz, the amplification factor obtained from nonlinear method is 3.08 at 0.40 Hz and the amplification factor obtained from equivalent linear method is 4.49 at 0.40 Hz.

Response Spectra

Response spectra obtained from DEEPSOIL program in both equivalent linear and nonlinear method is presented in the following Figure 4.45b. The peak spectral acceleration (PSA) obtained using the nonlinear method is 0.49g and PSA obtained using equivalent linear method is 0.64g for the specific site.

Maximum Peak Ground Acceleration (PGA)

Maximum Peak Ground Acceleration (PGA) at different depths for this site is shown in Figure 4.45c at surface, which is obtained from equivalent linear and nonlinear analysis. The averages of PGA values at surface are observed 0.27g for equivalent linear analysis and 0.18g for nonlinear analysis.

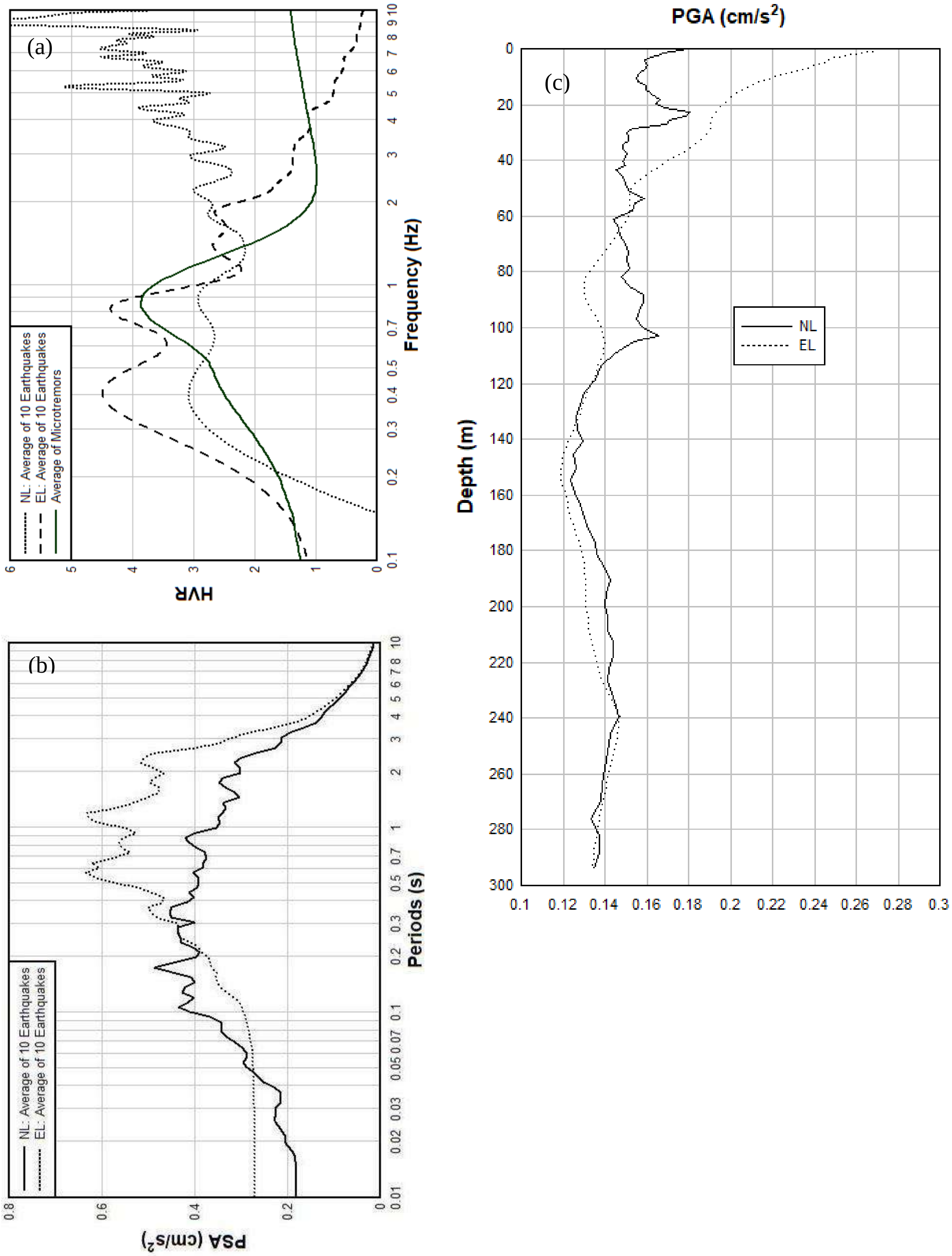


Figure 4.45 (a) Horizontal to Vertical Spectral Ratio (HVR), (b) Response Spectra and (c) Maximum peak ground acceleration (PGA) for the site-BH341

4.2.46 Site Response Analysis for BH347

The location is at Maleker Bari Road, Sakrauri, Gacha, Joydebpur, Gazipur. The co-ordinate of the location is lat: 23° 58' 2.2656"N and long: 90° 23' 41.4816"E and the performed borehole depth of SPT is 49.5 and the performed seismic downhole test depth is 49.0m.

Spectral Ratio Analysis

The comparison of spectral ratio analysis using SPT and shear wave velocity data by DEEPSOIL program and the Horizontal to Vertical Spectral Ratio (HVR) obtained from the microtremors using Geopsy program is shown in Figure 4.46a. Both equivalent linear and nonlinear methods have been applied in the case of DEEPSOIL analysis. For estimation of ground response site amplification factors at sub surface layers are often used as one of the parameters. The amplification factor is the maximum amplitude of the HVR curve.

Hence, the amplification factor obtained from the microtremors is 3.05 at 0.60 Hz, the amplification factor obtained from nonlinear method is 3.57 at 0.40 Hz and the amplification factor obtained from equivalent linear method is 3.78 at 0.42 Hz.

Response Spectra

Response spectra obtained from DEEPSOIL program in both equivalent linear and nonlinear method is presented in the following Figure 4.46b. The peak spectral acceleration (PSA) obtained using the nonlinear method is 0.66 g and PSA obtained using equivalent linear method is 0.50g for the specific site.

Maximum Peak Ground Acceleration (PGA)

Maximum Peak Ground Acceleration (PGA) at different depths for this site is shown in Figure 4.46c at surface, which is obtained from equivalent linear and nonlinear analysis. The averages of PGA values at surface are observed 0.22g for equivalent linear analysis and 0.23g for nonlinear analysis.

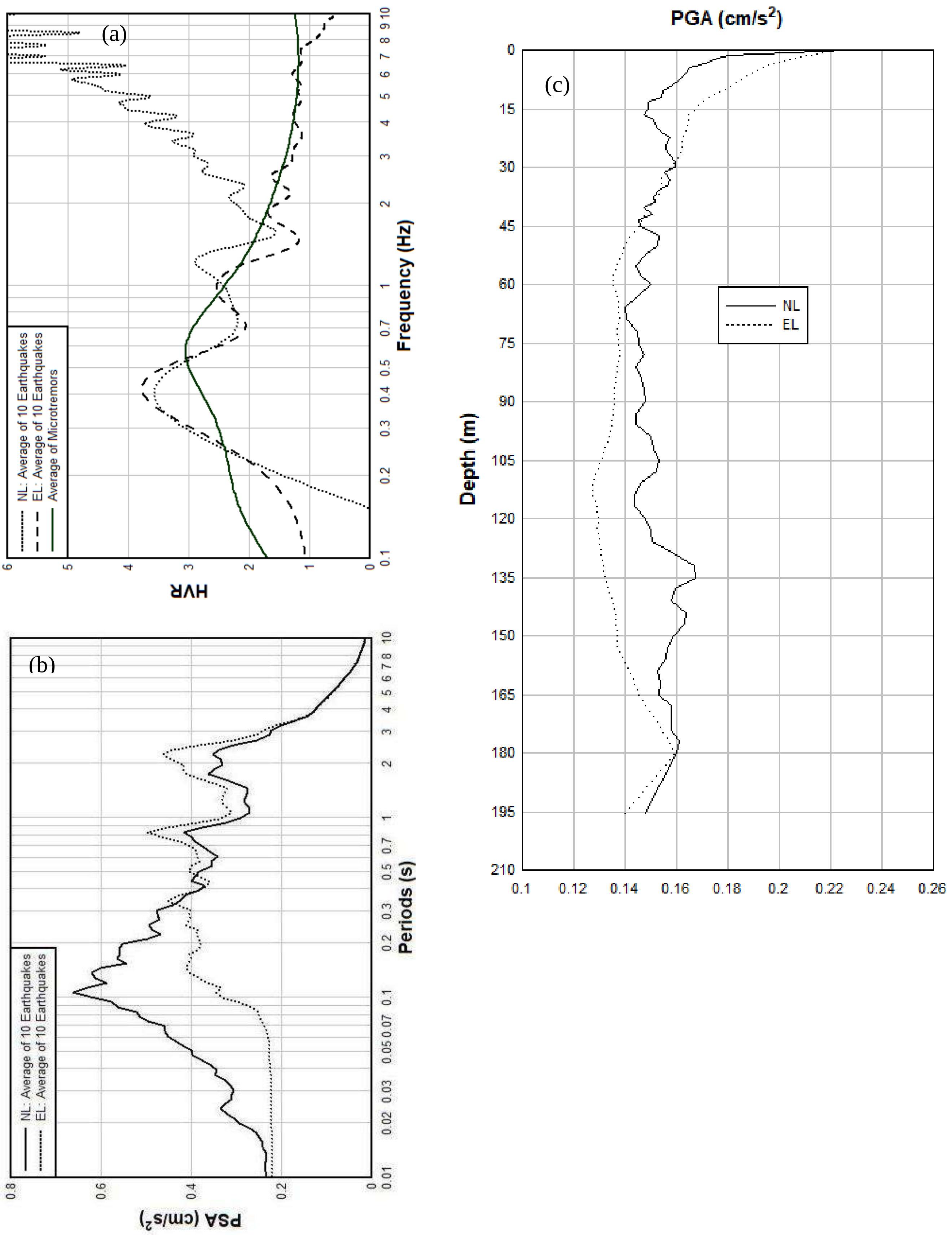


Figure.4.46 (a) Horizontal to Vertical Spectral Ratio (HVR), (b) Response Spectra and (c) Maximum peak ground acceleration (PGA) for the site-BH347

4.2.47 Site Response Analysis for BH361

The location is at Baluchakuli, Gazipur. The co-ordinate of the location is lat: 23° 58' 52.7694"N and long: 90° 26' 42.0036"E and the performed borehole depth of SPT is 31.5 and the performed seismic downhole test depth is 31.0m.

Spectral Ratio Analysis

The comparison of spectral ratio analysis using SPT and shear wave velocity data by DEEPSOIL program and the Horizontal to Vertical Spectral Ratio (HVR) obtained from the microtremors using Geopsy program is shown in Figure 4.47a. Both equivalent linear and nonlinear methods have been applied in the case of DEEPSOIL analysis. For estimation of ground response site amplification factors at sub surface layers are often used as one of the parameters. The amplification factor is the maximum amplitude of the HVR curve.

Hence, the amplification factor obtained from the microtremors is 3.47 at 1.03 Hz, the amplification factor obtained from nonlinear method is 3.65 at 0.42 Hz and the amplification factor obtained from equivalent linear method is 3.89 at 0.42 Hz.

Response Spectra

Response spectra obtained from DEEPSOIL program in both equivalent linear and nonlinear method is presented in the following Figure 4.47b. The peak spectral acceleration (PSA) obtained using the nonlinear method is 0.59g and PSA obtained using equivalent linear method is 0.67g for the specific site.

Maximum Peak Ground Acceleration (PGA)

Maximum Peak Ground Acceleration (PGA) at different depths for this site is shown in Figure 4.47c at surface, which is obtained from equivalent linear and nonlinear analysis. The averages of PGA values at surface are observed 0.28g for equivalent linear analysis and 0.19g for nonlinear analysis.

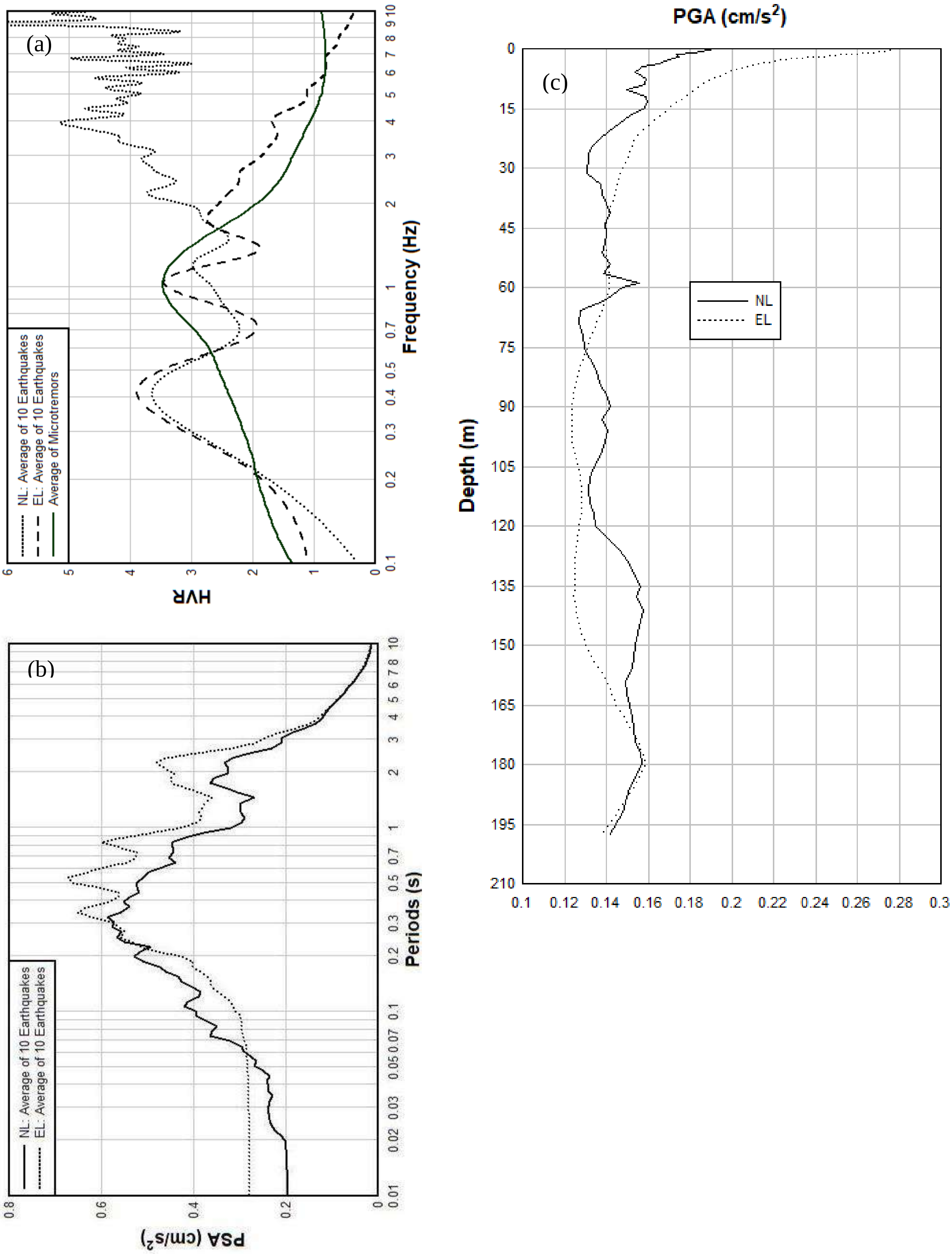


Figure 4.47 (a) Horizontal to Vertical Spectral Ratio (HVR), (b) Response Spectra and (c) Maximum peak ground acceleration (PGA) for the site-BH361

4.2.48 Site Response Analysis for BH369

The location is at Tetultala, Eatahata, Kolabagan, Gazipur. The co-ordinate of the location is lat: 23° 59' 58.1202"N and long: 90° 21' 35.7402"E and the performed borehole depth of SPT is 40.5 and the performed seismic downhole test depth is 40.0m.

Spectral Ratio Analysis

The comparison of spectral ratio analysis using SPT and shear wave velocity data by DEEPSOIL program and the Horizontal to Vertical Spectral Ratio (HVR) obtained from the microtremors using Geopsy program is shown in Figure 4.48a. Both equivalent linear and nonlinear methods have been applied in the case of DEEPSOIL analysis. For estimation of ground response site amplification factors at sub surface layers are often used as one of the parameters. The amplification factor is the maximum amplitude of the HVR curve.

Hence, the amplification factor obtained from the microtremors is 3.60 at 0.41 Hz, the amplification factor obtained from nonlinear method is 3.59 at 0.41 Hz and the amplification factor obtained from equivalent linear method is 3.91 at 0.43 Hz.

Response Spectra

Response spectra obtained from DEEPSOIL program in both equivalent linear and nonlinear method is presented in the following Figure 4.48b. The peak spectral acceleration (PSA) obtained using the nonlinear method is 0.55g and PSA obtained using equivalent linear method is 0.57g for the specific site.

Maximum Peak Ground Acceleration (PGA)

Maximum Peak Ground Acceleration (PGA) at different depths for this site is shown in Figure 4.48c at surface, which is obtained from equivalent linear and nonlinear analysis. The averages of PGA values at surface are observed 0.24g for equivalent linear analysis and 0.20g for nonlinear analysis.

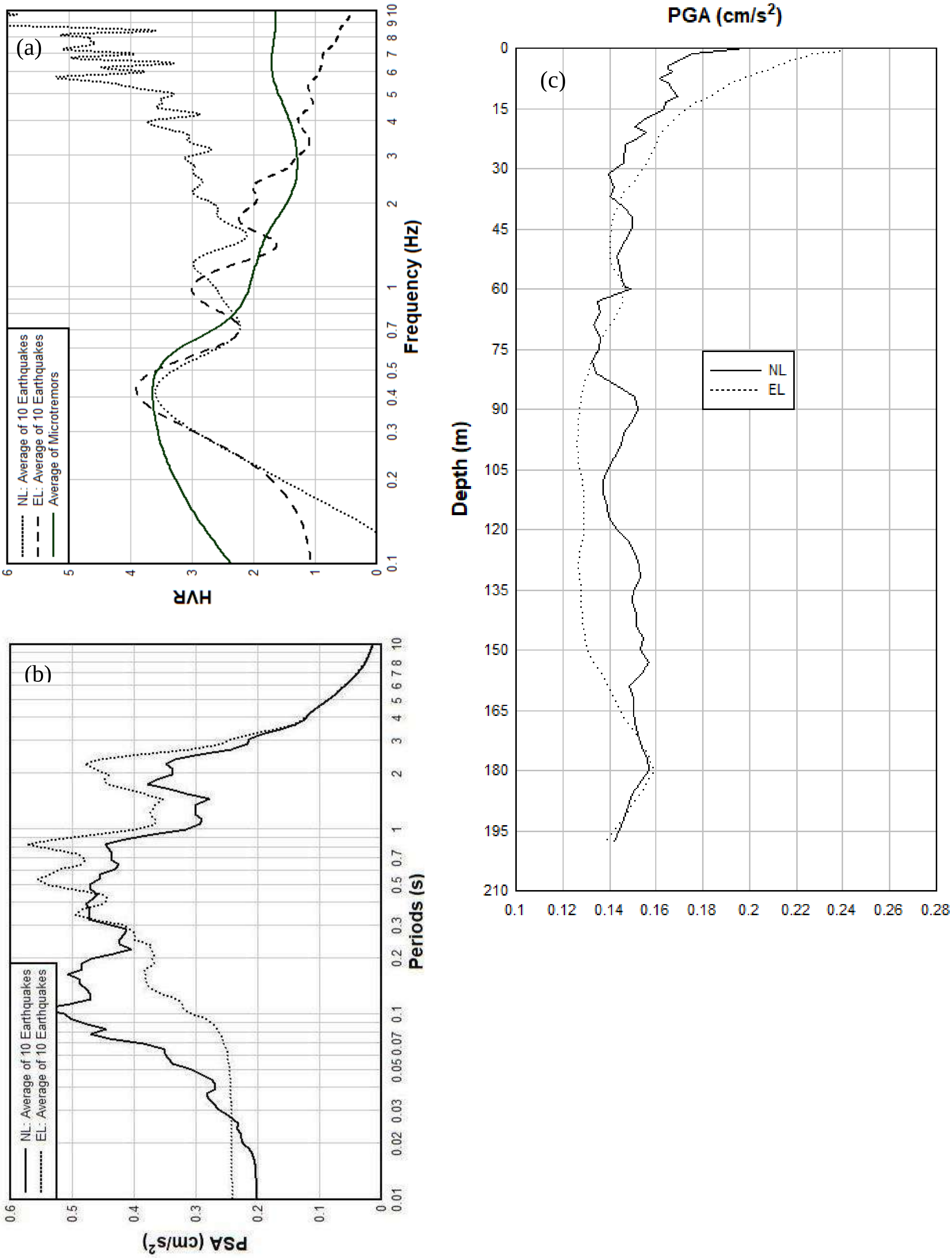


Figure 4.48 (a) Horizontal to Vertical Spectral Ratio (HVR), (b) Response Spectra and (c) Maximum peak ground acceleration (PGA) for the site-BH369

4.2.49 Site Response Analysis for BH376

The location is at Ambag Govt. Primary School, Konabari, Gazipur. The co-ordinate of the location is lat: 24° 1' 15.3222"N and long: 90° 19' 18.159"E and the performed borehole depth of SPT is 51.0 and the performed seismic downhole test depth is 51.0m.

Spectral Ratio Analysis

The comparison of spectral ratio analysis using SPT and shear wave velocity data by DEEPSOIL program and the Horizontal to Vertical Spectral Ratio (HVR) obtained from the microtremors using Geopsy program is shown in Figure 4.49a. Both equivalent linear and nonlinear methods have been applied in the case of DEEPSOIL analysis. For estimation of ground response site amplification factors at sub surface layers are often used as one of the parameters. The amplification factor is the maximum amplitude of the HVR curve.

Hence, the amplification factor obtained from the microtremors is 3.55 at 0.40 Hz, the amplification factor obtained from nonlinear method is 3.66 at 0.39 Hz and the amplification factor obtained from equivalent linear method is 4.36 at 0.40 Hz.

Response Spectra

Response spectra obtained from DEEPSOIL program in both equivalent linear and nonlinear method is presented in the following Figure 4.49b. The peak spectral acceleration (PSA) obtained using the nonlinear method is 0.56g and PSA obtained using equivalent linear method is 0.69g for the specific site.

Maximum Peak Ground Acceleration (PGA)

Maximum Peak Ground Acceleration (PGA) at different depths for this site is shown in Figure 4.49c at surface, which is obtained from equivalent linear and nonlinear analysis. The averages of PGA values at surface are observed 0.27g for equivalent linear analysis and 0.20g for nonlinear analysis.

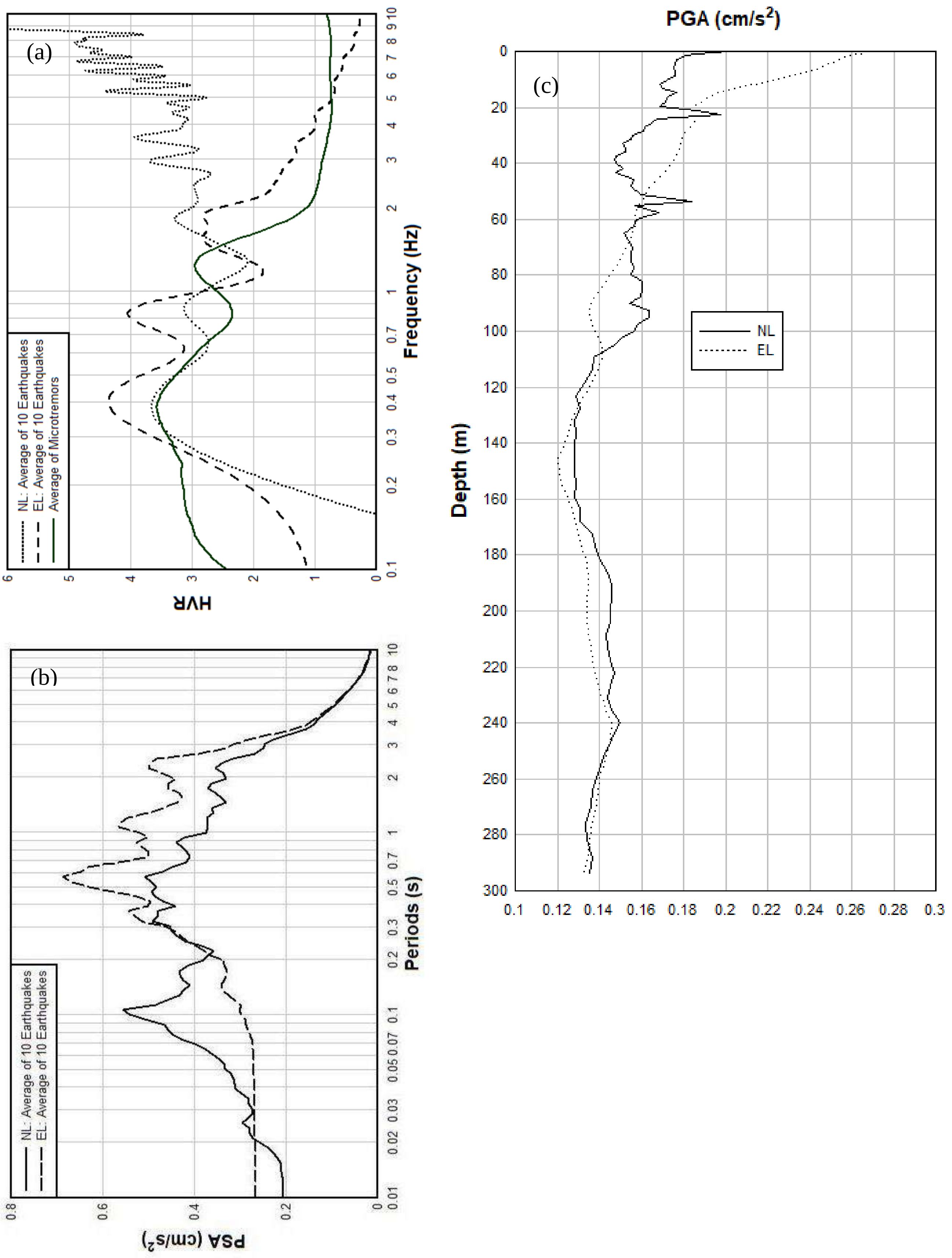


Figure 4.49 (a) Horizontal to Vertical Spectral Ratio (HVR), (b) Response Spectra and (c) Maximum peak ground acceleration (PGA) for the site-BH376

4.2.50 Site Response Analysis for BH380

The location is at Gazipur sadar upojilla Gazipur. The co-ordinate of the location is lat: 24° 1' 13.7994"N and long: 90° 25' 4.1988"E and the performed borehole depth of SPT is 43.5 and the performed seismic downhole test depth is 45.0m.

Spectral Ratio Analysis

The comparison of spectral ratio analysis using SPT and shear wave velocity data by DEEPSOIL program and the Horizontal to Vertical Spectral Ratio (HVR) obtained from the microtremors using Geopsy program is shown in Figure 4.50aa. Both equivalent linear and nonlinear methods have been applied in the case of DEEPSOIL analysis. For estimation of ground response site amplification factors at sub surface layers are often used as one of the parameters. The amplification factor is the maximum amplitude of the HVR curve.

Hence, the amplification factor obtained from the microtremors is 6.58 at 0.41 Hz, the amplification factor obtained from nonlinear method is 3.28 at 0.41 Hz and the amplification factor obtained from equivalent linear method is 3.84 at 0.43 Hz.

Response Spectra

Response spectra obtained from DEEPSOIL program in both equivalent linear and nonlinear method is presented in the following Figure 4.50bb. The peak spectral acceleration (PSA) obtained using the nonlinear method is 0.54g and PSA obtained using equivalent linear method is 0.62g for the specific site.

Maximum Peak Ground Acceleration (PGA)

Maximum Peak Ground Acceleration (PGA) at different depths for this site is shown in Figure 4.50cc at surface, which is obtained from equivalent linear and nonlinear analysis. The averages of PGA values at surface are observed 0.26g for equivalent linear analysis and 0.19g for nonlinear analysis.

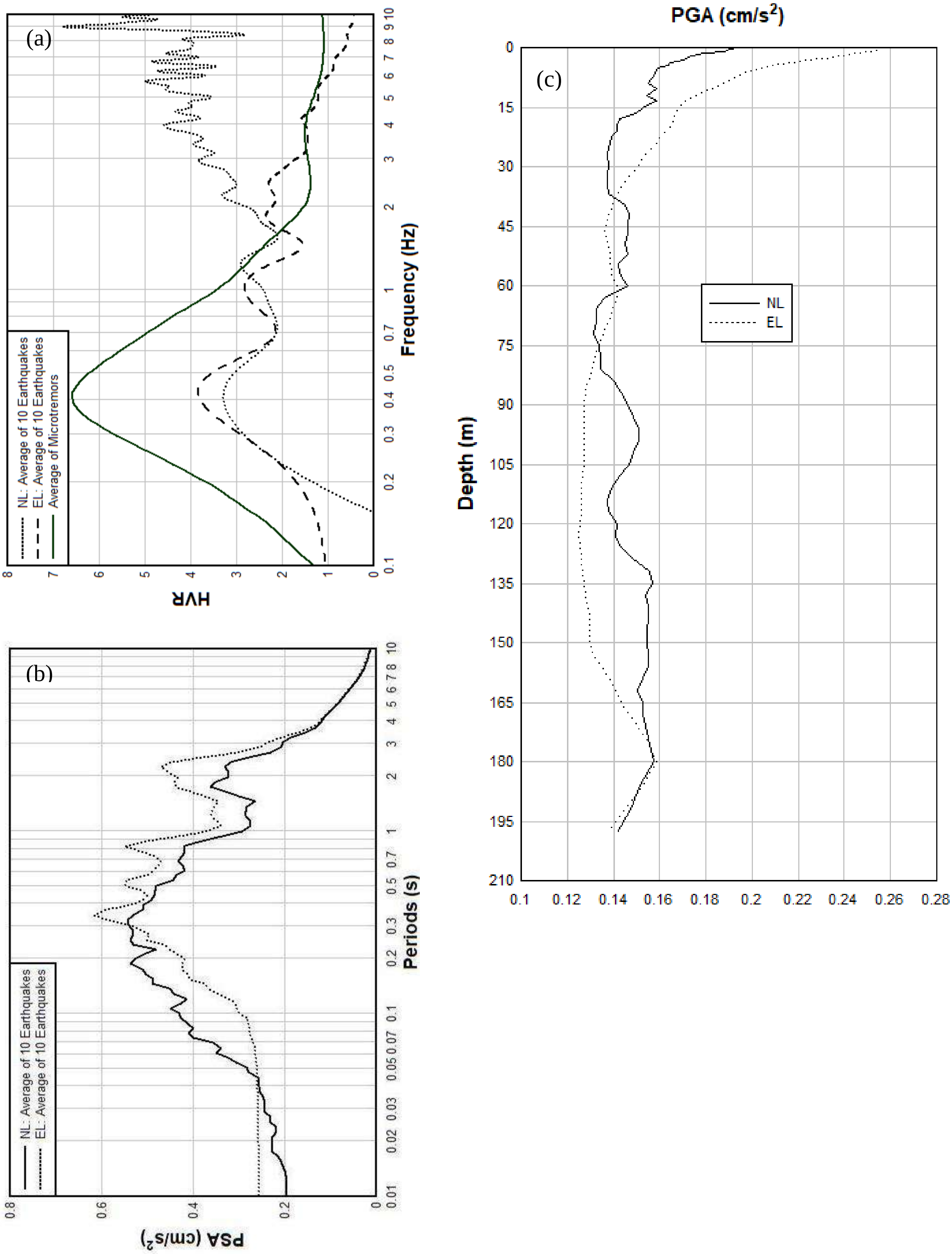


Figure 4.50 (a) Horizontal to Vertical Spectral Ratio (HVR), (b) Response Spectra and (c) Maximum peak ground acceleration (PGA) for the site-BH380

4.3 RESULTS SUMMARY

The result of the nonlinear and equivalent linear response analysis shows that the rock ground motion is de-amplified at short spectral periods and amplified at long spectral periods (Response spectra curves). With increasing ground motion acceleration, the de-amplification is increased. In this study area, the short-period seismic waves are de-amplified, and the long-period seismic waves are amplified due to the presence of very thick and soft sedimentary deposits (sand and clay) above the bedrock (Vs = 800 m/s).

4.3.1 Comparison of Amplification factor

The values of site amplification for DMDP area using both nonlinear and equivalent linear methods and also using microtremor data are given in table 4.2.

Table 4.2 Amplification factor obtained from DEEPSOIL and Microtremor analysis

SL No.	BH No.	Site Address	Amplification factor using nonlinear approach	Amplification factor using equivalent linear approach	Amplification factor using Microtremor Data
1	BH_006	Aligonj Madrasa ghat, Fatulla, Narayanganj	3.926	5.319	3.399
2	BH_010	Baghair High School, Keraniganj	4.857	6.103	3.209
3	BH_018	Amulla Model Town 1 No. Road, Amuli, Demra, Dhaka	3.724	4.364	4.177
4	BH_024	Sher-E Bangla Nagar Agricultural University, Dhaka	3.515	4.106	5.609
5	BH_027	Block-M, Road-4, Sector-4, Aftab Nagar, Dhaka	4.76	4.685	3.428
6	BH_029	Gulshan Central Mosque (Ajad Mosque), Gulshan, Dhaka	3.811	4.822	3.888
7	BH_042	Bauniya Bazar jame mosque Turag ,Dhaka	3.943	4.576	3.006
8	BH_045	Gakulnagar Eidgah math Ashulia Savar Dhaka	4.034	4.491	3.159
9	BH_049	Khilgaon Primary School, Pubail, Gazipur	4	4.314	4.15
10	BH_061	Nyebbari, Uttar Salna, Gazipur, Dhaka	3.467	3.993	2.964
11	BH_071	Govt Hazi Ibrahim School and College, Bandar, Narayanganj	4.225	4.556	5.981

SL No.	BH No.	Site Address	Amplification factor using nonlinear approach	Amplification factor using equivalent linear approach	Amplification factor using Microtremor Data
12	BH_074	Purbo Gopalnagar Govt. Primary School, Purbo Gopalnagar, Fatullah, Narayanganj	4.14	4.71	4.221
13	BH_085	T Hossain Garden, Bandar, Narayanganj	4	5.723	4.275
14	BH_088	55 No Mograpara Govt. Primary School Sonagaon, Sonargaon	4.658	5.223	4.082
15	BH_107	Sonamia Market S.O Road Balurmath, Sumilpara	4.782	5.745	3.189
16	BH_112	122 No Goalkhali Poshchim Govt. Primary School, Keraniganj, Dhaka	4.28	5.378	4.2104
17	BH_116	Doleshwar Government Primary School, Keraniganj	4.243	5.101	3.205
18	BH_139	Kharakandi Govt. Primary School, Keraniganj	4.095	4.447	3.611
19	BH_146	Samad Nagar, Jatrabari, Dhaka	4.075	4.362	3.131
20	BH_150	sonali paper mills Ltd tarabo narayanganj	4.168	4.782	4.016
21	BH_153	Sommalon Math, Noyapur Bazar, Sadipur, Sonargaon	4.142	4.356	4.244
22	BH_160	Modderchor Govt. Primary School, Keraniganj	4.161	4.915	2.900
23	BH_163	Kakrail Mosque (Tablig Jamat), Dhaka	4.371	5.516	2.034
24	BH_185	baitunnur lalmia mosque,golakandail Rupganj narayanganj	3.921	4.952	4.205
25	BH_189	11 No Mograkanda Govt. School, Savar, Dhaka	3.871	4.408	4.243
26	BH_195	Ichakhali, Kaiup para, Rupganj, Narayanganj	5.496	6.659	3.693
27	BH_199	Rupayan Sity, Hamiyetpur, Savar, Dhaka	4.733	5.511	4.169
28	BH_203	Golertek playground Darussalam, Mirpur, Dhaka	4.773	5.718	2.314
29	BH_209	Rowshan Ara girls high school, Beraid Badda	3.876	5.013	2.326

SL No.	BH No.	Site Address	Amplification factor using nonlinear approach	Amplification factor using equivalent linear approach	Amplification factor using Microtremor Data
30	BH_213	Moirabo, Bhulta, Rupganj, Narayanganj	4.271	4.408	3.307
31	BH_230	Awal Market, Sadupur, Kazipara, Bongayo, Savar, Dhaka	3.707	4.303	5.559
32	BH_236	Bagber, Rupganj, Narayanganj	3.824	4.452	2.816
33	BH_245	Barua (shilon para) khilkhet, Dhaka	4.017	4.628	2.103
34	BH_253	Kakabo Birulia Savar Dhaka	3.233	4.453	2.433
35	BH_263	Rajuk Land Area, Zinda Park, Gazipur	4.218	4.555	3.663
36	BH_275	Teromukh bridge uttarkhan dhaka	3.523	3.975	2.164
37	BH_286	Ashulia, Savar, Dhaka	5.155	8.497	1.286
38	BH_289	BTCL Tongi, Gazipur	3.706	3.962	3.213
39	BH_293	Bhasania Primary School, Gazipur	4.206	4.214	2.343
40	BH_298	Madhobi Sheltech Project, Plot No. 63, Katgora, Ashulia	5.293	6.173	5.133
41	BH_311	Victoria Hondachiam Interbita School, Kaliganj	4.994	5.685	4.201
42	BH_311	Kunia Moddho para Jame mosjid ,Gazipur	3.395	4	2.747
43	BH_320	Kudaba, Pubail, Gazipur	3.735	4.047	3.117
44	BH_329	Tajpur, Model High School, Ashulia, Savar	3.606	4.448	3.006
45	BH_341	Stand Housing, Dehra, Ashulia	3.082	4.489	3.869
46	BH_347	Maleker Bari Road, Sakrauri, Gacha, Joydebpur, Gazipur	3.569	3.776	3.049
47	BH_361	Baluchakuli, Gazipur	3.645	3.893	3.467
48	BH_369	Tetultala, Eatahata, Kolabagan, Gazipur	3.592	3.905	3.602
49	BH_376	Ambag Govt. Primary School, Konabari, Gazipur	3.656	4.364	3.553
50	BH_380	Gazipur sadar upojilla Gazipur	3.283	3.842	6.578

Amplification map of DMDP area was prepared using nonlinear and equivalent linear approaches. Amplification maps are show in the following Figure 4.51, Figure 4.52 and Figure 4.53. Also, it has been counted the site number lies in intervals of <2, 2-3, 3-4, 4-5, 5-6, 6-7 and >7, which depicted in the Figure 4.54.

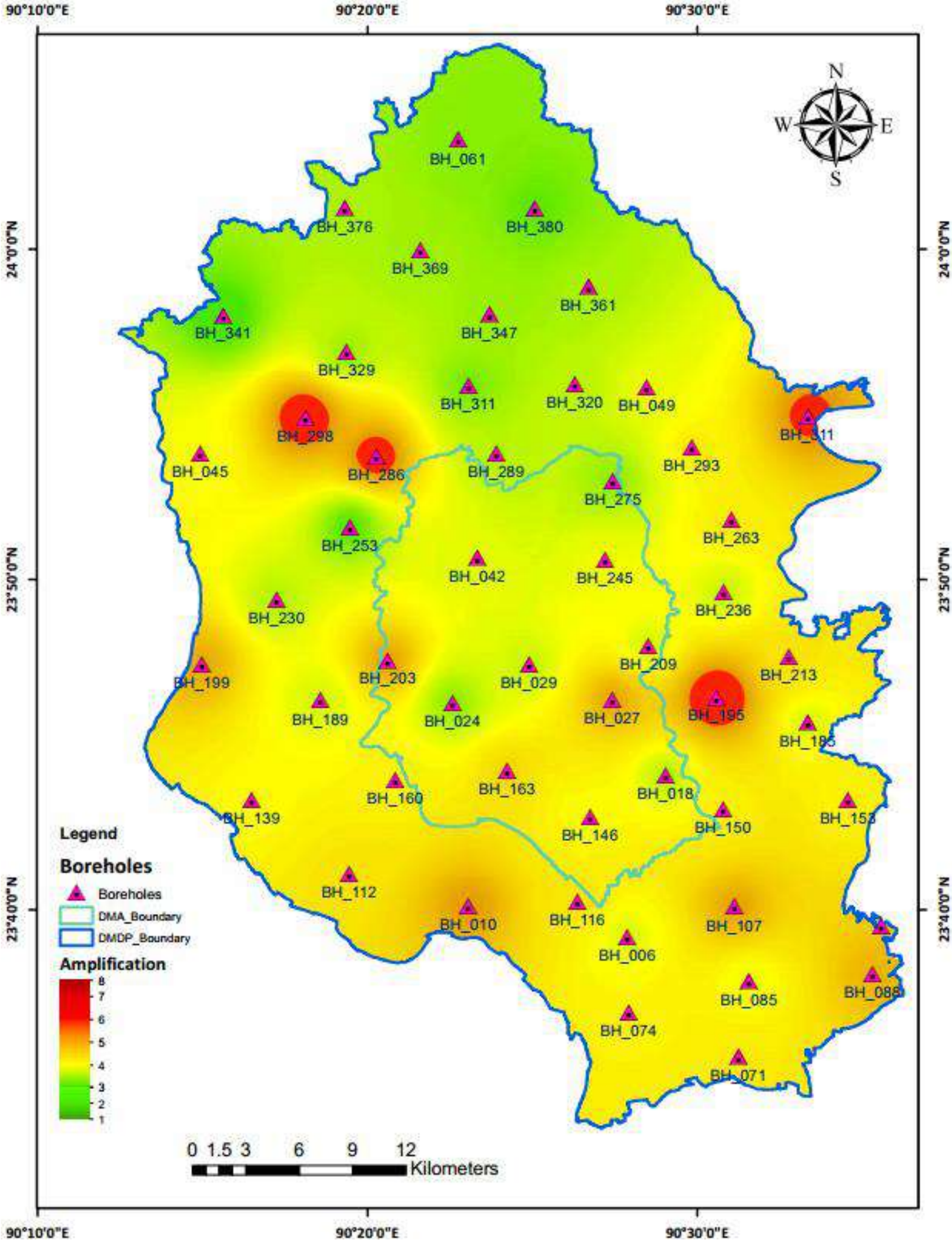


Figure 4.51 Amplification map of DMDP area using nonlinear approach

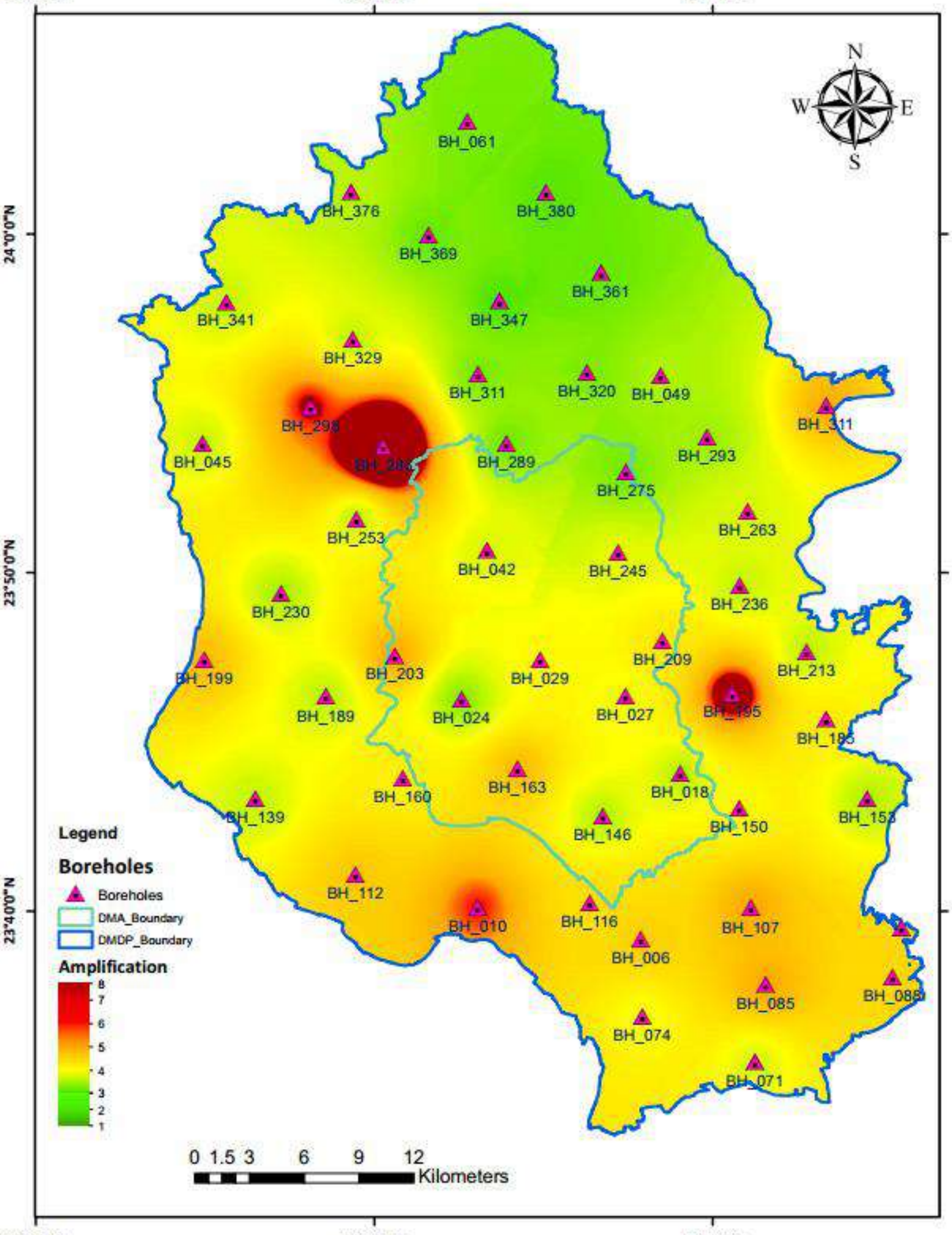


Figure 4.52 Amplification map of DMDP area using equivalent linear approach

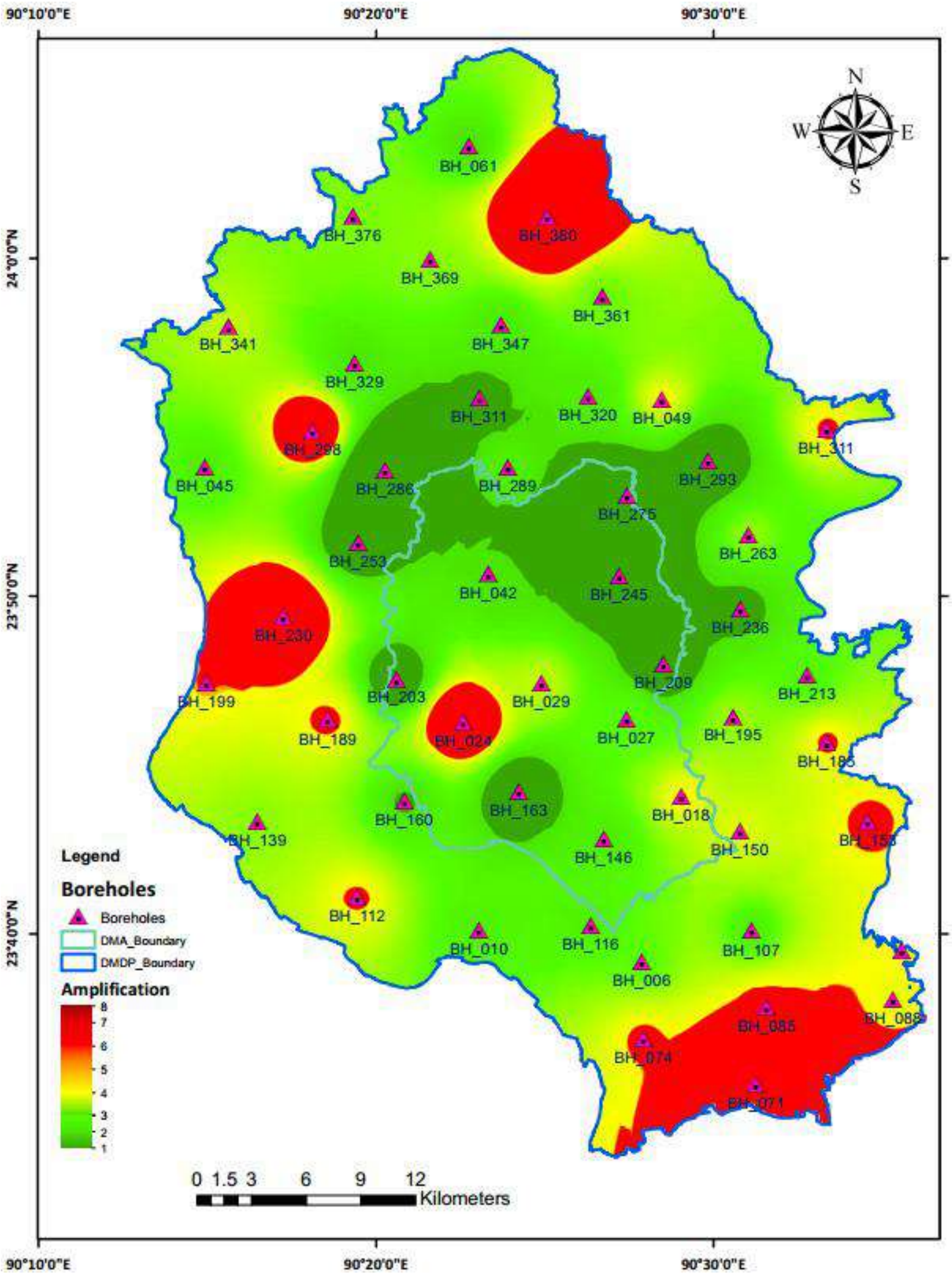


Figure 4.53 Amplification map of DMDP area using Microtremor data

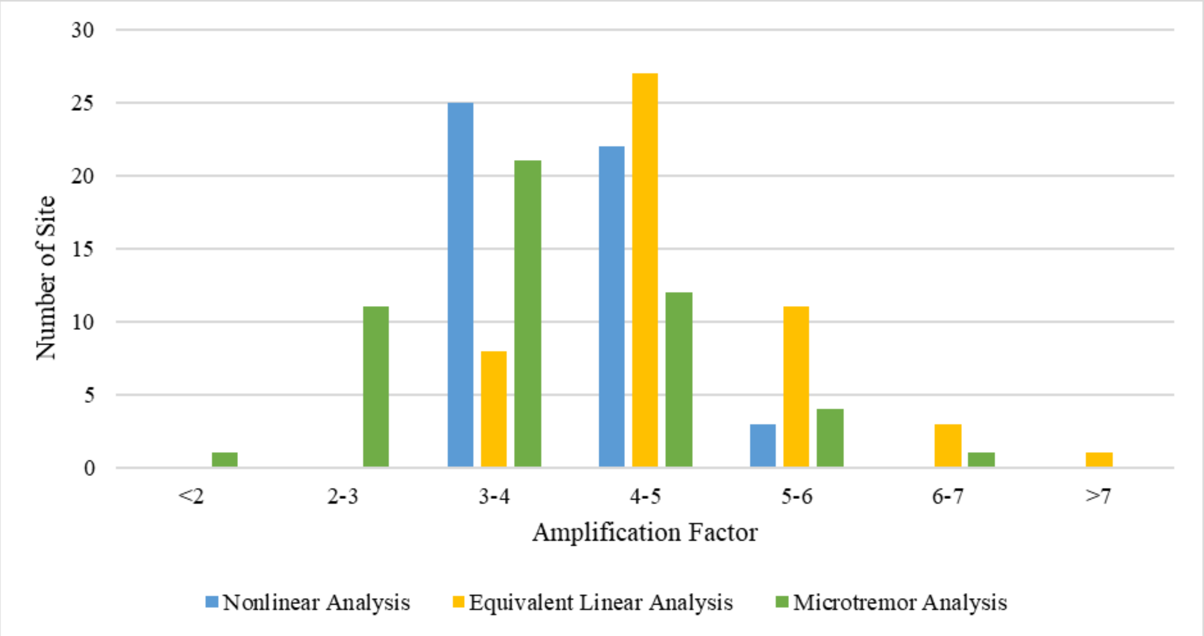


Figure 4.54 Number of sites of each amplification Factor interval from Different Analysis Approaches

4.3.2 Comparison of Predominant Frequency

The values of soil pre-dominant frequency for DMDP area using both nonlinear and equivalent linear methods and also using microtremor data are given in table 4.3.

Table 4.3 Soil predominant Frequency using different methods

SL No.	BH No.	Site Address	Pre-dominant Frequency using nonlinear approach	Pre-dominant Frequency using equivalent linear approach	Pre-dominant Frequency using Microtremor Data
1	BH_006	Aligonj Madrasa ghat, Fatulla, Narayanganj	0.442	0.431	0.530
2	BH_010	Baghair High School, Keraniganj	0.82	0.425	0.995
3	BH_018	Amulla Model Town 1 No. Road, Amuli, Demra, Dhaka	0.837	0.386	0.899
4	BH_024	Sher-E Bangla Nagar Agricultural University, Dhaka	0.374	0.369	0.445
5	BH_027	Block-M, Road-4, Sector-4, Aftab Nagar, Dhaka	0.425	0.922	0.819
6	BH_029	Gulshan Central Mosque (Ajad Mosque), Gulshan, Dhaka	0.437	0.866	2.682
7	BH_042	Bauniya Bazar jame mosque Turag ,Dhaka	0.414	0.815	0.712

SL No.	BH No.	Site Address	Pre-dominant Frequency using nonlinear approach	Pre-dominant Frequency using equivalent linear approach	Pre-dominant Frequency using Microtremor Data
8	BH_045	Gakulnagar Eidgah math Ashulia Savar Dhaka	0.397	0.391	0.401
9	BH_049	Khilgaon Primary School, Pubail, Gazipur	1.046	0.916	0.388
10	BH_061	Nyebbari, Uttar Salna, Gazipur, Dhaka	0.425	0.425	0.347
11	BH_071	Govt Hazi Ibrahim School and College, Bandar, Narayanganj	0.408	0.397	0.309
12	BH_074	Purbo Gopalnagar Govt. Primary School, Purbo Gopalnagar, Fatullah, Narayanganj	0.414	0.82	0.227
13	BH_085	T Hossain Garden, Bandar, Narayanganj	0.866	0.804	0.343
14	BH_088	55 No Mograpara Govt. Primary School Sonagaon, Sonargaon	0.798	0.769	0.821
15	BH_107	Sonamia Market S.O Road Balurmath, Sumilpara	0.815	0.775	0.715
16	BH_112	122 No Goalkhali Poshchim Govt. Primary School, Keraniganj, Dhaka	0.933	0.883	0.981
17	BH_116	Doleshwar Government Primary School, Keraniganj, Dhaka	0.837	0.805	0.752
18	BH_139	Kharakandi Govt. Primary School, Keraniganj	0.787	0.384	0.763
19	BH_146	Samad Nagar, Jatrabari, Dhaka	0.414	0.419	1.395
20	BH_150	sonali paper mills Ltd tarabo narayanganj	0.764	0.732	0.881
21	BH_153	Sommalon Math, Noyapur Bazar, Sadipur, Sonargaon	0.408	0.403	0.682
22	BH_160	Modderchor Govt. Primary School, Keraniganj	0.356	0.741	0.557
23	BH_163	Kakrail Mosque (Tablig Jamat), Dhaka	0.927	0.888	0.758
24	BH_185	baitunnur lalmia mosque,golakandail Rupganj narayanganj	0.769	0.741	0.876
25	BH_189	11 No Mograkanda Govt. School, Savar, Dhaka	0.775	0.38	0.706
26	BH_195	Ichakhali, Kaiup para, Rupganj, Narayanganj	0.86	.82.	0.856

SL No.	BH No.	Site Address	Pre-dominant Frequency using nonlinear approach	Pre-dominant Frequency using equivalent linear approach	Pre-dominant Frequency using Microtremor Data
27	BH_199	Rupayan Sity, Hamiyetpur, Savar, Dhaka	0.921	0.859	0.380
28	BH_203	Golertek playground Darussalam , Mirpur, Dhaka	0.871	0.826	0.898
29	BH_209	Rowshan Ara girls high school, Beraid Badda	0.905	0.888	0.825
30	BH_213	Moirabo, Bhulta, Rupganj, Narayanganj	1.21	0.476	0.728
31	BH_230	Awal Market, Sadupur, Kazipara, Bongayo, Savar, Dhaka	0.933	0.876	0.271
32	BH_236	Bagber, Rupganj, Narayanganj	0.408	0.927	0.505
33	BH_245	Barua (shilon para) khilkhet, Dhaka	1.05	0.927	0.759
34	BH_253	Kakabo Birulia Savar Dhaka	0.414	0.403	0.493
35	BH_263	Rajuk Land Area, Zinda Park, Gazipur	0.391	0.883	0.845
36	BH_275	Teromukh bridge uttarkhan dhaka	0.414	0.419	0.762
37	BH_286	Ashulia, Savar, Dhaka	0.437	0.408	1.457
38	BH_289	BTCL Tongi, Gazipur, Dhaka	0.419	0.425	0.526
39	BH_293	Bhasania Primary School, Gazipur	0.402	0.408	0.786
40	BH_298	Madhobi Sheltech Project, Plot No. 63, Katgora, Ashulia	0.702	0.517	0.747
41	BH_311	Victoria Hondachiam Interbita School, Kaliganj	1.119	0.95	1.081
42	BH_311	Kunia Moddho para Jame mosjid ,Gazipur	0.419	0.431	0.911
43	BH_320	Kudaba, Pubail, Gazipur	0.414	0.427	0.726
44	BH_329	Tajpur, Model High School, Ashulia, Savar	0.397	0.955	0.793
45	BH_341	Stand Housing, Dehra, Ashulia	0.403	0.403	0.849
46	BH_347	Maleker Bari Road, Sakrauri, Gacha, Joydebpur, Gazipur	0.403	0.419	0.599
47	BH_361	Baluchakuli, Gazipur	0.408	0.415	1.026
48	BH_369	Tetultala, Eatahata, Kolabagan, Gazipur	0.414	0.425	0.411
49	BH_376	Ambag Govt. Primary School, Konabari, Gazipur	0.385	0.403	0.401
50	BH_380	Gazipur sadar upojilla Gazipur	0.408	0.425	0.409

Soil pre-dominant frequency map of DMDP area was prepared using nonlinear and equivalent linear approaches as well as using microtremor analysis also. Frequency maps are show in the following Figure 4.55, Figure 4.56 and Figure 4.57. The site number lies in intervals of <0.2, 0.25-0.50, 0.50-0.75, 0.75-1.0, 1.0-1.5, 1.5-2.0 and >2.0 has been counted also which depicted in the Figure 4.58.

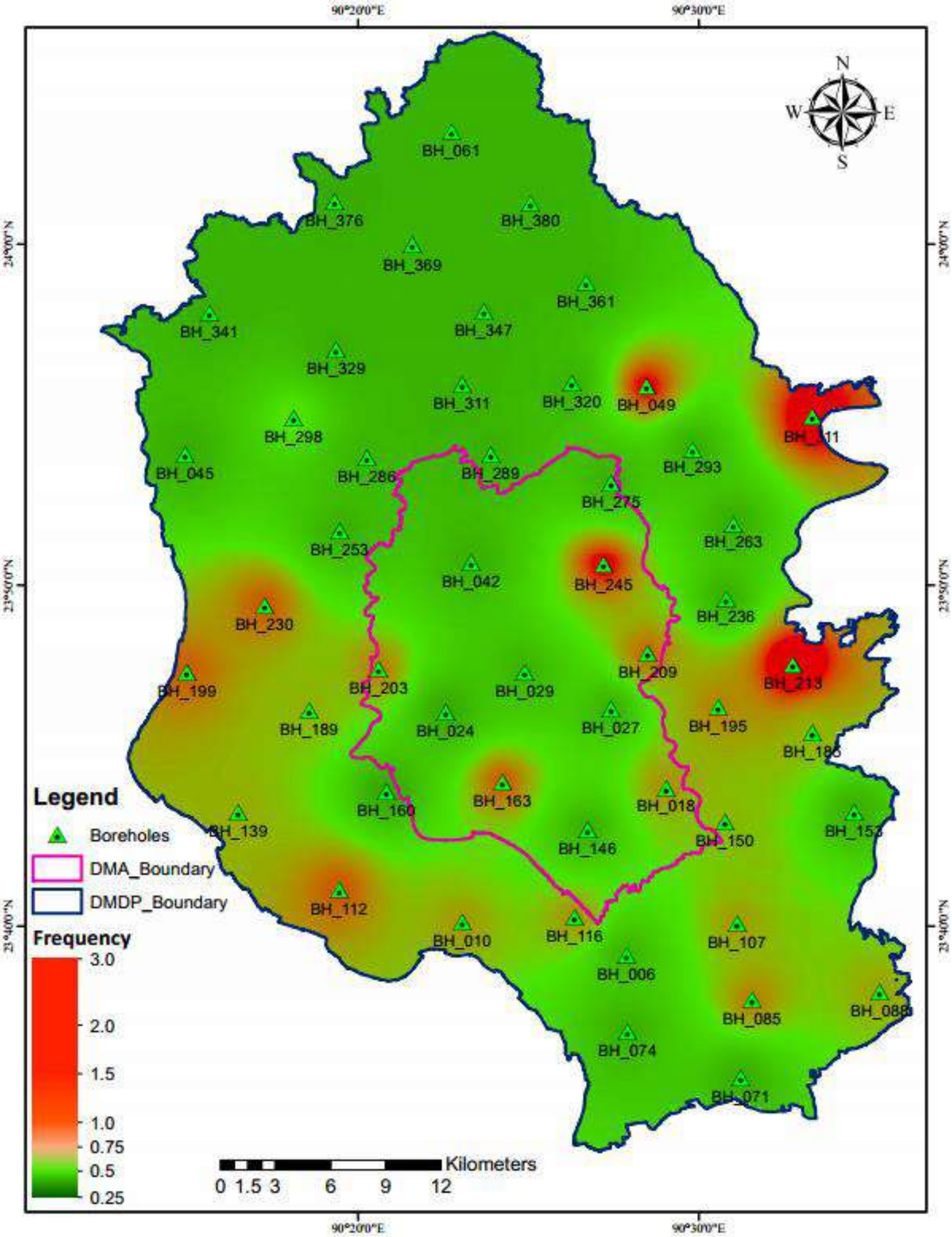


Figure 4.55 Soil Pre-dominant frequency map of DMDP area using nonlinear approach

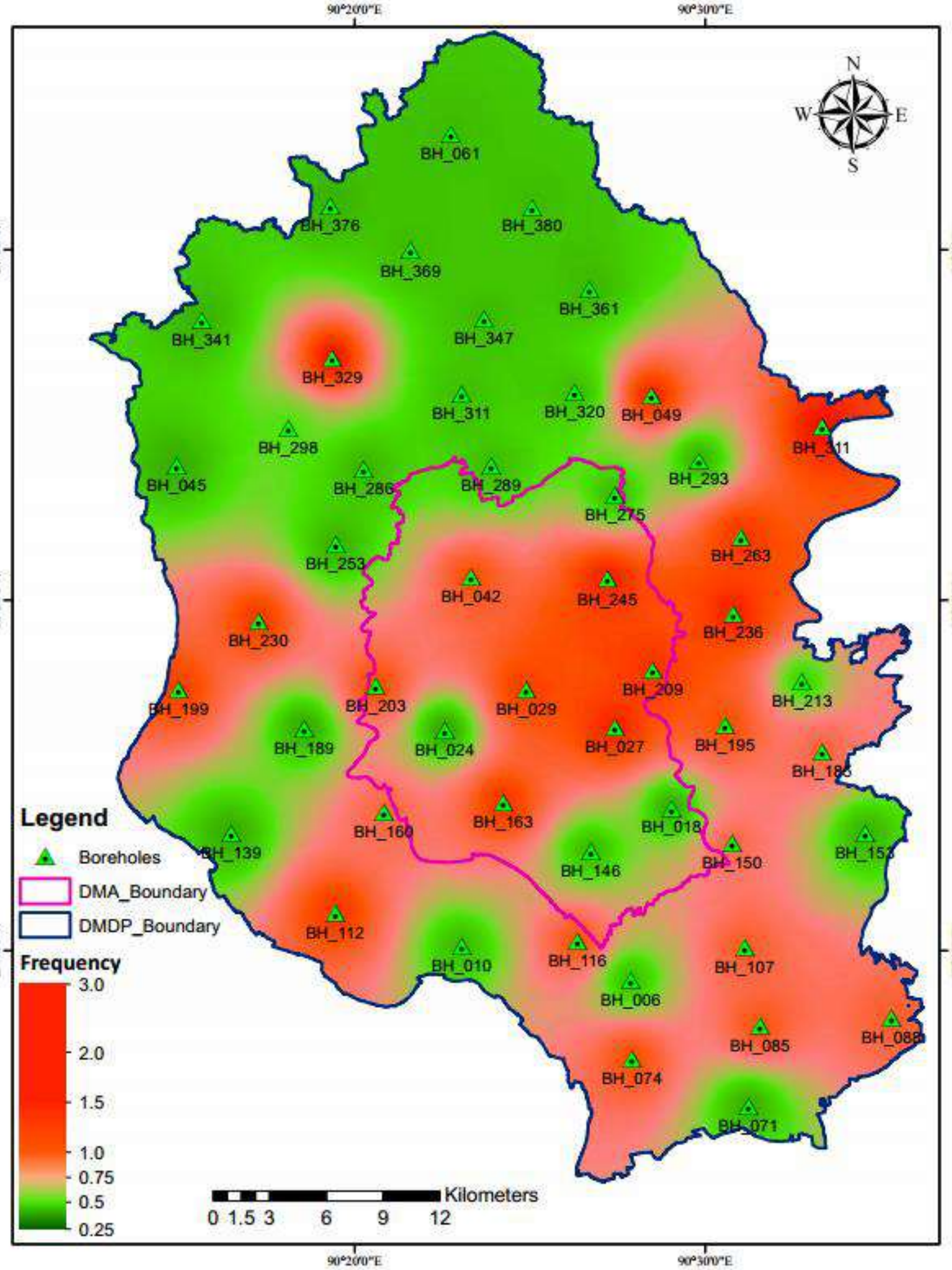


Figure 4.56 Soil Pre-dominant frequency map of DMDP area using equivalent linear approach

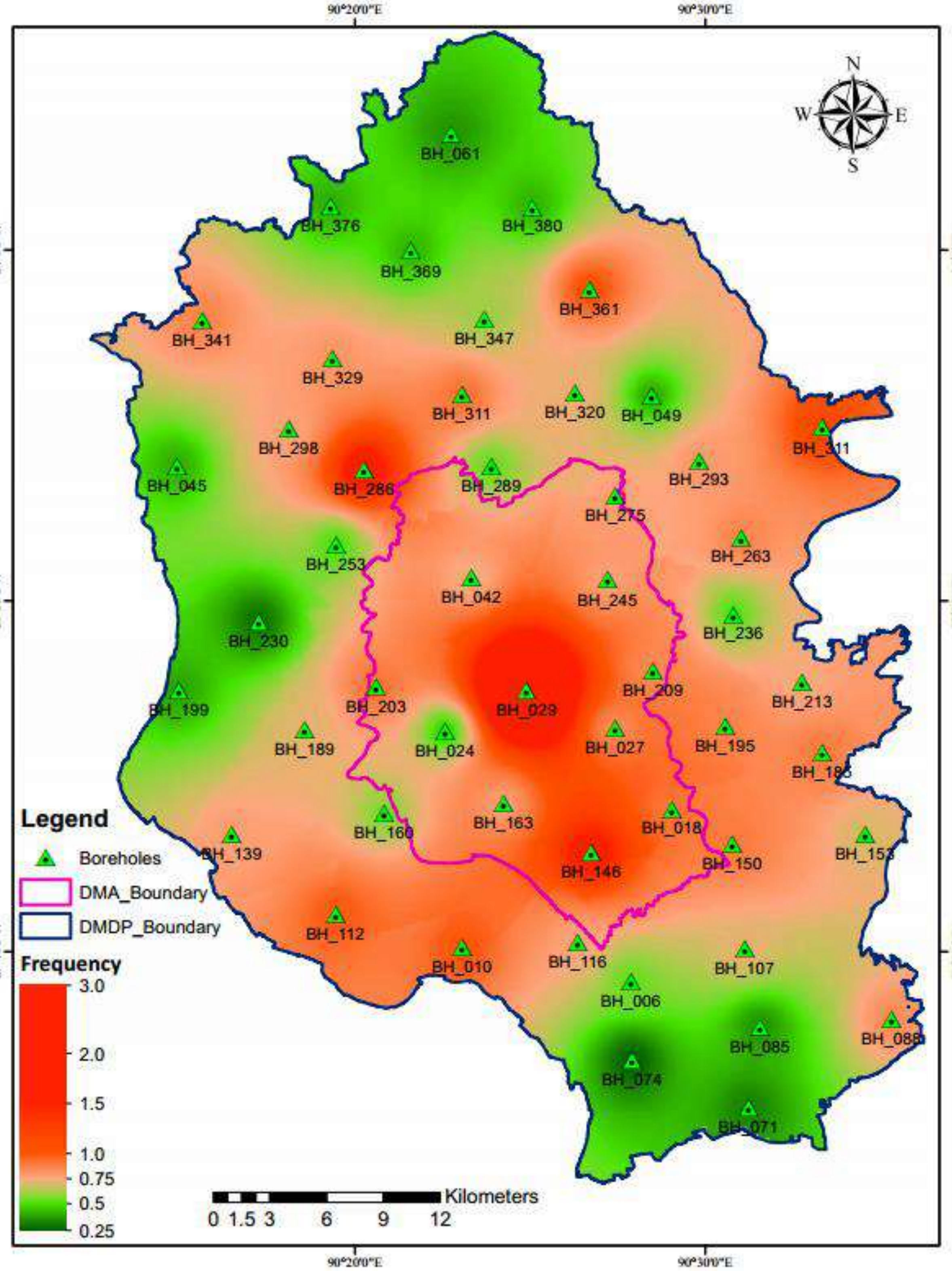


Figure 4.57 Soil Pre-dominant frequency map of DMDP area using microtremor measurement

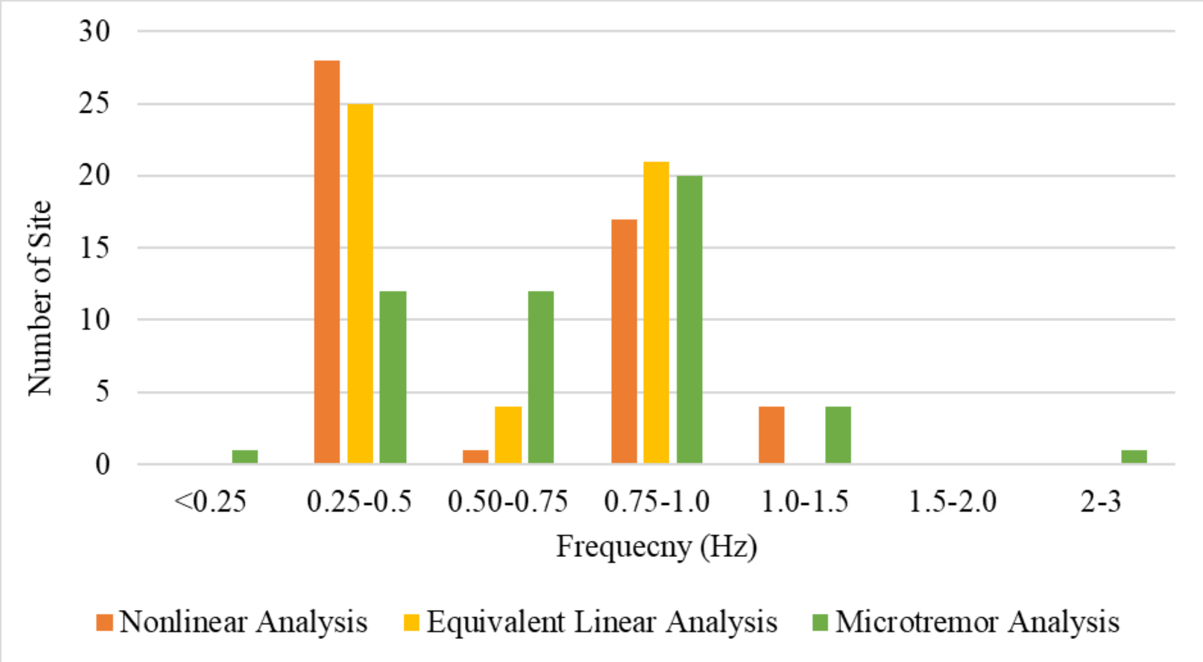


Figure 4.58 Number of sites of each frequency interval from Different Analysis Approaches

4.3.3 Comparison of Peak Ground Acceleration (PGA)

The values of soil pre-dominant frequency for DMDP area using both nonlinear and equivalent linear methods and also using microtremor data are given in table 4.4.

Table 4.4 Peak Ground Acceleration (PGA) using DEEPSOIL

SL No.	BH No.	Site Address	Peak Ground Acceleration (PGA) using equivalent linear approach	Peak Ground Acceleration (PGA) using nonlinear approach
1	BH_006	Aligonj Madrasa ghat, Fatulla, Narayanganj	0.238	0.178
2	BH_010	Baghair High School, Keraniganj	0.321	0.224
3	BH_018	Amulla Model Town 1 No. Road, Amuli, Demra, Dhaka	0.242	0.174
4	BH_024	Sher-E Bangla Nagar Agricultural University, Dhaka	0.221	0.168
5	BH_027	Block-M, Road-4, Sector-4, Aftab Nagar, Dhaka	0.341	0.257
6	BH_029	Gulshan Central Mosque (Ajad Mosque), Gulshan, Dhaka	0.294	0.191
7	BH_042	Bauniya Bazar jame mosque Turag ,Dhaka	0.29	0.213
8	BH_045	Gakulnagar Eidgah math Ashulia Savar	0.269	0.193

SL No.	BH No.	Site Address	Peak Ground Acceleration (PGA) using equivalent linear approach	Peak Ground Acceleration (PGA) using nonlinear approach
		Dhaka		
9	BH_049	Khilgaon Primary School, Pubail, Gazipur	0.29	0.196
10	BH_061	Nyebbari, Uttar Salna, Gazipur, Dhaka	0.271	0.201
11	BH_071	Govt Hazi Ibrahim School and College, Bandar, Narayanganj	0.292	0.203
12	BH_074	Purbo Gopalnagar Govt. Primary School, Purbo Gopalnagar, Fatullah, Narayanganj	0.31	0.207
13	BH_085	T Hossain Garden, Bandar, Narayanganj	0.386	0.221
14	BH_088	55 No Mograpara Govt. Primary School Sonagaon, Sonargaon	0.343	0.229
15	BH_107	Sonamia Market S.O Road Balurmath, Sumilpara	0.356	0.216
16	BH_112	122 No Goalkhali Poshchim Govt. Primary School, Keraniganj, Dhaka	0.328	0.231
17	BH_116	Doleshwar Government Primary School, Keraniganj, Dhaka	0.318	0.212
18	BH_139	Kharakandi Govt. Primary School, Keraniganj	0.243	0.191
19	BH_146	Samad Nagar, Jatrabari, Dhaka	0.286	0.214
20	BH_150	sonali paper mills Ltd tarabo narayanganj	0.289	0.209
21	BH_153	Sommalon Math, Noyapur Bazar, Sadipur, Sonargaon	0.242	0.204
22	BH_160	Modderchor Govt. Primary School, Keraniganj	0.323	0.215
23	BH_163	Kakrail Mosque (Tablig Jamat), Dhaka	0.337	0.229
24	BH_185	baitunnur lalmia mosque,golakandail Rupganj narayanganj	0.284	0.195
25	BH_189	11 No Mograkanda Govt. School, Savar, Dhaka	0.28	0.203
26	BH_195	Ichakhali, Kaiup para, Rupganj, Narayanganj	0.433	0.239
27	BH_199	Rupayan Sity, Hamiyetpur, Savar, Dhaka	0.33	0.227
28	BH_203	Golertek playground Darussalam , Mirpur, Dhaka	0.321	0.224
29	BH_209	Rowshan Ara girls high school, Beraid Badda	0.31	0.218

SL No.	BH No.	Site Address	Peak Ground Acceleration (PGA) using equivalent linear approach	Peak Ground Acceleration (PGA) using nonlinear approach
30	BH_213	Moirabo, Bhulta, Rupganj, Narayanganj	0.311	0.249
31	BH_230	Awal Market, Sadupur, Kazipara, Bongayo, Savar, Dhaka	0.254	0.201
32	BH_236	Bagber, Rupganj, Narayanganj	0.336	0.249
33	BH_245	Barua (shilon para) khilkhet, Dhaka	0.321	0.223
34	BH_253	Kakabo Birulia Savar Dhaka	0.303	0.213
35	BH_263	Rajuk Land Area, Zinda Park, Gazipur	0.284	0.211
36	BH_275	Teromukh bridge uttarkhan dhaka	0.223	0.178
37	BH_286	Ashulia, Savar, Dhaka	0.229	0.185
38	BH_289	BTCL Tongi, Gazipur, Dhaka	0.262	0.202
39	BH_293	Bhasania Primary School, Gazipur	0.299	0.225
40	BH_298	Madhobi Sheltech Project, Plot No. 63, Katgora, Ashulia	0.379	0.219
41	BH_311	Victoria Hondachiam Interbita School, Kaliganj	0.336	0.229
42	BH_311	Kunia Moddho para Jame mosjid ,Gazipur	0.258	0.201
43	BH_320	Kudaba, Pubail, Gazipur	0.223	0.177
44	BH_329	Tajpur, Model High School, Ashulia, Savar	0.216	0.187
45	BH_341	Stand Housing, Dehra, Ashulia	0.27	0.18
46	BH_347	Maleker Bari Road, Sakrauri, Gacha, Joydebpur, Gazipur	0.221	0.227
47	BH_361	Baluchakuli, Gazipur	0.279	0.192
48	BH_369	Tetultala, Eatahata, Kolabagan, Gazipur	0.241	0.199
49	BH_376	Ambag Govt. Primary School, Konabari, Gazipur	0.267	0.202
50	BH_380	Gazipur sadar upojilla Gazipur	0.256	0.194

Peak Ground Acceleration (PGA) map of DMDP area was prepared using nonlinear and equivalent linear approaches as well as using microtremor analysis also. Frequency maps are show in the following Figure 4.59 and Figure 4.60. Also, it has been counted the site number lies in intervals of 00.15-0.20, 0.2-0.25, 0.25-0.3, 0.3-0.35, 0.35-0.4, and >0.4, which presented in the Figure 4.61.

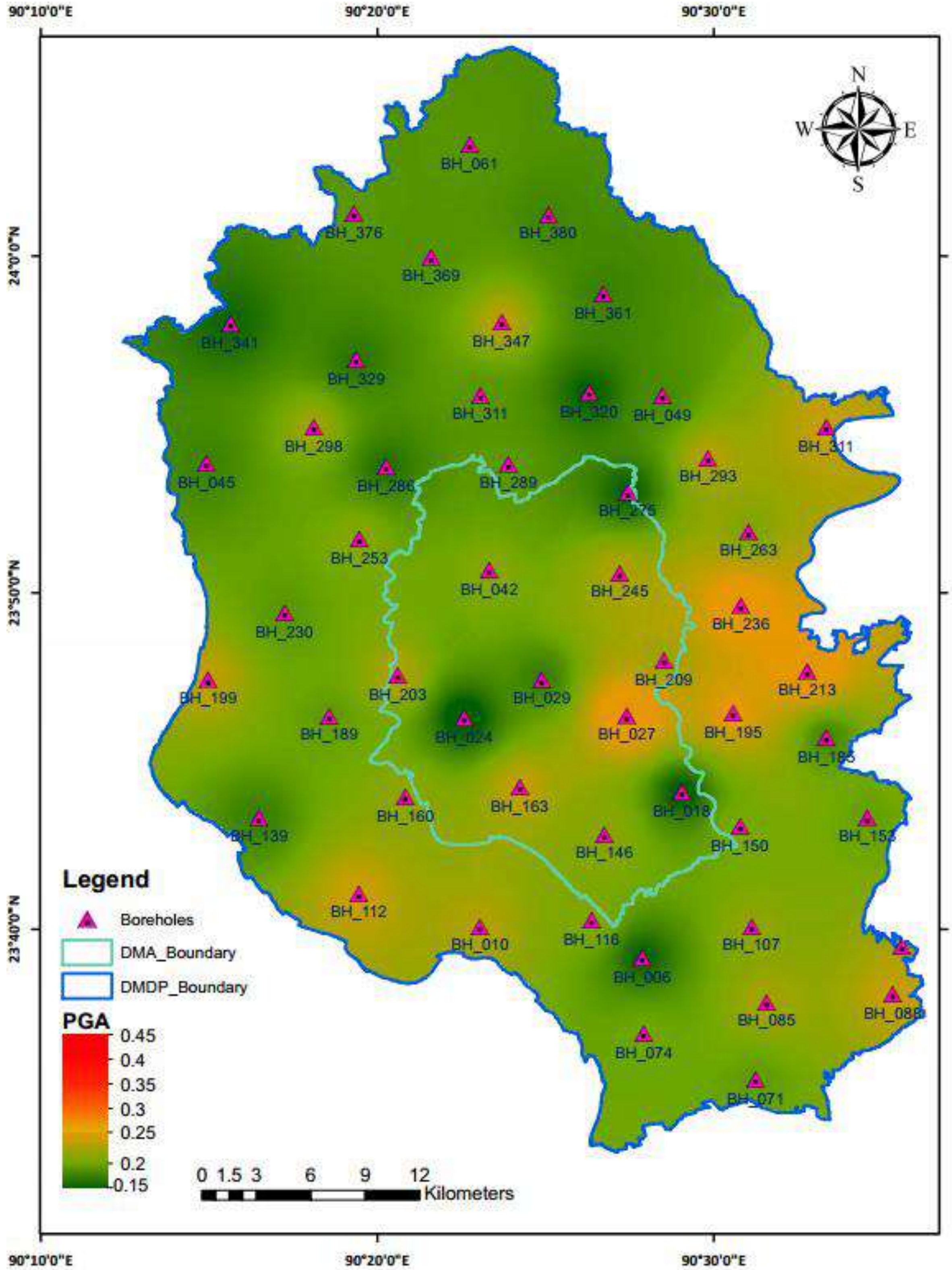


Figure 4.59 Peak Ground Acceleration (PGA) map of DMDP area using nonlinear approach

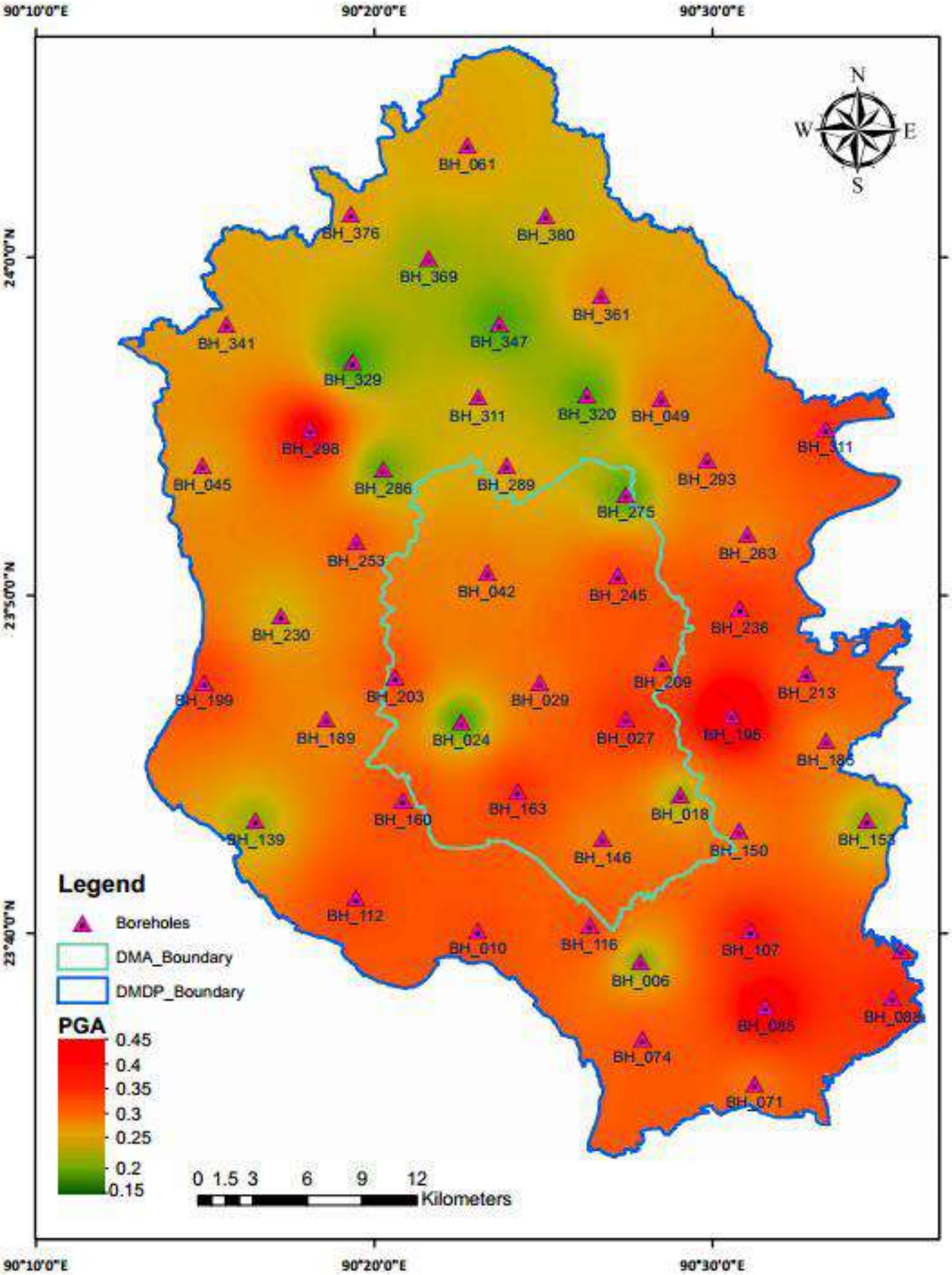


Figure 4.60 Soil Pre-dominant frequency map of DMDP area using equivalent linear approach

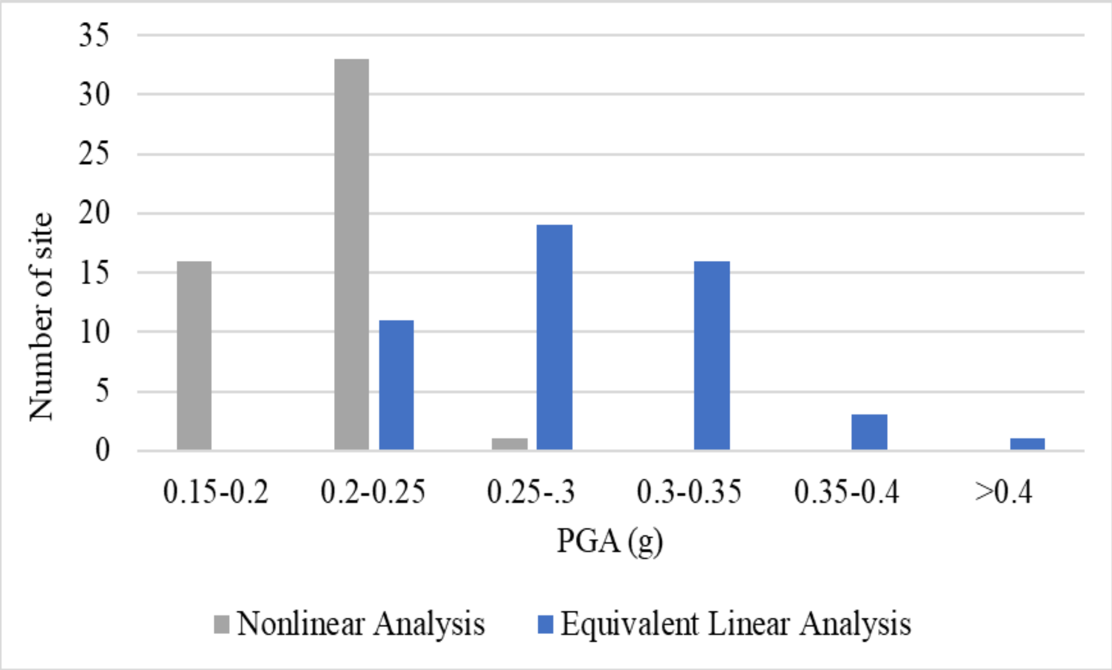


Figure 4.61 Number of sites of each PGA interval from Different Analysis Approaches

4.3.4 Target Response Spectrum

According to the BNBC-2020 the normalized design acceleration response spectrum for different site classes is shown in Figure 2.7 (Chapter 2). The design spectral acceleration was calculated by multiplying the normalized design acceleration response spectrum by design basis PGA_{rock} (0.13g for study area) as recommended by BNBC (2020). After that, the spectral acceleration (SA) for the SC and SD site classes have been plotted in the SA vs. period curve.

Figure 4.62 and Figure 4.63 shows the Comparison of the variation of spectral acceleration with BNBC for the site classes SC and SD respectively. The black dotted line illustrates the average nonlinear spectral acceleration for five boreholes, the black dashed dotted illustrates the average equivalent linear spectral acceleration for five boreholes and the black solid line depicts the spectral acceleration as per BNBC (2020) site class. Both the Figures show that the SA for the site class SC and SD is much lower than the SA obtained from the 1D analysis.

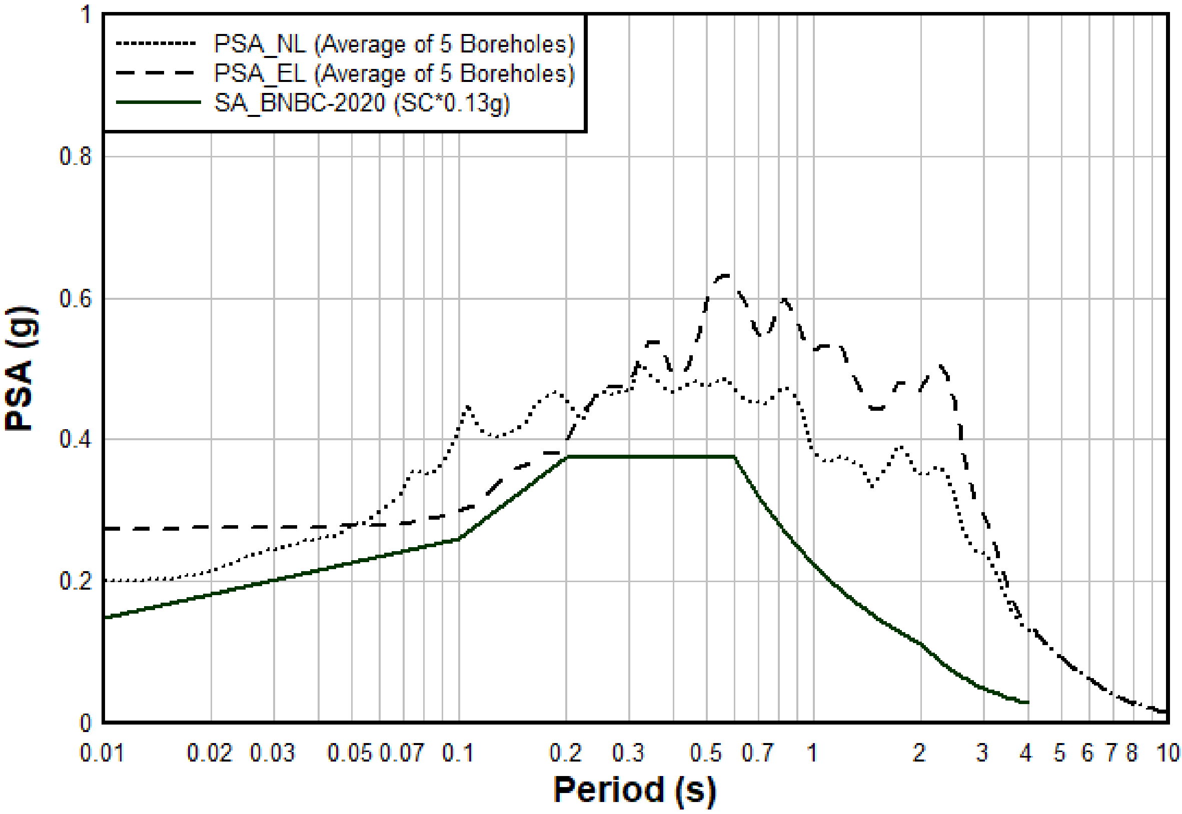


Figure 4.62 Comparison of the variation of spectral acceleration with BNBC (SC site class)

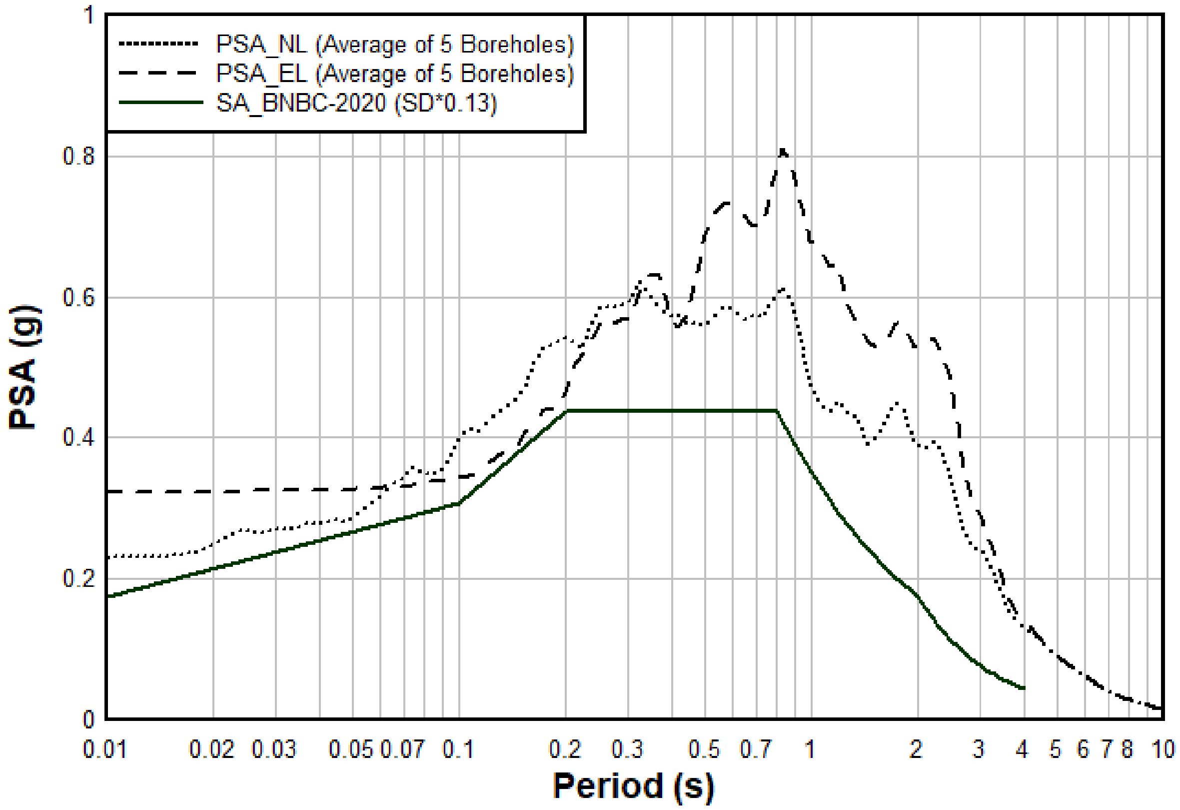


Figure 4.63 Comparison of the variation of spectral acceleration with BNBC (SD site class)

4.3.5 Proposed Design Acceleration Response Spectrum for DMDP area

Based on the SPT N̄ values, and the site class has been determined in accordance with BNBC (2020). All the sites are classified either SC site class or SD site class based on SPT N̄ values for DMDP area (following Table 3.4). The site class of 21 of the 50 boreholes is determined to be SC, whereas the site class of 29 of the boreholes is determined to be SD, as shown in Table 3.5.

From the 1D analysis it showed that the spectral acceleration is significantly greater than the BNBC site class SC and SD. Design acceleration response spectrum has been presented for site class SC and site class SD, which have been shown in Figure 4.64 and Figure 4.65. The black dotted line illustrates the average nonlinear spectral acceleration for five boreholes, the black dashed dotted illustrates the average equivalent linear spectral acceleration for five boreholes, the black solid line depicts the BNBC site classes, and the solid magenta line illustrates the recommended SA for the Study area.

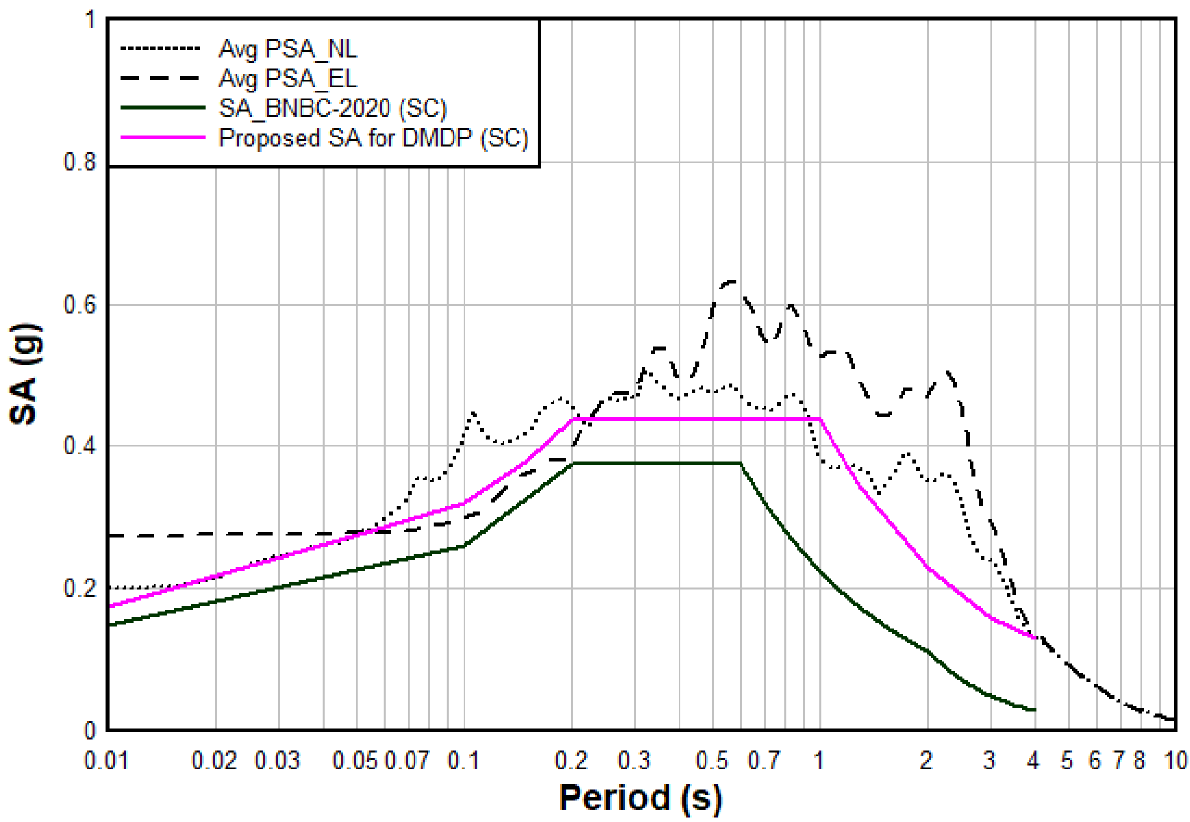


Figure 4.64 Proposed design Spectral Acceleration Response Spectrum for DMDP area of site class SC

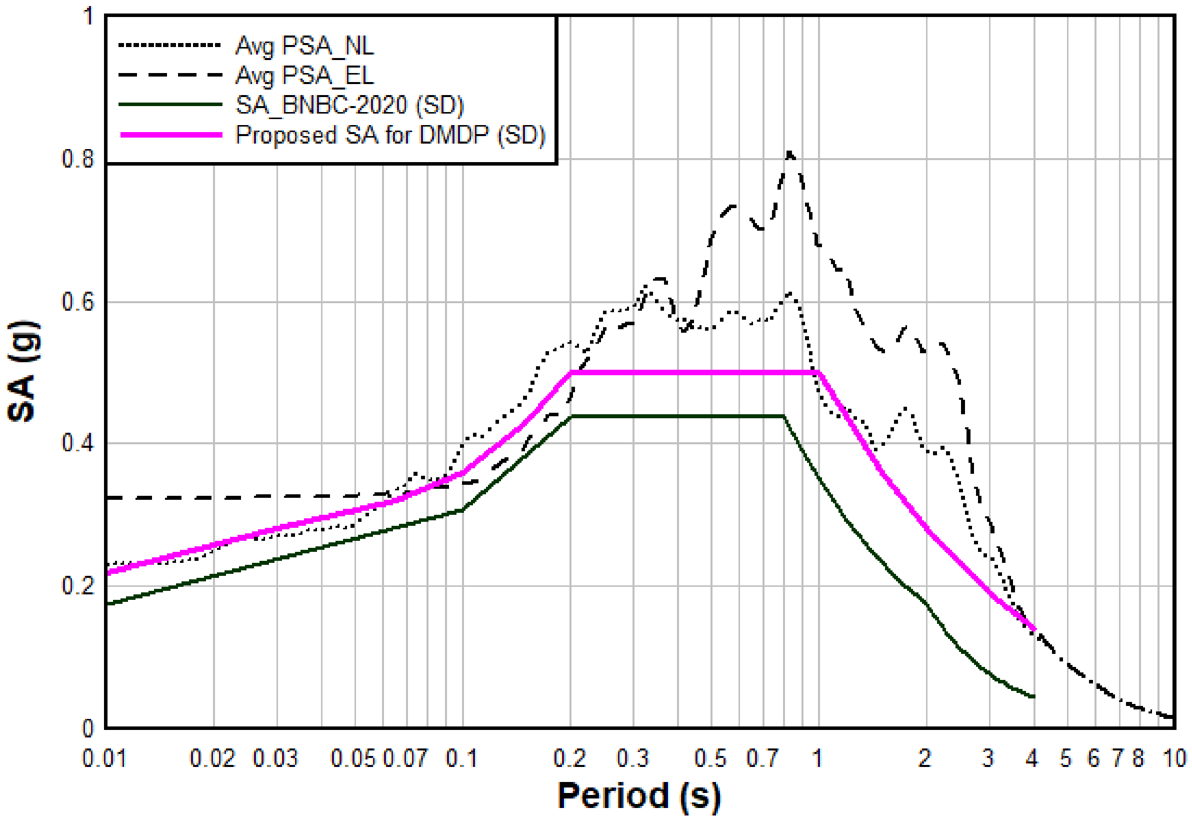


Figure 4.65 Proposed design Spectral Acceleration Response Spectrum for DMDP area of site class SD

Since last 20 years the Dhaka city has been expanded to the surrounding Holocene floodplains and many high-rise buildings have been constructed on both the Pleistocene Terrace and Holocene floodplains after uplifting the ground using sand filling from the river. As the sources of large crustal and subduction earthquakes are not present within a radius of 50 km and 100 km (Rahman, M. Z. et al, 2021) respectively, from the Dhaka city, mostly during propagation through the thick and soft sedimentary deposits, the long-period seismic waves will amplify. The spectral periods of these waves will match with the natural periods of the high-rise buildings to cause resonance. Therefore, the damage to the high-rise buildings that are located on the Holocene floodplains will be increased. The short-period seismic waves will amplify at the sites, where the Pleistocene deposits are overlain by a thin layer of artificially filled sand and clay or the Holocene sand and clay. The spectral periods of these waves will match with the natural periods of the low-rise buildings to cause resonance. Therefore, the damage to the low-rise buildings that are located on the Pleistocene Terrace will be increased.

CHAPTER 5
CONCLUSIONS AND RECOMMENDATIONS

5.1 GENERAL

The cities of developing countries situated in seismically active regions, such as Dhaka in Bangladesh, are more vulnerable than those of the developed countries due to high population density, unplanned urbanization, non-engineered construction practices, ignorance of building codes, inadequate knowledge of the seismic design of structures, and poor monitoring system of the concerned urban authorities during the construction of structures. To mitigate the seismic risk, seismic hazard analysis is needed to design structures, prepare regional seismic hazard maps to use in building codes, and develop emergency response system. Site response analysis is one of the main techniques in the field of seismic hazard analysis.

The main purpose of this research was to conduct 1D site response analysis on DMDP soil deposit to investigate the behavior of soil layer under ten ground motions using nonlinear and equivalent linear approaches in DEEPSOIL program. The results are presented in terms of the peak ground acceleration, amplification factor, Fourier amplitude ratio and peak spectral acceleration obtained from both nonlinear and equivalent linear analysis technique. Comparison of the results obtained from both 1D model and microtremor analysis technique has also been presented.

5.2 CONCLUSIONS

Based on the results obtained the major findings and conclusions are summarized below:

i. The obtained amplification values are varying between 3.1 to 5.5 for nonlinear analysis, 3.8 to 8.5 for equivalent linear analysis and 1.3 to 6.6 for microtremor analysis.

ii. The estimated values of soil pre-dominant frequencies are lying in between 0.4Hz to 0.5Hz for whole DMDP area whereas soil pre-dominant frequencies for equivalent linear analysis are little higher ranges and for microtremor analysis the maximum values are beyond 0.7Hz.

iii. The peak spectral acceleration (PSA) for 50 sites varies between 0.41g to 0.80g in the case of nonlinear analysis whereas the range of PSA is 0.50g to 1.12g for equivalent linear analysis.

iv. The PGA values for earth surface obtained from nonlinear analysis varies between 0.17g to 0.26g while PGA values obtained from equivalent linear analysis mostly varies between 0.22g to 0.43g.
v. As the Pleistocene deposits (Madhupur Clay) present in and around central Dhaka towards Savar and Gazipur and Holocene floodplains present at Narayangonj and Keraniganj area, in terms of amplification the result obtained from both DEEPSOIL analysis and microtremor analysis have given a rational scenario of the study area but in terms of pre-dominant frequency the result obtained from microtremor analysis shows more realistic value than the result obtained from the DEEPSOIL analysis.
vi. In areas of thick and soft Holocene deposit the amplification is more, and the resonance may occur with the high-rise building's natural frequency and may lead damage to high rise buildings.
vii. In areas where shallow valleys of Pleistocene deposits with artificially filled sand any clay in top layer the amplification is less, and resonance may occur with the low-rise buildings and therefore the damage to low-rise buildings will be more in these areas.

5.3 RECOMMENDATIONS FOR FURTHER STUDY

The following recommendations are suggested for future research

i. It is recommended to validate the results of the nonlinear site response for the deep and soft sedimentary deposits with the site response of the similar deposits during an earthquake in the similar seismotectonic setting.
ii. Shear wave velocity should be measured up to the depth of the bedrock using direct methods, such as downhole seismic investigation to estimate the site effects of the deep and soft sedimentary deposits using one-dimensional nonlinear site response analysis.
iii. As there were some limitations to select the study points the results may not the average scenario of the study area.
iv. As there was no other study available for whole DMDP area on the site response analysis for the deep and soft sedimentary deposits, this study will provide an understanding on the effects of the deep and soft sedimentary deposits of the study area during strong ground motion (earthquake). Therefore, the results of this study should not be used to prepare design response spectra.
v. It also recommended to perform site specific response analysis using more accurate database to prepare design response spectra and to perform nonlinear dynamic analysis of structures.

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Appendix A

Soil Class, Unit weight and SPT N Values at different Locations

Table A-1: Site- Aligonj Madrasa ghat, Fatulla, Narayanganj

BH-006				
Depth to Sampler Tip (m)	Layer Thickness (m)	Soil Classification	Unit Weight (kN/m^3)	SPT N-value (N_{60})
1.5	1.5	Poorly Graded SAND with Silt (NP)	14.5	3
3	1.5	SILT (NP)	16.4	4
4.5	1.5	SILT	16.4	5
6	1.5	SILT (NP)	15.8	7
7.5	1.5	SILT	15.8	8
9	1.5	Fat CLAY	15.8	19
10.5	1.5	Fat CLAY	15.8	21
12	1.5	Fat CLAY	15.8	24
13.5	1.5	Fat CLAY	16.5	23
15	1.5	Fat CLAY	16.5	25
16.5	1.5	Silty SAND (NP)	16.5	30
18	1.5	Sandy SILT (NP)	17.2	36
19.5	1.5	Silty SAND (NP)	17.1	39
21	1.5	Lean CLAY	17.1	13
22.5	1.5	Lean CLAY	17.1	14
24	1.5	Lean CLAY	17.1	48
25.5	1.5	SILT (NP)	19.2	50
27	1.5	SILT (NP)	19.2	56
28.5	1.5	SILT (NP)	19.7	82
30	1.5	SILT with Sand (NP)	18.9	67
31.5	1.5	Silty SAND (NP)	18.4	84
33	1.5	Silty SAND (NP)	18.7	80
34.5	1.5	Sandy SILT (NP)	18.5	60
36	1.5	Silty SAND (NP)	18.7	65
37.5	1.5	SILT with Sand (NP)	20	75
39	1.5	SILT with Sand (NP)	20.4	84
40.5	1.5	SILT with Sand (NP)	20.8	110
42	1.5	SILT (NP)	21.6	171

Table A-2: Site- Baghair High School, Keraniganj

BH-010				
Depth to Sampler Tip (m)	Layer Thickness (m)	Soil Classification	Unit Weight (kN/m^3)	SPT N-value (N_{60})
1.5	1.5	Lean CLAY	15.4	4
3	1.5	Lean CLAY	15.4	5
4.5	1.5	Lean CLAY	15.4	7
6	1.5	SILT (NP)	15.8	6
7.5	1.5	SILT (NP)	17	13
9	1.5	SILT (NP)	16.3	8
10.5	1.5	Sandy SILT (NP)	16.5	13
12	1.5	Sandy SILT (NP)	18	26
13.5	1.5	Silty SAND (NP)	16.5	19
15	1.5	Silty SAND (NP)	19.1	46
16.5	1.5	Silty SAND (NP)	18	34
18	1.5	Silty SAND (NP)	16.2	18
19.5	1.5	Silty SAND (NP)	19.3	54
21	1.5	Silty SAND (NP)	16.8	24
22.5	1.5	Sandy SILT (NP)	21.7	78
24	1.5	Sandy SILT (NP)	21.6	72
25.5	1.5	Sandy SILT (NP)	21.8	83
27	1.5	Silty SAND (NP)	19.1	82
28.5	1.5	Silty SAND (NP)	17.8	43
30	1.5	Silty SAND (NP)	18.3	48
31.5	1.5	Silty SAND (NP)	27.6	85
33	1.5	Silty SAND (NP)	29.1	83
34.5	1.5	Silty SAND (NP)	29.2	89

Table A-3: Site- Amulla Model Town 1 No. Road, Amuli, Demra, Dhaka

BH-018				
Depth to Sampler Tip (m)	**Layer Thickness (m)**	**Soil Classification**	**Unit Weight (kN/m^3)**	**SPT N-value (N_{60})**
1.5	1.5	Lean CLAY	15.4	4
3	1.5	Lean CLAY	15.4	5
4.5	1.5	Lean CLAY	15.4	7
6	1.5	SILT (NP)	15.8	6
7.5	1.5	SILT (NP)	17	13
9	1.5	SILT (NP)	16.3	8
10.5	1.5	Sandy SILT (NP)	16.5	13
12	1.5	Sandy SILT (NP)	18	26
13.5	1.5	Silty SAND (NP)	16.5	19
15	1.5	Silty SAND (NP)	19.1	46
16.5	1.5	Silty SAND (NP)	18	34
18	1.5	Silty SAND (NP)	16.2	18
19.5	1.5	Silty SAND (NP)	19.3	54
21	1.5	Silty SAND (NP)	16.8	24
22.5	1.5	Sandy SILT (NP)	21.7	78
24	1.5	Sandy SILT (NP)	21.6	72
25.5	1.5	Sandy SILT (NP)	21.8	83
27	1.5	Silty SAND (NP)	19.1	82
28.5	1.5	Silty SAND (NP)	17.8	43
30	1.5	Silty SAND (NP)	18.3	48
31.5	1.5	Silty SAND (NP)	27.6	85
33	1.5	Silty SAND (NP)	29.1	83
34.5	1.5	Silty SAND (NP)	29.2	89

Table A-4: Site- Sher-E Bangla Nagar Agricultural University, Dhaka

BH-024				
Depth to Sampler Tip (m)	**Layer Thickness (m)**	**Soil Classification**	**Unit Weight (kN/m^3)**	**SPT N-value (N_{60})**
1.5	1.5	Fat CLAY	15.5	6
3	1.5	Fat CLAY	16.7	14
4.5	1.5	Fat CLAY	17.7	9
6	1.5	Sandy SILT (NP)	17.7	12
7.5	1.5	Lean CLAY	17.7	6
9	1.5	Silty SAND (NP)	15.2	14
10.5	1.5	Sandy SILT (NP)	18.7	23
12	1.5	Sandy SILT (NP)	18.7	25
13.5	1.5	Silty SAND (NP)	15.7	28
15	1.5	Silty SAND (NP)	16.4	36
16.5	1.5	Silty SAND (NP)	16.3	33
18	1.5	Silty SAND (NP)	17.6	63
19.5	1.5	Silty SAND (NP)	17.5	63
21	1.5	Silty SAND (NP)	17.5	60
22.5	1.5	Silty SAND (NP)	17.5	63
24	1.5	Silty SAND (NP)	17.3	50
25.5	1.5	Silty SAND (NP)	17.6	64
27	1.5	Silty SAND (NP)	18	83
28.5	1.5	Silty SAND (NP)	17.7	82
30	1.5	Silty SAND (NP)	17.9	85

Table A-5: Site- Block-M, Road-4, Sector-4, Aftab Nagar, Dhaka

BH-027				
Depth to Sampler Tip (m)	**Layer Thickness (m)**	**Soil Classification**	**Unit Weight (kN/m^3)**	**SPT N-value (N_{60})**
1.5	1.5	Silty SAND (NP)	14.8	5
3	1.5	Silty SAND (NP)	15.1	6
4.5	1.5	Elastic SILT	15.1	5
6	1.5	Elastic SILT	15.1	7
7.5	1.5	Elastic SILT	15.1	5
9	1.5	Elastic SILT	15.1	1
10.5	1.5	Lean CLAY	18.1	1
12	1.5	Lean CLAY	18.1	6
13.5	1.5	Lean CLAY	18.1	8
15	1.5	Fat CLAY	18.1	6
16.5	1.5	Elastic SILT	18.1	6
18	1.5	Silty SAND (NP)	18	33
19.5	1.5	Silty SAND (NP)	17.9	36
21	1.5	Silty SAND (NP)	18.3	35
22.5	1.5	SILT (NP)	17.9	11
24	1.5	Elastic SILT	17.9	14
25.5	1.5	Elastic SILT	17.9	6
27	1.5	Fat CLAY	17.9	8
28.5	1.5	Fat CLAY	17.9	14
30	1.5	SILT	17.9	18
31.5	1.5	Elastic SILT	18.2	21
33	1.5	Fat CLAY	18.2	24
34.5	1.5	Fat CLAY	18.2	25
36	1.5	Fat CLAY	18.2	29
37.5	1.5	Fat CLAY	18.2	26
39	1.5	Lean CLAY	18.2	38
40.5	1.5	Fat CLAY	18.2	36
42	1.5	Fat CLAY	18.2	38
43.5	1.5	Fat CLAY	18.2	41
45	1.5	Lean CLAY	20.7	82
46.5	1.5	Silty SAND (NP)	18.2	85
48	1.5	Silty SAND (NP)	18.6	125

Table A-6: Site- Gulshan Central Mosque (Ajad Mosque), Gulshan, Dhaka

BH-029				
Depth to Sampler Tip (m)	**Layer Thickness (m)**	**Soil Classification**	**Unit Weight (kN/m^3)**	**SPT N-value (N_{60})**
1.5	1.5	Fat CLAY	15.4	4
3	1.5	Fat CLAY	15.4	8
4.5	1.5	Fat CLAY with Sand	15.4	11
6	1.5	Sandy Lean CLAY	16.4	13
7.5	1.5	Sandy SILT (NP)	16.4	14
9	1.5	Silty SAND (NP)	15.4	13
10.5	1.5	Silty SAND (NP)	15.3	14
12	1.5	Silty SAND (NP)	15.5	15
13.5	1.5	Silty SAND (NP)	15.5	20
15	1.5	Silty SAND (NP)	15.8	24
16.5	1.5	Silty SAND (NP)	16.3	25
18	1.5	Silty SAND (NP)	15.8	26
19.5	1.5	Silty SAND (NP)	17.2	44
21	1.5	Silty SAND (NP)	17.5	45
22.5	1.5	Silty SAND (NP)	16.5	39
24	1.5	Silty SAND (NP)	17.7	60
25.5	1.5	Silty SAND (NP)	18	69
27	1.5	Silty SAND (NP)	18.9	104
28.5	1.5	Silty SAND (NP)	19.1	94
30	1.5	Silty SAND (NP)	18.9	99

Table A-7: Site- Bauniya Bazar jame mosque Turag ,Dhaka

BH-042				
Depth to Sampler Tip (m)	Layer Thickness (m)	Soil Classification	Unit Weight (kN/m^3)	SPT N-value (N_{60})
1.5	1.5	-	14.4	
3	1.5	Fat CLAY with Sand	14.4	10
4.5	1.5	Fat CLAY with Sand	14.4	10
6	1.5	Sandy Fat CLAY	14.4	14
7.5	1.5	Sandy Lean CLAY	14.4	10
9	1.5	Clayey SAND	15.4	10
10.5	1.5	Fat CLAY	15.4	21
12	1.5	Fat CLAY	15.4	16
13.5	1.5	Fat CLAY	16	29
15	1.5	Elastic SILT	16	21
16.5	1.5	SILT	17	30
18	1.5	SILT	17	21
19.5	1.5	Fat CLAY	17	29
21	1.5	Lean CLAY	16	19
22.5	1.5	Lean CLAY	16	18
24	1.5	Lean CLAY	18	25
25.5	1.5	Lean CLAY with Sand	18	23
27	1.5	Lean CLAY	17.5	23
28.5	1.5	Silty SAND (NP)	18.8	82
30	1.5	Silty SAND (NP)	18.4	82
31.5	1.5	Silty SAND (NP)	18.9	94

Table A-8: Site- Gakulnagar Eidgah math Ashulia Savar Dhaka

BH-045				
Depth to Sampler Tip (m)	Layer Thickness (m)	Soil Classification	Unit Weight (kN/m^3)	SPT N-value (N_{60})
1.5	1.5	Lean CLAY	16.4	4
3	1.5	Fat CLAY	16.4	5
4.5	1.5	Sandy Lean CLAY	16.4	17
6	1.5	Lean CLAY	16.4	21
7.5	1.5	Lean CLAY	16.4	14
9	1.5	Sandy SILT (NP)	16.4	15
10.5	1.5	Sandy SILT (NP)	17.6	21
12	1.5	Sandy SILT (NP)	17.6	24
13.5	1.5	Sandy SILT (NP)	17.6	23
15	1.5	Sandy SILT (NP)	17.6	25
16.5	1.5	Silty SAND (NP)	18.2	49
18	1.5	Silty SAND (NP)	18.4	50
19.5	1.5	Silty SAND (NP)	17.7	33
21	1.5	Silty SAND (NP)	17.4	34
22.5	1.5	Silty SAND (NP)	17.3	33
24	1.5	Silty SAND (NP)	17.5	31
25.5	1.5	Silty SAND (NP)	17.8	41
27	1.5	Silty SAND (NP)	17.7	43
28.5	1.5	Silty SAND (NP)	18.5	63
30	1.5	Silty SAND (NP)	19.2	65
31.5	1.5	Silty SAND (NP)	19.1	74
33	1.5	Silty SAND (NP)	18.9	53
34.5	1.5	Silty SAND (NP)	18.7	59
36	1.5	Silty SAND (NP)	18.6	53
37.5	1.5	Silty SAND (NP)	18.6	49
39	1.5	Silty SAND (NP)	18.6	45
40.5	1.5	Silty SAND (NP)	18.9	56
42	1.5	Silty SAND (NP)	18.9	63
43.5	1.5	Silty SAND (NP)	18.9	65
45	1.5	Silty SAND (NP)	19	67
46.5	1.5	Silty SAND (NP)	19.4	83
48	1.5	Silty SAND (NP)	19.5	91
49.5	1.5	Silty SAND (NP)	19.2	89

Table A-9: Site- Khilgaon Primary School, Pubail, Gazipur

BH-049				
Depth to Sampler Tip (m)	**Layer Thickness (m)**	**Soil Classification**	**Unit Weight (kN/m^3)**	**SPT N-value (N_{60})**
1.5	1.5	Fat CLAY	14.6	4
3	1.5	Fat CLAY	14.6	5
4.5	1.5	Fat CLAY	14.6	12
6	1.5	Fat CLAY	14.6	12
7.5	1.5	Lean CLAY	14.6	8
9	1.5	Lean CLAY	14.6	26
10.5	1.5	SILT with Sand (NP)	15.1	29
12	1.5	SILT	15.1	14
13.5	1.5	Fat CLAY	15.1	18
15	1.5	SILT	16.6	30
16.5	1.5	Fat CLAY	16.6	28
18	1.5	Lean CLAY	16.6	16
19.5	1.5	Fat CLAY	16.6	24
21	1.5	Fat CLAY	16.6	19
22.5	1.5	Lean CLAY	16.6	21
24	1.5	SILT	16.6	29
25.5	1.5	Fat CLAY	17.8	67
27	1.5	Fat CLAY	17.7	50
28.5	1.5	Fat CLAY	17.7	36
30	1.5	Fat CLAY	16.5	29
31.5	1.5	SILT	19.1	60
33	1.5	Fat CLAY	18.4	38
34.5	1.5	Fat CLAY	18.2	28
36	1.5	Lean CLAY	18.6	31
37.5	1.5	Fat CLAY	18.6	49
39	1.5	Sandy Lean CLAY	18.6	43
40.5	1.5	Silty SAND (NP)	19.6	85
42	1.5	Silty SAND (NP)	19.6	89
43.5	1.5	Silty SAND (NP)	19.8	87

Table A-10: Site- Nyebbari, Uttar Salna, Gazipur, Dhaka

BH-061				
Depth to Sampler Tip (m)	**Layer Thickness (m)**	**Soil Classification**	**Unit Weight (kN/m^3)**	**SPT N-value (N_{60})**
1.5	1.5	Fat CLAY	14.4	7
3	1.5	Fat CLAY	14.4	10
4.5	1.5	Fat CLAY	14.4	13
6	1.5	Fat CLAY	15	15
7.5	1.5	Fat CLAY	16.1	17
9	1.5	Fat CLAY	15.5	15
10.5	1.5	Silty SAND (NP)	17.4	44
12	1.5	Silty SAND (NP)	17.2	48
13.5	1.5	Silty SAND (NP)	16.2	24
15	1.5	Sandy SILT (NP)	16.6	28
16.5	1.5	Silty SAND (NP)	16.6	29
18	1.5	Fat CLAY	16.8	30
19.5	1.5	Fat CLAY	16.8	31
21	1.5	Lean CLAY with Sand	16.8	31
22.5	1.5	Fat CLAY	16.8	35
24	1.5	Fat CLAY	17	28
25.5	1.5	Lean CLAY	17.5	36
27	1.5	SILT (NP)	18	44
28.5	1.5	SILT with Sand (NP)	18.4	50
30	1.5	SILT with Sand (NP)	18.4	58
31.5	1.5	Sandy SILT (NP)	18.4	85
33	1.5	Sandy SILT (NP)	19	89
34.5	1.5	SILT with Sand (NP)	19.5	104

Table A-11: Site- Govt Hazi Ibrahim School and College, Bandar, Narayanganj

BH-071				
Depth to Sampler Tip (m)	**Layer Thickness (m)**	**Soil Classification**	**Unit Weight (kN/m^3)**	**SPT N-value (N_{60})**
1.5	1.5	SILT (NP)	15	5
3	1.5	SILT (NP)	16.1	7
4.5	1.5	Sandy SILT (NP)	16.5	9
6	1.5	Silty SAND (NP)	16.1	13
7.5	1.5	Silty SAND (NP)	15.7	8
9	1.5	Silty SAND (NP)	16.4	14
10.5	1.5	Silty SAND (NP)	16.7	18
12	1.5	Silty SAND (NP)	17	20
13.5	1.5	Silty SAND (NP)	17.8	23
15	1.5	Poorly Graded SAND with Silt (NP)	17.4	26
16.5	1.5	Silty SAND (NP)	17.3	29
18	1.5	Silty SAND (NP)	18.8	31
19.5	1.5	Silty SAND (NP)	17.8	28
21	1.5	Silty SAND (NP)	17	25
22.5	1.5	Silty SAND (NP)	17.4	28
24	1.5	Silty SAND (NP)	17.3	30
25.5	1.5	Silty SAND (NP)	17	23
27	1.5	Silty SAND (NP)	17	25
28.5	1.5	Silty SAND (NP)	19	38
30	1.5	Silty SAND (NP)	19.6	44
31.5	1.5	Silty SAND (NP)	18.6	46
33	1.5	Silty SAND (NP)	18.7	50
34.5	1.5	Silty SAND (NP)	19.6	83
36	1.5	Silty SAND (NP)	18.9	84
37.5	1.5	Lean CLAY	18.6	21
39	1.5	Lean CLAY	18.6	26
40.5	1.5	Lean CLAY	18.6	28
42	1.5	Fat CLAY	18.6	16
43.5	1.5	Fat CLAY	18.6	19
45	1.5	Fat CLAY	18.6	20
46.5	1.5	Elastic SILT	18.6	18
48	1.5	Fat CLAY	18.6	19
49.5	1.5	Elastic SILT	18.6	21
51	1.5	Lean CLAY	19.6	84
52.5	1.5	SILT with Sand (NP)	19.7	89
54	1.5	SILT with Sand (NP)	20	117

Table A-12: Site- Purbo Gopalnagar Govt. Primary School, Purbo Gopalnagar, Fatullah, Narayanganj

BH-074				
Depth to Sampler Tip (m)	**Layer Thickness (m)**	**Soil Classification**	**Unit Weight (kN/m^3)**	**SPT N-value (N_{60})**
1.5	1.5	SILT (NP)	14.8	5
3	1.5	SILT with Sand (NP)	14.8	5
4.5	1.5	Silty SAND (NP)	15.1	11
6	1.5	Sandy SILT (NP)	15.9	12
7.5	1.5	Silty SAND (NP)	15.4	14
9	1.5	Silty SAND (NP)	16.2	25
10.5	1.5	Silty SAND (NP)	16.3	23
12	1.5	Silty SAND (NP)	16.8	21
13.5	1.5	Silty SAND (NP)	17.2	18
15	1.5	Silty SAND (NP)	17.2	23
16.5	1.5	Silty SAND (NP)	16.5	20
18	1.5	Silty SAND (NP)	17.3	25
19.5	1.5	Silty SAND (NP)	17.9	29
21	1.5	SILT	17.1	13
22.5	1.5	SILT	17.1	20
24	1.5	Silty SAND (NP)	18.4	34
25.5	1.5	Silty SAND (NP)	18.8	40
27	1.5	Silty SAND (NP)	18.9	54
28.5	1.5	Silty SAND (NP)	18.6	45
30	1.5	Silty SAND (NP)	19.5	68
31.5	1.5	Silty SAND (NP)	19.2	50
33	1.5	Silty SAND (NP)	20.4	74
34.5	1.5	Silty SAND (NP)	18.9	58
36	1.5	Silty SAND (NP)	19.3	75
37.5	1.5	Silty SAND (NP)	18.5	74
39	1.5	Silty SAND (NP)	18.8	67
40.5	1.5	Silty SAND (NP)	18.7	58
42	1.5	Sandy SILT (NP)	19.2	46
43.5	1.5	Silty SAND (NP)	19.7	67
45	1.5	Silty SAND (NP)	17.7	38
46.5	1.5	Silty SAND (NP)	18.7	59
48	1.5	Silty SAND (NP)	19.2	63
49.5	1.5	Silty SAND (NP)	18.5	49
51	1.5	Fat CLAY	18.2	30
52.5	1.5	Fat CLAY	18.2	36
54	1.5	Fat CLAY	18.2	40
55.5	1.5	Lean CLAY	18.2	29
57	1.5	Lean CLAY	18.2	39
58.5	1.5	Fat CLAY	19.1	51
60	1.5	Fat CLAY	19.1	36
61.5	1.5	Silty SAND (NP)	20.6	188
63	1.5	Fat CLAY	18.7	34
64.5	1.5	Fat CLAY	18.7	38
66	1.5	Fat CLAY	18.7	39
67.5	1.5	Fat CLAY	19.3	55
69	1.5	Fat CLAY	19.3	41
70.5	1.5	Fat CLAY	19.3	44
72	1.5	Fat CLAY	19.3	45
73.5	1.5	Lean CLAY	18.8	39
75	1.5	SILT	19.5	50
76.5	1.5	Lean CLAY	19.5	48
78	1.5	Lean CLAY	19.5	53
79.5	1.5	Lean CLAY	19.5	56
81	1.5	Lean CLAY	19.5	69
82.5	1.5	Silty SAND (NP)	19.7	119
84	1.5	Silty SAND (NP)	20.6	163
85.5	1.5	Sandy SILT (NP)	20.5	125

Table A-13: Site- T Hossain Garden, Bandar, Narayanganj

BH-085				
Depth to Sampler Tip (m)	**Layer Thickness (m)**	**Soil Classification**	**Unit Weight (kN/m^3)**	**SPT N-value (N_{60})**
1.5	1.5	Silty SAND (NP)	15.1	7
3	1.5	Elastic SILT	15.7	3
4.5	1.5	SILT	15.7	9
6	1.5	SILT	15.7	4
7.5	1.5	Lean CLAY	15.7	4
9	1.5	SILT (NP)	17.1	23
10.5	1.5	Lean CLAY	16.7	15
12	1.5	SILT (NP)	18.8	14
13.5	1.5	SILT	14.5	5
15	1.5	SILT with Sand (NP)	18.8	26
16.5	1.5	Silty SAND (NP)	19.1	40
18	1.5	Silty SAND (NP)	18.4	28
19.5	1.5	Silty SAND (NP)	18.2	29
21	1.5	Silty SAND (NP)	18	20
22.5	1.5	Silty SAND (NP)	17.9	24
24	1.5	SILT with Sand (NP)	19.3	40
25.5	1.5	Sandy SILT (NP)	20.6	63
27	1.5	Sandy SILT (NP)	20.9	92
28.5	1.5	Sandy SILT (NP)	20.4	94
30	1.5	Silty SAND (NP)	20.2	85
31.5	1.5	Silty SAND (NP)	20.5	96

Table A-14: Site- 55 No Mograpara Govt. Primary School Sonagaon, Sonargaon, Narayanganj

BH-088				
Depth to Sampler Tip (m)	**Layer Thickness (m)**	**Soil Classification**	**Unit Weight (kN/m^3)**	**SPT N-value (N_{60})**
1.5	1.5	Lean CLAY	15	3
3	1.5	Sandy SILT (NP)	15	4
4.5	1.5	SILT with Sand (NP)	15.5	4
6	1.5	SILT	15.7	6
7.5	1.5	SILT with Sand (NP)	16	5
9	1.5	SILT with Sand (NP)	16.1	6
10.5	1.5	Sandy SILT (NP)	16.4	9
12	1.5	Silty SAND (NP)	16.8	13
13.5	1.5	Silty SAND (NP)	16.6	15
15	1.5	Silty SAND (NP)	16.3	14
16.5	1.5	Silty SAND (NP)	18.7	33
18	1.5	Silty SAND (NP)	16.2	16
19.5	1.5	Silty SAND (NP)	18.4	40
21	1.5	Silty SAND (NP)	17	21
22.5	1.5	Silty SAND (NP)	17.1	25
24	1.5	Silty SAND (NP)	17.6	29
25.5	1.5	Silty SAND (NP)	18.3	35
27	1.5	Silty SAND (NP)	18	36
28.5	1.5	Silty SAND (NP)	16.8	24
30	1.5	Silty SAND (NP)	18.3	40
31.5	1.5	Silty SAND (NP)	17.8	46
33	1.5	Silty SAND (NP)	18.9	65
34.5	1.5	Silty SAND (NP)	18.9	75
36	1.5	Silty SAND (NP)	18.9	55
37.5	1.5	Silty SAND (NP)	19.6	89
39	1.5	Silty SAND (NP)	19.4	82
40.5	1.5	Silty SAND (NP)	19	85

Table A-15: Site- Sonamia Market S.O Road Balurmath, Sumilpara, Narayanganj

BH-107				
Depth to Sampler Tip (m)	**Layer Thickness (m)**	**Soil Classification**	**Unit Weight (kN/m^3)**	**SPT N-value (N_{60})**
1.5	1.5	Silty SAND (NP)	14.8	3
3	1.5	SILT	14.8	3
4.5	1.5	SILT	15.5	10
6	1.5	SILT	15.5	8
7.5	1.5	Elastic SILT	14.7	2
9	1.5	Organic SILT with Sand	15.1	10
10.5	1.5	Lean CLAY	14.5	3
12	1.5	Lean CLAY	14.5	3
13.5	1.5	Fat CLAY	14.5	3
15	1.5	Fat CLAY	14.5	5
16.5	1.5	Fat CLAY	15.2	6
18	1.5	Fat CLAY	15.8	16
19.5	1.5	Fat CLAY	16.6	18
21	1.5	Fat CLAY	16.6	16
22.5	1.5	Lean CLAY	16.6	16
24	1.5	Lean CLAY with Sand	17.8	24
25.5	1.5	Lean CLAY	17.8	16
27	1.5	Lean CLAY	17.8	16
28.5	1.5	Lean CLAY	17.8	15
30	1.5	Lean CLAY	17.2	23
31.5	1.5	Fat CLAY	17.6	26
33	1.5	Fat CLAY	17.6	13
34.5	1.5	Lean CLAY	17.6	24
36	1.5	SILT with Sand	17.6	19
37.5	1.5	Silty SAND (NP)	20.9	108
39	1.5	Fat CLAY	19.6	85
40.5	1.5	Lean CLAY	19.6	109

Table A-16: Site- 122 No Goalkhali Poshchim Govt. Primary School, Keraniganj, Dhaka

BH-112				
Depth to Sampler Tip (m)	**Layer Thickness (m)**	**Soil Classification**	**Unit Weight (kN/m^3)**	**SPT N-value (N_{60})**
1.5	1.5	Lean CLAY	14.4	4
3	1.5	Lean CLAY	15.4	5
4.5	1.5	SILT (NP)	16.4	9
6	1.5	SILT (NP)	15.9	5
7.5	1.5	SILT (NP)	15.4	4
9	1.5	Sandy SILT (NP)	17.1	24
10.5	1.5	Silty SAND (NP)	17	19
12	1.5	Silty SAND (NP)	17.5	20
13.5	1.5	Silty SAND (NP)	18.2	26
15	1.5	Silty SAND (NP)	16.6	24
16.5	1.5	Silty SAND (NP)	17.1	25
18	1.5	Silty SAND (NP)	17.8	33
19.5	1.5	Silty SAND (NP)	18.7	40
21	1.5	Silty SAND (NP)	19.5	51
22.5	1.5	Silty SAND (NP)	17.9	40
24	1.5	Silty SAND (NP)	19	83
25.5	1.5	Silty SAND (NP)	18.6	43
27	1.5	Silty SAND (NP)	18	38
28.5	1.5	Silty SAND (NP)	18.3	45
30	1.5	Silty SAND (NP)	17.9	40
31.5	1.5	Silty SAND (NP)	17.3	35
33	1.5	Sandy SILT (NP)	19.9	82
34.5	1.5	Silty SAND (NP)	19.2	50
36	1.5	Silty SAND (NP)	18.3	45
37.5	1.5	Silty SAND (NP)	17.6	38
39	1.5	Silty SAND (NP)	19.2	45
40.5	1.5	Silty SAND (NP)	19.5	50
42	1.5	Silty SAND (NP)	19.5	51
43.5	1.5	Silty SAND (NP)	19.6	54
45	1.5	Silty SAND (NP)	19.3	49
46.5	1.5	Silty SAND (NP)	19.3	51
48	1.5	Silty SAND (NP)	19	56
49.5	1.5	Silty SAND (NP)	19.6	110
51	1.5	Silty SAND (NP)	20	121
52.5	1.5	Silty SAND (NP)	20.3	144

Table A-17: Site- Doleshwar Government Primary School, Keraniganj, Dhaka

BH-116				
Depth to Sampler Tip (m)	**Layer Thickness (m)**	**Soil Classification**	**Unit Weight (kN/m^3)**	**SPT N-value (N_{60})**
1.5	1.5	Silty SAND (NP)	14.3	3
3	1.5	Silty SAND (NP)	14.3	6
4.5	1.5	Silty SAND (NP)	15.5	5
6	1.5	Silty SAND (NP)	15.6	7
7.5	1.5	SILT with Sand (NP)	14.8	8
9	1.5	SILT (NP)	16.6	15
10.5	1.5	Sandy SILT (NP)	17	24
12	1.5	Sandy SILT (NP)	16.5	28
13.5	1.5	SILT with Sand (NP)	17.6	25
15	1.5	Silty SAND (NP)	16.1	30
16.5	1.5	Sandy SILT (NP)	15.4	21
18	1.5	SILT (NP)	18.1	24
19.5	1.5	SILT (NP)	19.2	30
21	1.5	SILT (NP)	19.1	33
22.5	1.5	Silty SAND (NP)	18.2	44
24	1.5	Sandy SILT (NP)	18.9	45
25.5	1.5	Silty SAND (NP)	17.7	48
27	1.5	Silty SAND (NP)	17.9	50
28.5	1.5	Poorly Graded SAND with Silt (NP)	18.9	53
30	1.5	Poorly Graded SAND with Silt (NP)	18.7	50
31.5	1.5	Silty SAND (NP)	19.5	54
33	1.5	Silty SAND (NP)	18.9	46
34.5	1.5	Silty SAND (NP)	19.7	50
36	1.5	Silty SAND (NP)	18.8	40
37.5	1.5	Silty SAND (NP)	18.7	43
39	1.5	Sandy SILT (NP)	18.6	48
40.5	1.5	Silty SAND (NP)	18.5	39
42	1.5	SILT	18.5	75
43.5	1.5	SILT	18.5	79
45	1.5	Silty SAND (NP)	18.5	69

Table A-18: Site- Kharakandi Govt. Primary School, Keraniganj

BH-139				
Depth to Sampler Tip (m)	**Layer Thickness (m)**	**Soil Classification**	**Unit Weight (kN/m^3)**	**SPT N-value (N_{60})**
1.5	1.5	SILT with Clay	14.4	2
3	1.5	SILT with Clay	14.4	5
4.5	1.5	SILT with Clay	14.4	7
6	1.5	Silty SAND (NP)	15.2	11
7.5	1.5	Silty SAND (NP)	15.3	12
9	1.5	Silty SAND (NP)	16.7	21
10.5	1.5	Silty SAND (NP)	17.6	28
12	1.5	Silty SAND (NP)	17.9	30
13.5	1.5	Silty SAND (NP)	17.6	31
15	1.5	Silty SAND (NP)	16.7	24
16.5	1.5	Silty SAND (NP)	17.7	28
18	1.5	Silty SAND (NP)	17.2	25
19.5	1.5	Silty SAND (NP)	16.9	23
21	1.5	Silty SAND (NP)	17.7	30
22.5	1.5	Silty SAND (NP)	17.9	34
24	1.5	Silty SAND (NP)	18.3	39
25.5	1.5	Silty SAND (NP)	18.3	43
27	1.5	Silty SAND (NP)	17.1	29
28.5	1.5	Silty SAND (NP)	17.8	31
30	1.5	Silty SAND (NP)	17.3	26
31.5	1.5	Silty SAND (NP)	17.1	28
33	1.5	Silty SAND (NP)	17.9	34
34.5	1.5	Silty SAND (NP)	17.5	30
36	1.5	Silty SAND (NP)	18.6	44
37.5	1.5	Silty SAND (NP)	18.8	46
39	1.5	Silty SAND (NP)	19.7	80
40.5	1.5	Silty SAND (NP)	20.6	123
42	1.5	Silty SAND (NP)	19.3	77
43.5	1.5	Silty SAND (NP)	19.7	63
45	1.5	Silty SAND (NP)	18.4	41
46.5	1.5	Silty SAND (NP)	18.9	44
48	1.5	Silty SAND (NP)	20.3	89
49.5	1.5	Silty SAND (NP)	19.8	85
51	1.5	Silty SAND (NP)	20.1	97

Table A-19: Site- Samad Nagar, Jatrabari, Dhaka

BH-146				
Depth to Sampler Tip (m)	**Layer Thickness (m)**	**Soil Classification**	**Unit Weight (kN/m^3)**	**SPT N-value (N_{60})**
1.5	1.5	Silty SAND (NP)	15.8	4.7
3	1.5	Fat CLAY	16.7	1.9
4.5	1.5	Fat CLAY	16.7	4.3
6	1.5	Fat CLAY	17.7	14.3
7.5	1.5	Fat CLAY	17.7	15.4
9	1.5	Lean CLAY	17.7	10.7
10.5	1.5	Lean CLAY	17.7	16.3
12	1.5	Fat CLAY	18.6	12.5
13.5	1.5	Fat CLAY	18.6	18.8
15	1.5	Fat CLAY	18.6	16.3
16.5	1.5	Lean CLAY	18.6	18.8
18	1.5	Sandy SILT (NP)	18	35
19.5	1.5	Fat CLAY	18.6	18.8
21	1.5	Lean CLAY	18.6	21.3
22.5	1.5	Lean CLAY	18.6	13.8
24	1.5	Lean CLAY with Sand	18.6	36.3
25.5	1.5	SILT	18.6	64.7
27	1.5	Elastic SILT	18.6	85.2
28.5	1.5	Sandy Lean CLAY	18.6	65.8
30	1.5	Lean CLAY	18.6	78.1

Table A-20: Site- Sonali paper mills Ltd, Tarabo, Narayanganj

BH-150				
Depth to Sampler Tip (m)	**Layer Thickness (m)**	**Soil Classification**	**Unit Weight (kN/m^3)**	**SPT N-value (N_{60})**
1.5	1.5	Silty SAND (NP)	14.8	6
3	1.5	Silty SAND (NP)	15.3	7
4.5	1.5	Lean CLAY	14.8	3
6	1.5	-	15.3	8
7.5	1.5	Lean CLAY	15.3	5
9	1.5	Lean CLAY	15.3	8
10.5	1.5	Elastic SILT	15.3	4
12	1.5	Fat CLAY	15.9	4
13.5	1.5	Lean CLAY	15.9	10
15	1.5	Fat CLAY	15.9	8
16.5	1.5	Fat CLAY	15.9	8
18	1.5	Fat CLAY	15.9	9
19.5	1.5	Fat CLAY	15.9	10
21	1.5	SILT with Sand (NP)	17.3	38
22.5	1.5	Sandy SILT (NP)	19.1	67
24	1.5	Lean CLAY	16.4	25
25.5	1.5	Lean CLAY	16.4	30
27	1.5	Lean CLAY	16.7	29
28.5	1.5	Lean CLAY	16.7	16
30	1.5	Lean CLAY	16.7	25
31.5	1.5	Lean CLAY	17.3	31
33	1.5	Silty SAND (NP)	19.3	69
34.5	1.5	Fat CLAY	14.7	38
36	1.5	Fat CLAY	14.7	30
37.5	1.5	SILT	14.7	18
39	1.5	Lean CLAY with Sand	15.8	23
40.5	1.5	Fat CLAY with Sand	16.1	25
42	1.5	Lean CLAY with Sand	18.7	83
43.5	1.5	Silty SAND (NP)	19.3	156
45	1.5	Silty SAND (NP)	18.8	110

Table A-21: Site- Sommalon Math, Noyapur Bazar, Sadipur, Sonargaon, Narayanganj

BH-153				
Depth to Sampler Tip (m)	**Layer Thickness (m)**	**Soil Classification**	**Unit Weight (kN/m^3)**	**SPT N-value (N_{60})**
1.5	1.5	Fat CLAY	17.5	9
3	1.5	Fat CLAY	17.5	11
4.5	1.5	Fat CLAY	17.5	18
6	1.5	Lean CLAY with Sand	17.5	15
7.5	1.5	Lean CLAY with Sand	17.5	17
9	1.5	SILT with Sand	17.5	19
10.5	1.5	Silty SAND (NP)	16.5	21
12	1.5	Silty SAND (NP)	16.3	24
13.5	1.5	Silty SAND (NP)	16.7	24
15	1.5	Silty SAND (NP)	16.6	29
16.5	1.5	Silty SAND (NP)	16.6	29
18	1.5	Silty SAND (NP)	17.6	38
19.5	1.5	Silty SAND (NP)	17.7	41
21	1.5	Silty SAND (NP)	18	44
22.5	1.5	Silty SAND (NP)	17.5	43
24	1.5	Silty SAND (NP)	17.9	50
25.5	1.5	Silty SAND (NP)	18.1	60
27	1.5	Silty SAND (NP)	19.1	107
28.5	1.5	Silty SAND (NP)	19.3	121
30	1.5	Fat CLAY	19.3	24
31.5	1.5	Elastic SILT	19.3	16
33	1.5	Lean CLAY	19.3	18
34.5	1.5	Silty CLAY	19.3	19
36	1.5	Lean CLAY	19.3	25
37.5	1.5	SILT (NP)	19.3	83
39	1.5	Silty SAND (NP)	19.9	125
40.5	1.5	SILT (NP)	19.9	125

Table A-22: Site- Modderchor Govt. Primary School, Keraniganj

BH-160				
Depth to Sampler Tip (m)	**Layer Thickness (m)**	**Soil Classification**	**Unit Weight (kN/m^3)**	**SPT N-value (N_{60})**
1.5	1.5	Silty SAND (NP)	14.6	4
3	1.5	SILT	16.6	3
4.5	1.5	SILT with Sand (NP)	15.1	19
6	1.5	Sandy SILT (NP)	14.1	12
7.5	1.5	Silty SAND (NP)	14.7	14
9	1.5	Silty SAND (NP)	15.1	21
10.5	1.5	Silty SAND (NP)	15.6	24
12	1.5	Silty SAND (NP)	16.1	14
13.5	1.5	Silty SAND (NP)	15.1	19
15	1.5	Silty SAND (NP)	19.2	46
16.5	1.5	Silty SAND (NP)	17.4	24
18	1.5	SILT with Sand (NP)	18	28
19.5	1.5	Silty SAND (NP)	17.4	20
21	1.5	SILT (NP)	17.3	10
22.5	1.5	SILT (NP)	20.7	15
24	1.5	SILT (NP)	15.9	11
25.5	1.5	SILT (NP)	14.9	10
27	1.5	Silty SAND (NP)	18	30
28.5	1.5	Silty SAND (NP)	17.1	39
30	1.5	Silty SAND (NP)	18.9	31
31.5	1.5	Silty SAND (NP)	19.5	58
33	1.5	Silty SAND (NP)	18.1	33
34.5	1.5	Silty SAND (NP)	19.4	50
36	1.5	Silty SAND (NP)	18.3	46
37.5	1.5	Silty SAND (NP)	17.2	34
39	1.5	Sandy SILT (NP)	19.4	63
40.5	1.5	Silty SAND (NP)	18.3	45
42	1.5	Silty SAND (NP)	19.7	58
43.5	1.5	Silty SAND (NP)	19.4	51
45	1.5	Silty SAND (NP)	19.1	67
46.5	1.5	Silty SAND (NP)	19	63
48	1.5	Silty SAND (NP)	19	94
49.5	1.5	Silty SAND (NP)	18.9	85
51	1.5	Silty SAND (NP)	18.6	63
52.5	1.5	Silty SAND (NP)	18.6	89
54	1.5	Silty SAND (NP)	18.6	85
55.5	1.5	Silty SAND (NP)	18.6	94

Table A-23: Site- Kakrail Mosque (Tablig Jamat), Dhaka

BH-163				
Depth to Sampler Tip (m)	**Layer Thickness (m)**	**Soil Classification**	**Unit Weight (kN/m^3)**	**SPT N-value (N_{60})**
1.5	1.5	Fat CLAY with Sand	15.4	8
3	1.5	Fat CLAY with Sand	15.4	6
4.5	1.5	Lean CLAY with Sand	15.4	9
6	1.5	Sandy Lean CLAY	15.9	14
7.5	1.5	Clayey SAND	16.0	13
9	1.5	Silty SAND (NP)	14.9	15
10.5	1.5	Silty SAND (NP)	15.2	18
12	1.5	Silty SAND (NP)	15.3	23
13.5	1.5	Silty SAND (NP)	16.4	25
15	1.5	Silty SAND (NP)	16.6	33
16.5	1.5	Silty SAND (NP)	17.2	34
18	1.5	Silty SAND (NP)	17.6	43
19.5	1.5	Silty SAND (NP)	18.6	59
21	1.5	Silty SAND (NP)	18.2	59
22.5	1.5	Silty SAND (NP)	19	60
24	1.5	Silty SAND (NP)	18.5	94
25.5	1.5	Silty SAND (NP)	17.1	35
27	1.5	Silty SAND (NP)	17.4	46
28.5	1.5	Silty SAND (NP)	19.2	99
30	1.5	Silty SAND (NP)	16.9	38
31.5	1.5	Silty SAND (NP)	17.7	89
33	1.5	Silty SAND (NP)	18.5	67
34.5	1.5	Silty SAND (NP)	18.6	104
36	1.5	Silty SAND (NP)	18.6	94
37.5	1.5	Silty SAND (NP)	18.6	85

Table A-24: Site- Baitunnur lalmia mosque,Golakandail, Rupganj, Narayanganj

BH-185				
Depth to Sampler Tip (m)	**Layer Thickness (m)**	**Soil Classification**	**Unit Weight (kN/m^3)**	**SPT N-value (N_{60})**
1.5	1.5	SILT	15.3	4
3	1.5	SILT with Sand (NP)	15.3	5
4.5	1.5	Fat CLAY	15.3	3
6	1.5	SILT	15.3	5
7.5	1.5	Lean CLAY	16.4	2
9	1.5	SILT	16.4	8
10.5	1.5	SILT (NP)	17.1	13
12	1.5	Lean CLAY	16.4	10
13.5	1.5	SILT (NP)	17.3	14
15	1.5	Fat CLAY	16.4	5
16.5	1.5	Fat CLAY	17.1	13
18	1.5	Fat CLAY	17.1	5
19.5	1.5	Fat CLAY	17.1	10
21	1.5	Silty SAND (NP)	16.6	14
22.5	1.5	Silty SAND (NP)	17.7	45
24	1.5	Silty SAND (NP)	17.8	48
25.5	1.5	Silty SAND (NP)	17	30
27	1.5	Silty SAND (NP)	18	43
28.5	1.5	Silty SAND (NP)	18.6	48
30	1.5	Silty SAND (NP)	18	43
31.5	1.5	Silty SAND (NP)	19	68
33	1.5	Silty SAND (NP)	18.4	65
34.5	1.5	Silty SAND (NP)	18.6	68

Table A-25: Site- 11 No Mograkanda Govt. School, Savar, Dhaka

BH-189				
Depth to Sampler Tip (m)	Layer Thickness (m)	Soil Classification	Unit Weight (kN/m^3)	SPT N-value (N_{60})
1.5	1.5	SILT	13.7	5
3	1.5	SILT with Sand (NP)	13.7	4
4.5	1.5	Silty SAND (NP)	13.8	12
6	1.5	Silty SAND (NP)	14.1	17
7.5	1.5	Silty SAND (NP)	14.7	19
9	1.5	Silty SAND (NP)	16.3	20
10.5	1.5	Silty SAND (NP)	16.9	24
12	1.5	Silty SAND (NP)	16.5	20
13.5	1.5	Silty SAND (NP)	14.8	24
15	1.5	Silty SAND (NP)	16.6	19
16.5	1.5	Silty SAND (NP)	16.3	20
18	1.5	Silty SAND (NP)	17	24
19.5	1.5	Silty SAND (NP)	17.1	26
21	1.5	Silty SAND (NP)	17	24
22.5	1.5	Silty SAND (NP)	17.5	30
24	1.5	Silty SAND (NP)	18.5	34
25.5	1.5	Sandy SILT (NP)	19.9	50
27	1.5	Silty SAND (NP)	20.4	85
28.5	1.5	Sandy SILT (NP)	19.9	54
30	1.5	Silty SAND (NP)	19.3	59
31.5	1.5	Silty SAND (NP)	19.4	63
33	1.5	Silty SAND (NP)	19.5	84
34.5	1.5	Silty SAND (NP)	18.2	45
36	1.5	Silty SAND (NP)	18.6	46
37.5	1.5	Silty SAND (NP)	18.2	44
39	1.5	Silty SAND (NP)	19.3	50
40.5	1.5	Silty SAND (NP)	19.4	46
42	1.5	Silty SAND (NP)	19	51
43.5	1.5	Silty SAND (NP)	19.4	54
45	1.5	Silty SAND (NP)	18.7	45
46.5	1.5	Silty SAND (NP)	19.3	50
48	1.5	Silty SAND (NP)	20.5	84
49.5	1.5	Silty SAND (NP)	19.5	112
51	1.5	Silty SAND (NP)	20.7	134

Table A-26: Site- Ichakhali, Kaiup para, Rupganj, Narayanganj

BH-195				
Depth to Sampler Tip (m)	Layer Thickness (m)	Soil Classification	Unit Weight (kN/m^3)	SPT N-value (N_{60})
1.5	1.5	Sandy SILT (NP)	15.7	5
3	1.5	Lean CLAY	16.7	6
4.5	1.5	SILT	16.7	5
6	1.5	SILT	17.7	4
7.5	1.5	SILT	17.7	2
9	1.5	SILT	17.7	2
10.5	1.5	SILT	17.7	4
12	1.5	SILT	18.6	3
13.5	1.5	Elastic SILT	18.6	6
15	1.5	SILT	18.6	10
16.5	1.5	SILT	18.6	8
18	1.5	Lean CLAY	18.6	6
19.5	1.5	SILT	18.6	6
21	1.5	Lean CLAY	18.6	10
22.5	1.5	Lean CLAY	18.6	9
24	1.5	SILT	18.6	8
25.5	1.5	SILT	18.6	14
27	1.5	Silty SAND (NP)	17	23
28.5	1.5	Silty SAND (NP)	17.9	54
30	1.5	Silty SAND (NP)	18.8	82
31.5	1.5	Silty SAND (NP)	19.2	94
33	1.5	Silty SAND (NP)	19.5	114

Table A-27: Site- Rupayan Sity, Hamiyetpur, Savar, Dhaka

BH-199				
Depth to Sampler Tip (m)	**Layer Thickness (m)**	**Soil Classification**	**Unit Weight (kN/m^3)**	**SPT N-value (N_{60})**
1.5	1.5	SILT (NP)	16.8	5
3	1.5	Silty SAND (NP)	16.8	8
4.5	1.5	Silty SAND (NP)	16.5	10
6	1.5	SILT (NP)	16.5	6
7.5	1.5	SILT (NP)	16.5	7
9	1.5	Silty SAND (NP)	16.7	12
10.5	1.5	Silty SAND (NP)	16.9	20
12	1.5	Silty SAND (NP)	17.5	25
13.5	1.5	Silty SAND (NP)	17.9	28
15	1.5	Silty SAND (NP)	17.8	13
16.5	1.5	Silty SAND (NP)	18.2	19
18	1.5	Silty SAND (NP)	17.8	15
19.5	1.5	Silty SAND (NP)	17.2	20
21	1.5	Silty SAND (NP)	17.6	19
22.5	1.5	Silty SAND (NP)	19.1	29
24	1.5	Silty SAND (NP)	17.4	33
25.5	1.5	Silty SAND (NP)	18.2	36
27	1.5	Silty SAND (NP)	17.1	26
28.5	1.5	Silty SAND (NP)	17.8	26
30	1.5	Silty SAND (NP)	17.6	28
31.5	1.5	Silty SAND (NP)	18.4	31
33	1.5	Silty SAND (NP)	18.1	35
34.5	1.5	Sandy SILT (NP)	18.5	41
36	1.5	Sandy SILT (NP)	18.5	29
37.5	1.5	SILT (NP)	18.5	20
39	1.5	SILT (NP)	18.5	67
40.5	1.5	Silty SAND (NP)	20.1	59
42	1.5	Silty SAND (NP)	20.5	89
43.5	1.5	Silty SAND (NP)	20.5	104
45	1.5	Silty SAND (NP)	20.3	69
46.5	1.5	Silty SAND (NP)	19.6	89
48	1.5	Silty SAND (NP)	21.1	85
49.5	1.5	Silty SAND (NP)	20.8	94

Table A-28: Site- Golertek playground Darussalam, Mirpur, Dhaka

BH-203				
Depth to Sampler Tip (m)	**Layer Thickness (m)**	**Soil Classification**	**Unit Weight (kN/m^3)**	**SPT N-value (N_{60})**
1.5	1.5	Lean CLAY	15.7	6
3	1.5	Fat CLAY	16.7	7
4.5	1.5	Fat CLAY	16.7	21
6	1.5	Sandy SILT (NP)	17.7	20
7.5	1.5	Sandy SILT (NP)	17.7	21
9	1.5	Sandy SILT (NP)	17.7	26
10.5	1.5	Silty SAND (NP)	16.9	30
12	1.5	Silty SAND (NP)	17.7	44
13.5	1.5	Silty SAND (NP)	16.3	33
15	1.5	Silty SAND (NP)	16.7	34
16.5	1.5	Silty SAND (NP)	18.2	38
18	1.5	Silty SAND (NP)	17.4	31
19.5	1.5	Silty SAND (NP)	17.2	30
21	1.5	Silty SAND (NP)	16.8	29
22.5	1.5	Sandy Lean CLAY	18.6	19
24	1.5	Sandy Lean CLAY	18.6	67
25.5	1.5	Silty SAND (NP)	18.6	69
27	1.5	Silty SAND (NP)	18.7	82
28.5	1.5	Silty SAND (NP)	18.9	83
30	1.5	Silty SAND (NP)	19.3	110

Table A-29: Site- Rowshan Ara girls high school, Beraid Badda, Dhaka

BH-209				
Depth to Sampler Tip (m)	**Layer Thickness (m)**	**Soil Classification**	**Unit Weight (kN/m^3)**	**SPT N-value (N_{60})**
1.5	1.5	-	-	-
3	1.5	Fat CLAY	15.1	9
4.5	1.5	Fat CLAY	15.1	14
6	1.5	Fat CLAY	15.1	11
7.5	1.5	Sandy Lean CLAY	15.1	11
9	1.5	Silty SAND (NP)	15.1	10
10.5	1.5	Silty SAND (NP)	16.5	29
12	1.5	Silty SAND (NP)	16.6	30
13.5	1.5	Silty SAND (NP)	16.4	28
15	1.5	Silty SAND (NP)	16.5	33
16.5	1.5	Silty SAND (NP)	16.8	38
18	1.5	Sandy SILT (NP)	17.7	43
19.5	1.5	Sandy SILT (NP)	18.8	59
21	1.5	SILT with Sand (NP)	18.8	53
22.5	1.5	Sandy SILT (NP)	18.8	51
24	1.5	Silty SAND (NP)	18.3	63
25.5	1.5	Silty SAND (NP)	18.3	75
27	1.5	Silty SAND (NP)	18.6	91
28.5	1.5	SILT with Sand (NP)	18.6	83
30	1.5	SILT with Sand (NP)	18.6	99

Table A-30: Site- Moirabo, Bhulta, Rupganj, Narayanganj

BH-213				
Depth to Sampler Tip (m)	**Layer Thickness (m)**	**Soil Classification**	**Unit Weight (kN/m^3)**	**SPT N-value (N_{60})**
1.5	1.5	Silty SAND (NP)	13.1	3
3	1.5	Sandy SILT (NP)	13.1	5
4.5	1.5	Sandy SILT (NP)	13.1	9
6	1.5	Fat CLAY	17.0	7
7.5	1.5	Fat CLAY	17.0	12
9	1.5	Sandy Lean CLAY	17.0	12
10.5	1.5	Sandy Lean CLAY	17.0	23
12	1.5	Fat CLAY	17.5	20
13.5	1.5	Fat CLAY	17.5	24
15	1.5	Fat CLAY	17.5	25
16.5	1.5	Fat CLAY	18.5	35
18	1.5	Lean CLAY	18.5	39
19.5	1.5	Silty SAND (NP)	17.1	35
21	1.5	Silty SAND (NP)	17	39
22.5	1.5	Silty SAND (NP)	17.9	49
24	1.5	Silty SAND (NP)	17.3	38
25.5	1.5	Silty SAND (NP)	18.2	46
27	1.5	Silty SAND (NP)	19.2	75
28.5	1.5	Silty SAND (NP)	19.3	75
30	1.5	Silty SAND (NP)	19.7	78
31.5	1.5	Silty SAND (NP)	19.4	85
33	1.5	Silty SAND (NP)	19.5	94
34.5	1.5	Silty SAND (NP)	19.2	94

Table A-31: Site- Awal Market, Sadupur, Kazipara, Bongayo, Savar, Dhaka

BH-230				
Depth to Sampler Tip (m)	**Layer Thickness (m)**	**Soil Classification**	**Unit Weight (kN/m^3)**	**SPT N-value (N_{60})**
1.5	1.5	Fat CLAY	14.6	10
3	1.5	Fat CLAY	14.6	19
4.5	1.5	Fat CLAY	14.6	14
6	1.5	Fat CLAY	14.6	21
7.5	1.5	Fat CLAY	14.6	38
9	1.5	Fat CLAY	14.6	21
10.5	1.5	Fat CLAY with Sand	15.1	16
12	1.5	Sandy SILT (NP)	15.1	21
13.5	1.5	Sandy SILT (NP)	15.1	21
15	1.5	Sandy SILT (NP)	15.1	21
16.5	1.5	Sandy SILT (NP)	16	24
18	1.5	Sandy SILT (NP)	16	30
19.5	1.5	Silty SAND (NP)	17	34
21	1.5	Silty SAND (NP)	17	26
22.5	1.5	Silty SAND (NP)	17.1	23
24	1.5	Silty SAND (NP)	16.7	20
25.5	1.5	Silty SAND (NP)	16.5	20
27	1.5	Silty SAND (NP)	16.7	20
28.5	1.5	Silty SAND (NP)	18	35
30	1.5	Silty SAND (NP)	17.9	36
31.5	1.5	Silty SAND (NP)	17.6	36
33	1.5	Silty SAND (NP)	18.2	39
34.5	1.5	Silty SAND (NP)	17.5	28
36	1.5	Silty SAND (NP)	18.7	36
37.5	1.5	Silty SAND (NP)	17.9	38
39	1.5	Silty SAND (NP)	18.8	55
40.5	1.5	Silty SAND (NP)	18.8	43
42	1.5	Silty SAND (NP)	18.7	44
43.5	1.5	Silty SAND (NP)	19	44
45	1.5	Silty SAND (NP)	18.7	41
46.5	1.5	Silty SAND (NP)	19	46
48	1.5	Silty SAND (NP)	19.6	49
49.5	1.5	Silty SAND (NP)	19.5	48
51	1.5	Silty SAND (NP)	19.2	60
52.5	1.5	Silty SAND (NP)	18.9	60
54	1.5	Silty SAND (NP)	18.9	56
55.5	1.5	Silty SAND (NP)	18.8	51
57	1.5	Silty SAND (NP)	19.2	65
58.5	1.5	Silty SAND (NP)	19.1	61
60	1.5	Silty SAND (NP)	19.1	72
61.5	1.5	Silty SAND (NP)	19.3	72
63	1.5	Silty SAND (NP)	18.8	56
64.5	1.5	Silty SAND (NP)	19.2	85
66	1.5	Silty SAND (NP)	19.6	75
67.5	1.5	Silty SAND (NP)	19.5	72
69	1.5	Silty SAND (NP)	19.5	125
70.5	1.5	Silty SAND (NP)	18.7	87
72	1.5	Silty SAND (NP)	19.3	87

Table A-32: Site- Bagber, Rupganj, Narayanganj

BH-236				
Depth to Sampler Tip (m)	**Layer Thickness (m)**	**Soil Classification**	**Unit Weight (kN/m^3)**	**SPT N-value (N_{60})**
1.5	1.5	Silty SAND (NP)	13.1	2
3	1.5	Lean CLAY with Sand	15.1	8
4.5	1.5	Fat CLAY	15.1	18
6	1.5	Fat CLAY	15.1	33
7.5	1.5	Fat CLAY	15.1	31
9	1.5	Fat CLAY	15.1	21
10.5	1.5	Fat CLAY	15.1	28
12	1.5	Fat CLAY	15.1	23
13.5	1.5	Fat CLAY	15.1	25
15	1.5	Lean CLAY	15.1	28
16.5	1.5	Fat CLAY	16.5	18
18	1.5	Fat CLAY	16.6	24
19.5	1.5	Fat CLAY	16.6	16
21	1.5	Fat CLAY	16.4	15
22.5	1.5	Elastic SILT	16.5	18
24	1.5	Fat CLAY	16.5	16
25.5	1.5	Fat CLAY	16.8	30
27	1.5	Fat CLAY	17.7	35
28.5	1.5	Fat CLAY	17.7	41
30	1.5	Lean CLAY	18.8	34
31.5	1.5	Fat CLAY	18.8	49
33	1.5	Fat CLAY	18.8	50
34.5	1.5	Fat CLAY with Sand	18.0	85
36	1.5	Sandy SILT (NP)	18.3	89
37.5	1.5	Silty SAND (NP)	19.7	99

Table A-33: Site- Barua (shilon para) khilkhet, Dhaka

BH-245				
Depth to Sampler Tip (m)	**Layer Thickness (m)**	**Soil Classification**	**Unit Weight (kN/m^3)**	**SPT N-value (N_{60})**
1.5	1.5	Fat CLAY	14.4	5
3	1.5	Poorly Graded SAND with Silt (NP)	14.9	2
4.5	1.5	Fat CLAY	14.9	5
6	1.5	Fat CLAY	14.9	10
7.5	1.5	Sandy SILT (NP)	14.9	17
9	1.5	Silty SAND (NP)	15.4	18
10.5	1.5	Silty SAND (NP)	16	26
12	1.5	Sandy SILT (NP)	16	26
13.5	1.5	Silty SAND (NP)	16.3	34
15	1.5	Silty SAND (NP)	17.1	40
16.5	1.5	Silty SAND (NP)	17.1	43
18	1.5	Silty SAND (NP)	17.6	63
19.5	1.5	Silty SAND (NP)	17.6	63
21	1.5	Silty SAND (NP)	17.7	53
22.5	1.5	Silty SAND (NP)	17.6	55
24	1.5	Silty SAND (NP)	18.4	63
25.5	1.5	Silty SAND (NP)	18.6	68
27	1.5	Silty SAND (NP)	18.6	85
28.5	1.5	Silty SAND (NP)	18.7	89
30	1.5	Silty SAND (NP)	18.4	99

Table A-34: Site- Kakabo, Birulia, Savar, Dhaka

BH-253				
Depth to Sampler Tip (m)	**Layer Thickness (m)**	**Soil Classification**	**Unit Weight (kN/m3)**	**SPT N-value (N_{60})**
1.5	1.5	Lean CLAY	14.4	7
3	1.5	Fat CLAY	14.4	13
4.5	1.5	Fat CLAY	14.4	16
6	1.5	Fat CLAY	14.4	21
7.5	1.5	Fat CLAY	14.4	15
9	1.5	Fat CLAY	14.4	13
10.5	1.5	Lean CLAY	14.4	11
12	1.5	Silty SAND (NP)	15.6	14
13.5	1.5	SILT (NP)	15.6	16
15	1.5	SILT (NP)	15.6	20
16.5	1.5	SILT (NP)	15.6	39
18	1.5	SILT (NP)	15.6	34
19.5	1.5	SILT (NP)	15.6	38
21	1.5	SILT (NP)	15.6	28
22.5	1.5	SILT (NP)	15.6	19
24	1.5	Silty SAND (NP)	16.5	36
25.5	1.5	Silty SAND (NP)	16.5	38
27	1.5	Silty SAND (NP)	16.6	33
28.5	1.5	Silty SAND (NP)	16.4	31
30	1.5	Silty SAND (NP)	17.1	25
31.5	1.5	Silty SAND (NP)	17.9	33
33	1.5	Silty SAND (NP)	18.4	39
34.5	1.5	Silty SAND (NP)	17.5	35
36	1.5	Silty SAND (NP)	17.5	36
37.5	1.5	Silty SAND (NP)	17.3	33
39	1.5	Silty SAND (NP)	19	49
40.5	1.5	Silty SAND (NP)	19.4	63
42	1.5	Silty SAND (NP)	19.3	75
43.5	1.5	Silty SAND (NP)	19.9	80
45	1.5	Silty SAND (NP)	19.5	59
46.5	1.5	Silty SAND (NP)	19.6	63
48	1.5	SILT (NP)	19.6	83
49.5	1.5	Silty SAND (NP)	19.6	82
51	1.5	Silty SAND (NP)	19.3	89

Table A-35: Site- Rajuk Land Area, Zinda Park, Gazipur

BH-263				
Depth to Sampler Tip (m)	**Layer Thickness (m)**	**Soil Classification**	**Unit Weight (kN/m^3)**	**SPT N-value (N_{60})**
1.5	1.5	Fat CLAY	16.5	4
3	1.5	Silty SAND (NP)	15.9	7
4.5	1.5	Lean CLAY	16	3
6	1.5	Lean CLAY	16	2
7.5	1.5	Fat CLAY with Sand	16	2
9	1.5	Sandy Lean CLAY	16	4
10.5	1.5	Clayey SAND	16	15
12	1.5	Fat CLAY	17.5	24
13.5	1.5	Lean CLAY	17.5	34
15	1.5	Lean CLAY	18.5	28
16.5	1.5	Lean CLAY	18.5	39
18	1.5	Lean CLAY with Sand	18.5	38
19.5	1.5	Clayey SAND	18.5	69
21	1.5	Silty SAND (NP)	19	65
22.5	1.5	Silty SAND (NP)	19.7	75
24	1.5	Silty SAND (NP)	18.5	72
25.5	1.5	Silty SAND (NP)	18.8	85
27	1.5	Silty SAND (NP)	19	85
28.5	1.5	Silty SAND (NP)	18.4	82
30	1.5	Silty SAND (NP)	19.7	139

Table A-36: Site- Teromukh bridge, Uttarkhan, Dhaka

BH-275				
Depth to Sampler Tip (m)	**Layer Thickness (m)**	**Soil Classification**	**Unit Weight (kN/m^3)**	**SPT N-value (N_{60})**
1.5	1.5	Fat CLAY	15	5
3	1.5	Fat CLAY	16.6	7
4.5	1.5	Fat CLAY	16.6	9
6	1.5	Fat CLAY	16.6	8
7.5	1.5	Fat CLAY	16.6	6
9	1.5	Fat CLAY	16.6	7
10.5	1.5	SILT	16.6	9
12	1.5	SILT	17.7	34
13.5	1.5	SILT	17.7	35
15	1.5	Fat CLAY	17.7	28
16.5	1.5	Fat CLAY	17.7	29
18	1.5	Fat CLAY	17.7	21
19.5	1.5	Fat CLAY	17.7	24
21	1.5	SILT with Sand (NP)	17.7	35
22.5	1.5	Lean CLAY	17.7	35
24	1.5	Lean CLAY	17.7	38
25.5	1.5	Lean CLAY	16.8	14
27	1.5	Fat CLAY	17.5	23
28.5	1.5	SILT	18.8	39
30	1.5	Lean CLAY	19.1	61
31.5	1.5	SILT	17.7	46
33	1.5	SILT (NP)	17.5	78
34.5	1.5	SILT (NP)	18.8	85
36	1.5	Silty SAND (NP)	19	94
37.5	1.5	Silty SAND (NP)	19	104

Table A-37: Site- Ashulia, Savar, Dhaka

BH-286				
Depth to Sampler Tip (m)	**Layer Thickness (m)**	**Soil Classification**	**Unit Weight (kN/m^3)**	**SPT N-value (N_{60})**
1.5	1.5	Poorly Graded SAND with Silt (NP)	14.5	3
3	1.5	Silty SAND (NP)	14.5	4
4.5	1.5	Poorly Graded SAND with Silt (NP)	14.8	4
6	1.5	Poorly Graded SAND with Silt (NP)	15.1	6
7.5	1.5	Fat CLAY	15.1	5
9	1.5	SILT (NP)	16.5	15
10.5	1.5	SILT (NP)	16.5	18
12	1.5	SILT (NP)	17.5	21
13.5	1.5	SILT (NP)	17.5	25
15	1.5	SILT (NP)	17.5	20
16.5	1.5	SILT (NP)	17.5	18
18	1.5	SILT (NP)	18.5	16
19.5	1.5	SILT (NP)	18.5	34
21	1.5	SILT (NP)	18.5	36
22.5	1.5	SILT (NP)	18.1	39
24	1.5	SILT (NP)	18.1	45
25.5	1.5	Silty SAND (NP)	18.1	51
27	1.5	Silty SAND (NP)	18.6	67
28.5	1.5	Silty SAND (NP)	19.6	65
30	1.5	Silty SAND (NP)	19.1	72
31.5	1.5	Silty SAND (NP)	18.9	75
33	1.5	Silty SAND (NP)	18.5	55
34.5	1.5	Fat CLAY	17.1	9
36	1.5	Silty SAND (NP)	18.7	54
37.5	1.5	Silty SAND (NP)	19	83
39	1.5	Silty SAND (NP)	18.7	78
40.5	1.5	Silty SAND (NP)	19.5	85
42	1.5	Silty SAND (NP)	19.6	85
43.5	1.5	Silty SAND (NP)	19.2	99

Table A-38: Site- BTCL Tongi, Gazipur, Dhaka

BH-289				
Depth to Sampler Tip (m)	**Layer Thickness (m)**	**Soil Classification**	**Unit Weight (kN/m^3)**	**SPT N-value (N_{60})**
1.5	1.5	Fat CLAY	15.4	4
3	1.5	Fat CLAY	15.4	11
4.5	1.5	SILT	15.4	10
6	1.5	Lean CLAY	15.4	12
7.5	1.5	Lean CLAY	15.4	13
9	1.5	Lean CLAY	15.4	17
10.5	1.5	SILT	15.4	19
12	1.5	Silty SAND (NP)	17.8	28
13.5	1.5	Silty SAND (NP)	18.1	30
15	1.5	Silty SAND (NP)	18.5	29
16.5	1.5	Silty SAND (NP)	18.4	31
18	1.5	SILT	18	21
19.5	1.5	SILT	18	23
21	1.5	Lean CLAY	18	25
22.5	1.5	Fat CLAY	18	26
24	1.5	Fat CLAY	18	17
25.5	1.5	Elastic SILT	18	18
27	1.5	Lean CLAY	18	24
28.5	1.5	Fat CLAY	18	25
30	1.5	Fat CLAY	18	30
31.5	1.5	Fat CLAY	18.5	30
33	1.5	Lean CLAY	18.5	32
34.5	1.5	Lean CLAY	18.5	32
36	1.5	Lean CLAY	18.5	54
37.5	1.5	Fat CLAY	18.5	65
39	1.5	Fat CLAY	18.5	58
40.5	1.5	Fat CLAY	18.5	56
42	1.5	Fat CLAY	18.5	56
43.5	1.5	Lean CLAY	18.5	44
45	1.5	Lean CLAY	18.5	50
46.5	1.5	Lean CLAY	18.5	22
48	1.5	Lean CLAY	18.5	28
49.5	1.5	Silty SAND (NP)	20	83
51	1.5	Silty SAND (NP)	20	115
52.5	1.5	Silty SAND (NP)	20	200

Table A-39: Site- Bhasania Primary School, Gazipur

BH-293				
Depth to Sampler Tip (m)	**Layer Thickness (m)**	**Soil Classification**	**Unit Weight (kN/m^3)**	**SPT N-value (N_{60})**
1.5	1.5	Fat CLAY	15.4	7
3	1.5	Fat CLAY	15.4	9
4.5	1.5	Fat CLAY	15.4	10
6	1.5	Silty SAND (NP)	15.4	12
7.5	1.5	Silty SAND (NP)	16.4	27
9	1.5	Silty SAND (NP)	16.7	36
10.5	1.5	Silty SAND (NP)	16.8	34
12	1.5	Silty SAND (NP)	16.4	34
13.5	1.5	Silty SAND (NP)	17.4	51
15	1.5	Silty SAND (NP)	18.2	79
16.5	1.5	Silty SAND (NP)	17.4	67
18	1.5	Silty SAND (NP)	18.2	75
19.5	1.5	Silty SAND (NP)	18.1	60
21	1.5	Silty SAND (NP)	18.2	67
22.5	1.5	Silty SAND (NP)	18.7	91
24	1.5	Silty SAND (NP)	18	63
25.5	1.5	Silty SAND (NP)	19	134
27	1.5	Silty SAND (NP)	19.4	136
28.5	1.5	Silty SAND (NP)	18.8	125
30	1.5	Silty SAND (NP)	19	139

Table A-40: Site- Madhobi Sheltech Project, Plot No. 63, Katgora, Ashulia

BH-298				
Depth to Sampler Tip (m)	**Layer Thickness (m)**	**Soil Classification**	**Unit Weight (kN/m^3)**	**SPT N-value (N_{60})**
1.5	1.5	Fat CLAY	15.5	8
3	1.5	Fat CLAY	15.5	11
4.5	1.5	Fat CLAY	15.5	14
6	1.5	Fat CLAY	15.5	15
7.5	1.5	Sandy Lean CLAY	15.5	12
9	1.5	SILT (NP)	16.1	14
10.5	1.5	SILT (NP)	16.1	15
12	1.5	Silty SAND (NP)	15.7	18
13.5	1.5	Silty SAND (NP)	16.1	21
15	1.5	Silty SAND (NP)	16.2	21
16.5	1.5	Silty SAND (NP)	17	28
18	1.5	Silty SAND (NP)	16.9	31
19.5	1.5	Silty SAND (NP)	17.1	33
21	1.5	Silty SAND (NP)	17.6	36
22.5	1.5	Silty SAND (NP)	15.9	24
24	1.5	Silty SAND (NP)	16.8	33
25.5	1.5	Silty SAND (NP)	16.8	31
27	1.5	Silty SAND (NP)	17	34
28.5	1.5	Silty SAND (NP)	18.3	46
30	1.5	Silty SAND (NP)	17.8	30
31.5	1.5	Silty SAND (NP)	18.6	39
33	1.5	Silty SAND (NP)	17.7	35
34.5	1.5	Silty SAND (NP)	18.4	40
36	1.5	Silty SAND (NP)	17.9	43
37.5	1.5	Silty SAND (NP)	18.7	44
39	1.5	Silty SAND (NP)	19.5	55
40.5	1.5	Silty SAND (NP)	18.8	67
42	1.5	Silty SAND (NP)	18.6	59
43.5	1.5	Silty SAND (NP)	18.6	63
45	1.5	Silty SAND (NP)	18.9	50
46.5	1.5	Silty SAND (NP)	18.9	63
48	1.5	Silty SAND (NP)	18.5	65
49.5	1.5	Silty SAND (NP)	18.8	56
51	1.5	Silty SAND (NP)	18.8	75
52.5	1.5	Silty SAND (NP)	18.8	55
54	1.5	Silty SAND (NP)	19.6	94
55.5	1.5	Silty SAND (NP)	19.2	89
57	1.5	Silty SAND (NP)	19.9	134

Table A-41: Site- Victoria Hondachiam Interbita School, Kaliganj, Gazipur

BH-311				
Depth to Sampler Tip (m)	**Layer Thickness (m)**	**Soil Classification**	**Unit Weight (kN/m^3)**	**SPT N-value (N_{60})**
1.5	1.5	SILT	14.4	3
3	1.5	SILT	14.4	5
4.5	1.5	Fat CLAY	14.4	4
6	1.5	SILT	14.4	2
7.5	1.5	Elastic SILT	15.4	5
9	1.5	SILT	15.4	5
10.5	1.5	SILT (NP)	15.4	14
12	1.5	SILT	15.4	6
13.5	1.5	SILT	16.5	3
15	1.5	SILT	16.5	1
16.5	1.5	Lean CLAY	16.5	3
18	1.5	Lean CLAY	17.4	4
19.5	1.5	Fat CLAY	17.4	3
21	1.5	Fat CLAY	17.4	3
22.5	1.5	Lean CLAY	17.4	3
24	1.5	Fat CLAY	18	4
25.5	1.5	Fat CLAY	18	10
27	1.5	Lean CLAY with Sand	18	13
28.5	1.5	Silty SAND (NP)	19.2	89
30	1.5	Silty SAND (NP)	19.4	107
31.5	1.5	Silty SAND (NP)	19	104

Table A-42: Site- Kunia Moddho para Jame mosjid ,Gazipur

BH-320				
Depth to Sampler Tip (m)	**Layer Thickness (m)**	**Soil Classification**	**Unit Weight (kN/m^3)**	**SPT N-value (N_{60})**
1.5	1.5	Silty SAND (NP)	14.2	2
3	1.5	Poorly graded SAND with Silt	14.5	4
4.5	1.5	Fat CLAY	15.3	10
6	1.5	Fat CLAY	15.3	11
7.5	1.5	Fat CLAY	15.3	13
9	1.5	Fat CLAY	15.3	13
10.5	1.5	Fat CLAY	16.1	16
12	1.5	SILT	16.1	15
13.5	1.5	Fat CLAY	16.1	23
15	1.5	Fat CLAY	16.1	20
16.5	1.5	SILT	16.9	55
18	1.5	Lean CLAY	16.9	43
19.5	1.5	Fat CLAY	16.9	23
21	1.5	Fat CLAY	16.9	33
22.5	1.5	Fat CLAY	16.9	29
24	1.5	Lean CLAY	17.5	34
25.5	1.5	Lean CLAY	17.5	41
27	1.5	Lean CLAY	17.5	33
28.5	1.5	Fat CLAY	17.5	38
30	1.5	Fat CLAY	17.5	40
31.5	1.5	Lean CLAY	17.5	44
33	1.5	Fat CLAY	17.5	40
34.5	1.5	SILT (NP)	17.5	94
36	1.5	SILT (NP)	17.5	104
37.5	1.5	SILT (NP)	17.5	85

Table A-43: Site- Kudaba, Pubail, Gazipur

BH-320				
Depth to Sampler Tip (m)	**Layer Thickness (m)**	**Soil Classification**	**Unit Weight (kN/m^3)**	**SPT N-value (N_{60})**
1.5	1.5	Lean CLAY	14.3	4
3	1.5	Fat CLAY	14.6	17
4.5	1.5	Fat CLAY	14.6	17
6	1.5	Fat CLAY	15.1	21
7.5	1.5	Lean CLAY with Sand	15.1	10
9	1.5	SILT with Sand (NP)	15.1	14
10.5	1.5	SILT (NP)	15.3	24
12	1.5	Lean CLAY	16.1	18
13.5	1.5	Silty SAND (NP)	16.8	33
15	1.5	Silty SAND (NP)	16.3	38
16.5	1.5	Silty SAND (NP)	17.9	60
18	1.5	Silty SAND (NP)	17.6	63
19.5	1.5	Silty SAND (NP)	18.1	60
21	1.5	Fat CLAY	17.5	20
22.5	1.5	Elastic SILT	17.5	16
24	1.5	Fat CLAY	17.5	23
25.5	1.5	SILT	17.5	21
27	1.5	SILT (NP)	17.5	24
28.5	1.5	SILT (NP)	18.5	53
30	1.5	SILT (NP)	18.5	78
31.5	1.5	Fat CLAY	18.5	26
33	1.5	Fat CLAY	18.5	28
34.5	1.5	Lean CLAY	18.5	29
36	1.5	SILT	18.5	46
37.5	1.5	Fat CLAY	18.5	33
39	1.5	SILT with Sand (NP)	18.5	45
40.5	1.5	Sandy SILT (NP)	18.5	83
42	1.5	Elastic SILT	18.5	59
43.5	1.5	Fat CLAY	18.5	33
45	1.5	Fat CLAY	18.5	24
46.5	1.5	Fat CLAY	18.5	15
48	1.5	Fat CLAY	19	18
49.5	1.5	Lean CLAY	19	85
51	1.5	Fat CLAY with Sand	19	89
52.5	1.5	Fat CLAY with Sand	19	89

Table A-44: Site- Tajpur, Model High School, Ashulia, Savar

BH-329				
Depth to Sampler Tip (m)	**Layer Thickness (m)**	**Soil Classification**	**Unit Weight (kN/m^3)**	**SPT N-value (N_{60})**
1.5	1.5	Fat CLAY	14.6	2
3	1.5	Fat CLAY	14.6	8
4.5	1.5	Fat CLAY	15.1	11
6	1.5	Fat CLAY with Sand	15.1	8
7.5	1.5	Fat CLAY with Sand	15.1	10
9	1.5	Silty SAND (NP)	14	7
10.5	1.5	SILT with Sand (NP)	15.1	16
12	1.5	Silty SAND (NP)	16.3	25
13.5	1.5	Silty SAND (NP)	16.8	28
15	1.5	Silty SAND (NP)	17	30
16.5	1.5	Silty SAND (NP)	16.7	29
18	1.5	Silty SAND (NP)	17.1	30
19.5	1.5	Silty SAND (NP)	18.1	43
21	1.5	Silty SAND (NP)	17.8	41
22.5	1.5	Silty SAND (NP)	16.8	29
24	1.5	Silty SAND (NP)	17.9	40
25.5	1.5	Silty SAND (NP)	18.2	43
27	1.5	SILT (NP)	18.2	45
28.5	1.5	Silty SAND (NP)	18.1	38
30	1.5	Silty SAND (NP)	18.2	34
31.5	1.5	Silty SAND (NP)	18.2	36
33	1.5	Silty SAND (NP)	18.3	40
34.5	1.5	Silty SAND (NP)	18.6	56
36	1.5	Silty SAND (NP)	18.9	48
37.5	1.5	Silty SAND (NP)	19.7	75
39	1.5	Silty SAND (NP)	18.1	38
40.5	1.5	Silty SAND (NP)	19.2	75
42	1.5	Silty SAND (NP)	19	78
43.5	1.5	Silty SAND (NP)	20.1	125
45	1.5	Lean CLAY	20.1	117
46.5	1.5	Lean CLAY	20.1	94

Table A-45: Site- Stand Housing, Dehra, Ashulia, Dhaka

BH-341				
Depth to Sampler Tip (m)	**Layer Thickness (m)**	**Soil Classification**	**Unit Weight (kN/m^3)**	**SPT N-value (N_{60})**
1.5	1.5	Fat CLAY	14.4	5
3	1.5	Fat CLAY	14.4	6
4.5	1.5	Fat CLAY	14.4	4
6	1.5	Fat CLAY	14.4	5
7.5	1.5	Fat CLAY	14.4	11
9	1.5	Fat CLAY	14.4	13
10.5	1.5	Fat CLAY	14.4	15
12	1.5	Clayey SAND	14.4	9
13.5	1.5	Sandy Lean CLAY	14.4	11
15	1.5	Sandy Lean CLAY	15.4	14
16.5	1.5	Silty SAND (NP)	15.4	33
18	1.5	Silty SAND (NP)	15.4	33
19.5	1.5	Silty SAND (NP)	16.4	34
21	1.5	Silty SAND (NP)	16.7	36
22.5	1.5	Silty SAND (NP)	16.7	30
24	1.5	Silty SAND (NP)	16.6	30
25.5	1.5	Silty SAND (NP)	16.6	38
27	1.5	Silty SAND (NP)	17.4	39
28.5	1.5	Silty SAND (NP)	17.7	39
30	1.5	Silty SAND (NP)	18.4	33
31.5	1.5	Silty SAND (NP)	17.3	34
33	1.5	Silty SAND (NP)	17.1	41
34.5	1.5	Silty SAND (NP)	18.4	60
36	1.5	Silty SAND (NP)	18.7	60
37.5	1.5	Silty SAND (NP)	18.6	63
39	1.5	Silty SAND (NP)	19.5	68
40.5	1.5	Silty SAND (NP)	19.4	82
42	1.5	Silty SAND (NP)	18.9	89
43.5	1.5	Silty SAND (NP)	20.1	82

Table A-46: Site- Maleker Bari Road, Sakrauri, Gacha, Joydebpur, Gazipur

BH-347				
Depth to Sampler Tip (m)	**Layer Thickness (m)**	**Soil Classification**	**Unit Weight (kN/m^3)**	**SPT N-value (N_{60})**
1.5	1.5	Fat CLAY	17	8
3	1.5	Fat CLAY	17	13
4.5	1.5	Fat CLAY	17	13
6	1.5	Fat CLAY	17.8	15
7.5	1.5	Lean CLAY with Sand	17.8	20
9	1.5	Fat CLAY	17.8	36
10.5	1.5	Lean CLAY	17.8	23
12	1.5	SILT with Sand (NP)	17.8	25
13.5	1.5	Sandy SILT (NP)	17.8	28
15	1.5	Fat CLAY	17.8	31
16.5	1.5	Fat CLAY	17.8	30
18	1.5	Fat CLAY	17.8	35
19.5	1.5	Fat CLAY	17.8	38
21	1.5	Lean CLAY with Sand	17.8	55
22.5	1.5	Fat CLAY	17.8	28
24	1.5	Fat CLAY	17.8	38
25.5	1.5	Fat CLAY	17.8	41
27	1.5	Fat CLAY	17.8	53
28.5	1.5	Fat CLAY	17.8	50
30	1.5	Lean CLAY	17.8	40
31.5	1.5	Fat CLAY	17.8	39
33	1.5	Lean CLAY	17.8	44
34.5	1.5	Fat CLAY	18	58
36	1.5	Lean CLAY	18	50
37.5	1.5	Lean CLAY	18	59
39	1.5	Fat CLAY	18	67
40.5	1.5	Lean CLAY with Sand	18	54
42	1.5	Lean CLAY	18	50
43.5	1.5	Fat CLAY with Sand	18	41
45	1.5	Sandy Fat CLAY	19	31
46.5	1.5	Silty SAND (NP)	19	83
48	1.5	Silty SAND (NP)	19.3	91
49.5	1.5	Silty SAND (NP)	19.6	99

Table A-47: Site- Baluchakuli, Gazipur

BH-361				
Depth to Sampler Tip (m)	**Layer Thickness (m)**	**Soil Classification**	**Unit Weight (kN/m^3)**	**SPT N-value (N_{60})**
1.5	1.5	Fat CLAY	15.1	9
3	1.5	Fat CLAY	15.1	8
4.5	1.5	Fat CLAY	15.1	7
6	1.5	Fat CLAY	15.1	10
7.5	1.5	Fat CLAY	15.1	11
9	1.5	Fat CLAY	15.1	13
10.5	1.5	Fat CLAY with Sand	15.6	19
12	1.5	Silty SAND (NP)	15.6	16
13.5	1.5	Silty SAND (NP)	16	19
15	1.5	Silty SAND (NP)	16.5	20
16.5	1.5	Fat CLAY	17.5	15
18	1.5	Fat CLAY	17.5	25
19.5	1.5	Fat CLAY	17.5	24
21	1.5	Fat CLAY	17.5	24
22.5	1.5	SILT	17.5	36
24	1.5	Lean CLAY	19.5	23
25.5	1.5	Fat CLAY	19.5	28
27	1.5	Fat CLAY	19.5	30
28.5	1.5	Lean CLAY	19.5	85
30	1.5	Silty SAND (NP)	20.2	82
31.5	1.5	Silty SAND (NP)	20.4	89

Table A-48: Site- Tetultala, Eatahata, Kolabagan, Gazipur

BH-369				
Depth to Sampler Tip (m)	**Layer Thickness (m)**	**Soil Classification**	**Unit Weight (kN/m^3)**	**SPT N-value (N_{60})**
1.5	1.5	Fat CLAY	17	13
3	1.5	Fat CLAY	17	9
4.5	1.5	Fat CLAY	17	19
6	1.5	Fat CLAY	17	25
7.5	1.5	Fat CLAY	17	25
9	1.5	Fat CLAY	17	18
10.5	1.5	Fat CLAY	17	21
12	1.5	Sandy SILT (NP)	17	38
13.5	1.5	SILT with Sand (NP)	17	40
15	1.5	Silty SAND (NP)	17.4	29
16.5	1.5	Silty SAND (NP)	18.1	35
18	1.5	Fat CLAY	18.1	28
19.5	1.5	Fat CLAY	18.1	28
21	1.5	Fat CLAY	18.1	29
22.5	1.5	Fat CLAY	18.1	16
24	1.5	Fat CLAY	18.1	23
25.5	1.5	Fat CLAY	18.1	28
27	1.5	SILT	18.1	63
28.5	1.5	Lean CLAY	18.1	36
30	1.5	Fat CLAY	18.1	30
31.5	1.5	Fat CLAY	18.1	31
33	1.5	Fat CLAY	18.1	28
34.5	1.5	Fat CLAY	18.1	29
36	1.5	Sandy SILT (NP)	18.1	50
37.5	1.5	Sandy SILT (NP)	18.1	83
39	1.5	Silty SAND (NP)	18.1	91
40.5	1.5	Silty SAND (NP)	18.1	99

Table A-48: Site- Ambag Govt. Primary School, Konabari, Gazipur

BH-376				
Depth to Sampler Tip (m)	**Layer Thickness (m)**	**Soil Classification**	**Unit Weight (kN/m^3)**	**SPT N-value (N_{60})**
1.5	1.5	Fat CLAY	15	5
3	1.5	Fat CLAY	15.5	11
4.5	1.5	Fat CLAY with Sand	15.5	15
6	1.5	Fat CLAY with Sand	15.5	18
7.5	1.5	Sandy Lean CLAY	15.5	12
9	1.5	Silty SAND (NP)	15.7	21
10.5	1.5	Silty SAND (NP)	15.4	19
12	1.5	Silty SAND (NP)	15.3	20
13.5	1.5	Silty SAND (NP)	15	16
15	1.5	Silty SAND (NP)	13.8	16
16.5	1.5	Silty SAND (NP)	17.2	29
18	1.5	Silty SAND (NP)	16.5	34
19.5	1.5	Silty SAND (NP)	17.4	39
21	1.5	Silty SAND (NP)	16.4	38
22.5	1.5	Sandy SILT (NP)	17	28
24	1.5	Silty SAND (NP)	18.2	35
25.5	1.5	Silty SAND (NP)	17.9	35
27	1.5	Silty SAND (NP)	18.6	43
28.5	1.5	Silty SAND (NP)	17.7	38
30	1.5	Silty SAND (NP)	18.4	40
31.5	1.5	Silty SAND (NP)	18.7	51
33	1.5	Silty SAND (NP)	18.6	63
34.5	1.5	Silty SAND (NP)	19.2	82
36	1.5	Silty SAND (NP)	19.2	75
37.5	1.5	Silty SAND (NP)	19.1	87
39	1.5	Fat CLAY	19.1	94
40.5	1.5	Lean CLAY	19.1	78
42	1.5	Lean CLAY	19.1	50
43.5	1.5	Lean CLAY with Sand	19.1	43
45	1.5	Lean CLAY	20	41
46.5	1.5	Lean CLAY	20	44
48	1.5	Lean CLAY	20	87
49.5	1.5	Fat CLAY	20	85
51	1.5	Silty SAND (NP)	20	134

Table A-48: Site- Gazipur sadar upojilla, Gazipur

BH-380				
Depth to Sampler Tip (m)	**Layer Thickness (m)**	**Soil Classification**	**Unit Weight (kN/m^3)**	**SPT N-value (N_{60})**
1.5	1.5	Fat CLAY	14.4	2
3	1.5	Fat CLAY	14.4	5
4.5	1.5	Fat CLAY	14.4	10
6	1.5	Fat CLAY	14.4	11
7.5	1.5	Fat CLAY	15	11
9	1.5	Lean CLAY	15	15
10.5	1.5	Lean CLAY	15	20
12	1.5	Silty SAND (NP)	17.2	26
13.5	1.5	Silty SAND (NP)	17.3	33
15	1.5	Lean CLAY	16.6	29
16.5	1.5	Fat CLAY	16.6	18
18	1.5	Fat CLAY	16.6	28
19.5	1.5	SILT	17.6	39
21	1.5	Elastic SILT	17.6	30
22.5	1.5	Lean CLAY	18	46
24	1.5	Sandy SILT	18.5	50
25.5	1.5	Elastic SILT	18.5	43
27	1.5	Fat CLAY	18.5	26
28.5	1.5	Fat CLAY	19	28
30	1.5	Fat CLAY	19	35
31.5	1.5	Lean CLAY	19	19
33	1.5	SILT	19	67
34.5	1.5	Fat CLAY	19	28
36	1.5	Fat CLAY	19	21
37.5	1.5	Lean CLAY	19	25
39	1.5	Silty SAND (NP)	19	54
40.5	1.5	Silty SAND (NP)	18.8	63
42	1.5	Silty SAND (NP)	18.8	67
43.5	1.5	Silty SAND (NP)	19.4	110

Appendix B

Shear wave velocity profile at different locations

Figure B-1: Site- Aligonj Madrasa ghat, Fatulla, Narayanganj (BH006), Baghair High School, Keraniganj (BH010) and Bauniya Bazar jame mosque Turag ,Dhaka (BH042)

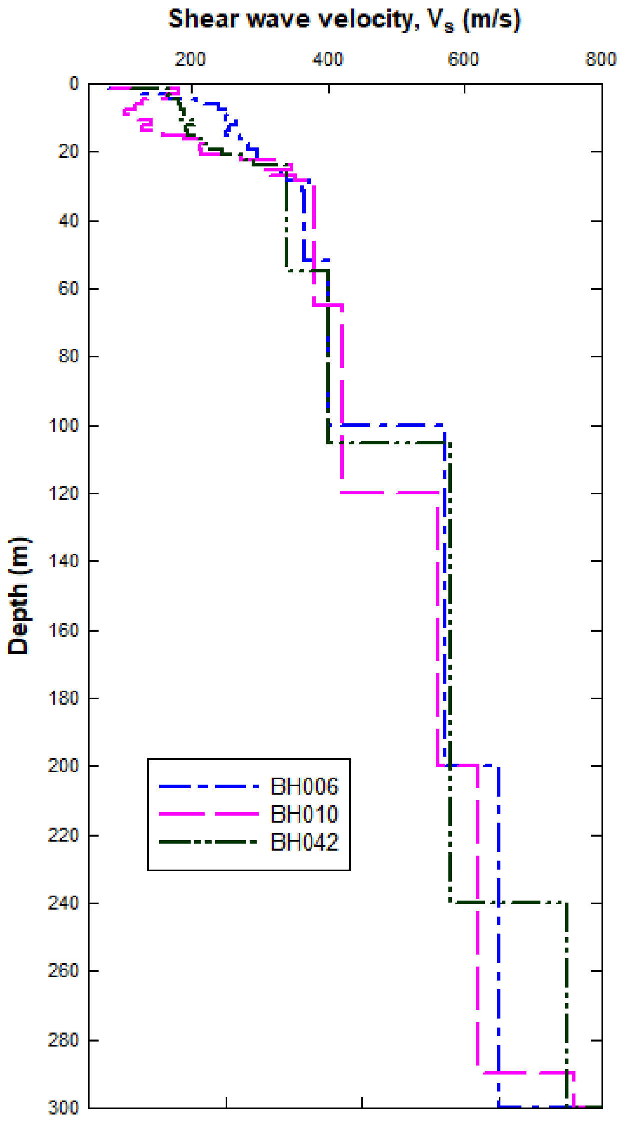


Figure B-2: Site- Sher-E Bangla Nagar Agricultural University, Dhaka (BH024), Block-M, Road-4, Sector-4, Aftab Nagar, Dhaka (BH027) and Gulshan Central Mosque (Ajad Mosque), Gulshan, Dhaka (BH029)

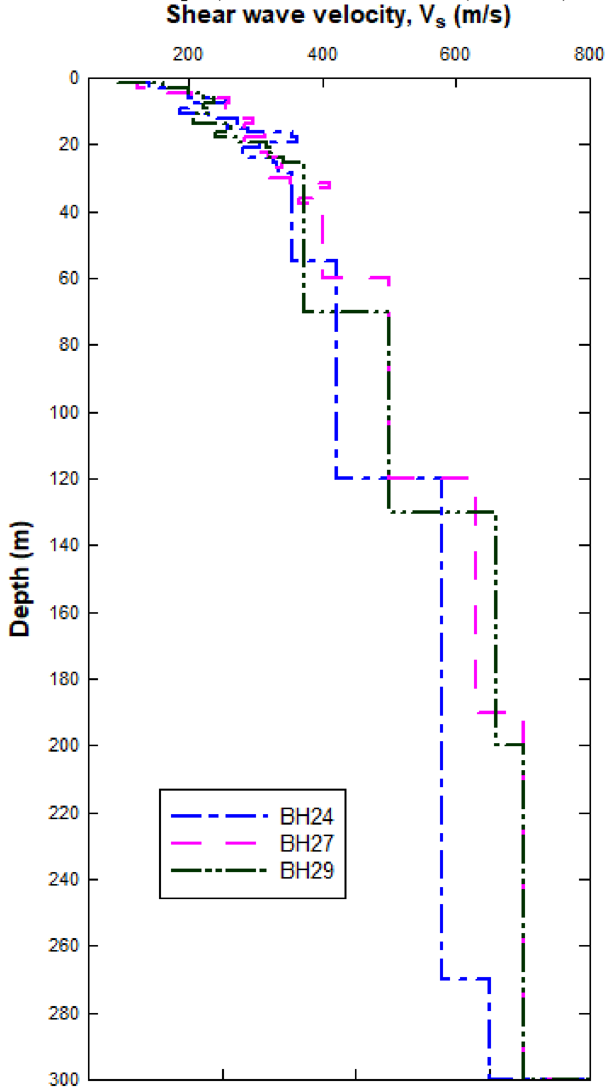


Figure B-3: Site- Gakulnagar Eidgah math, Ashulia, Savar, Dhaka (BH045), Khilgaon Primary School, Pubail, Gazipur (BH049) and Amulla Model Town 1 No. Road, Amuli, Demra, Dhaka (BH018)

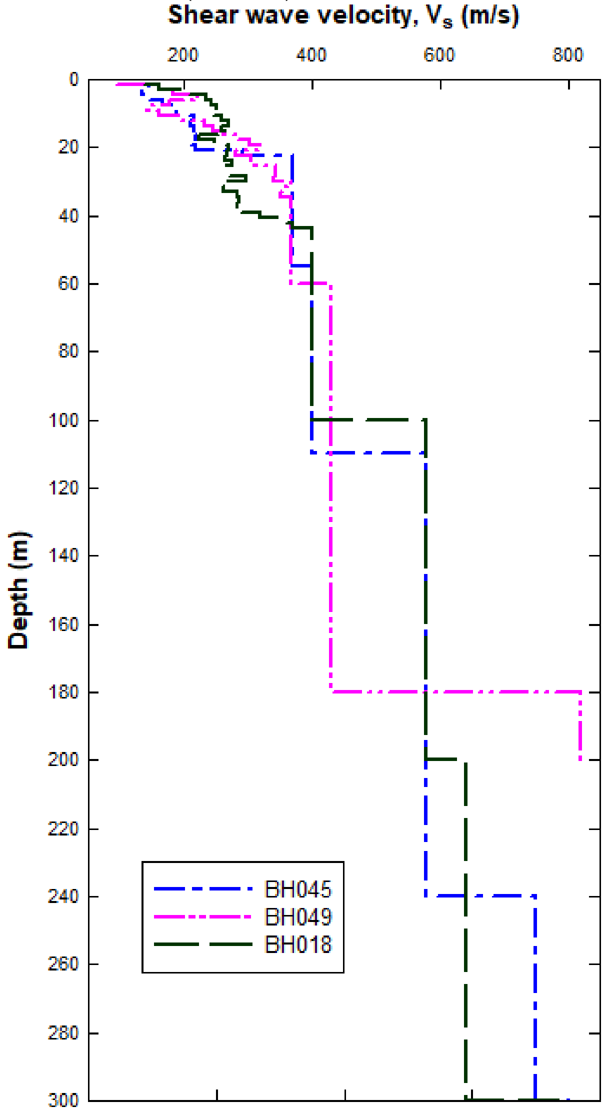


Figure B-4: Site- Nyebbari, Uttar Salna, Gazipur, Dhaka (BH061), Govt Hazi Ibrahim School and College, Bandar, Narayanganj (BH071) and Rowshan Ara girls high school, Beraid, Badda, Dhaka (BH209)

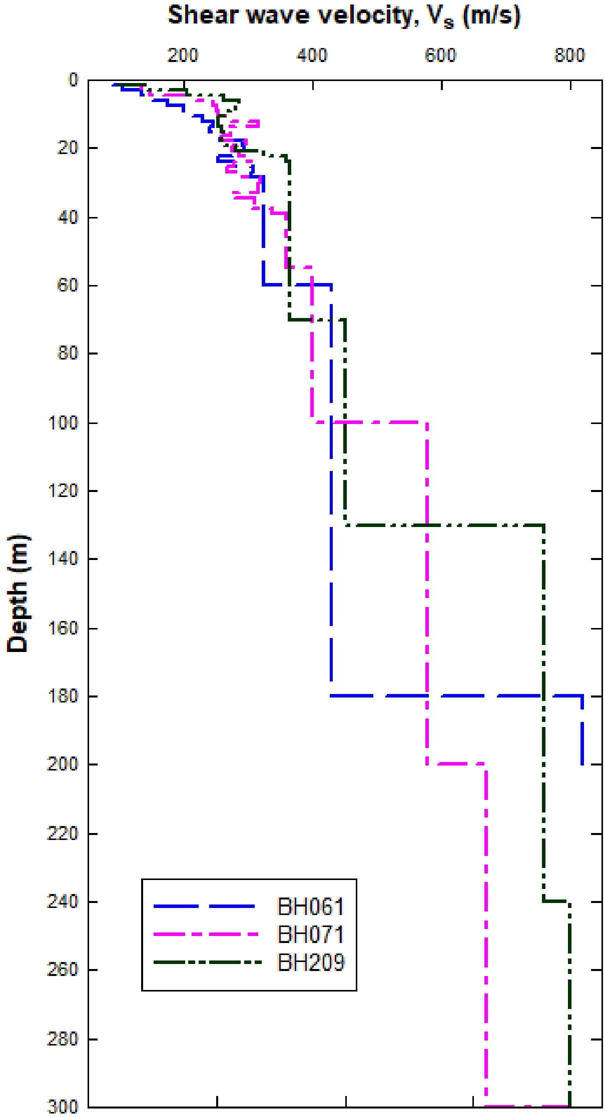


Figure B-5: Site- 122 No Goalkhali Poshchim Govt. Primary School, Keraniganj, Dhaka (BH112), Doleshwar Government Primary School, Keraniganj, Dhaka (BH116) and Kharakandi Govt. Primary School, Keraniganj (BH139)

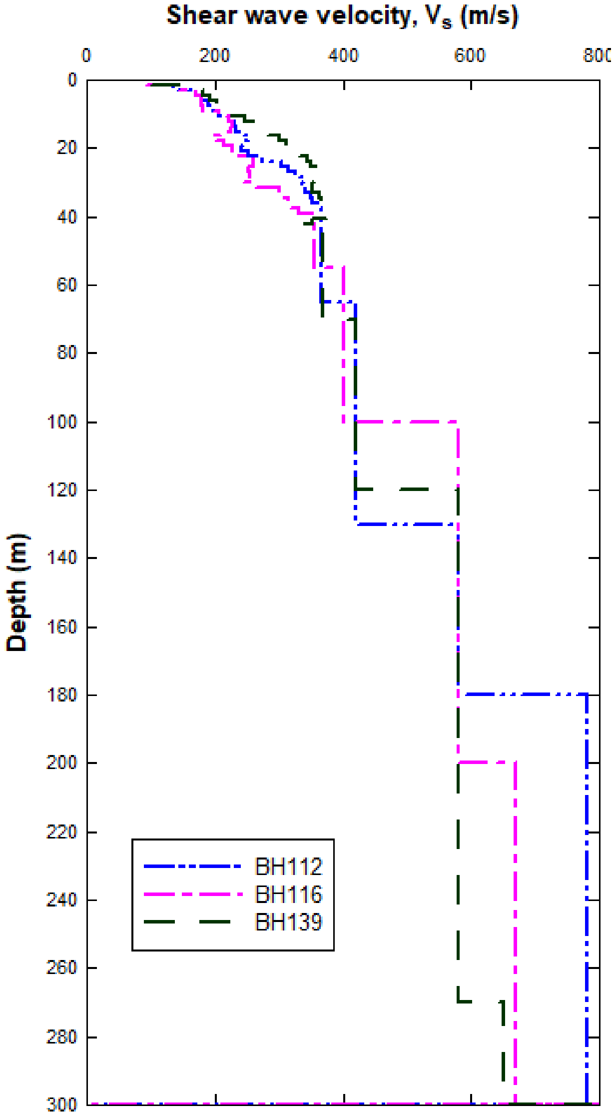


Figure B-6: Site- Sonali paper mills Ltd, Tarabo, Narayanganj (BH150) and Maleker Bari Road, Sakrauri, Gacha, Joydebpur, Gazipur (BH347)

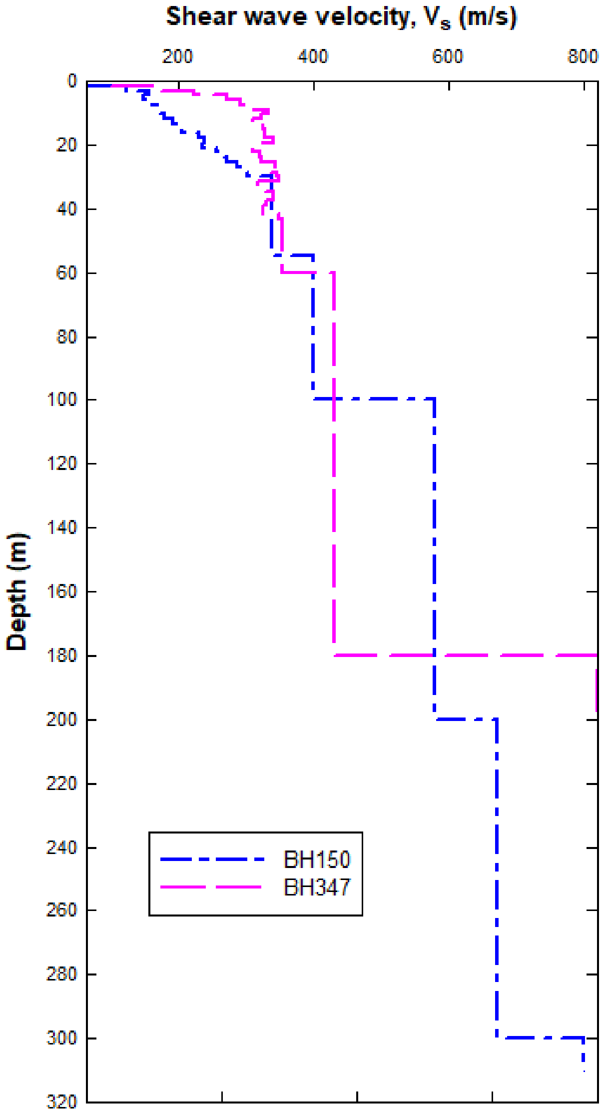


Figure B-7: Site- Modderchor Govt. Primary School, Keraniganj (BH160), Kakrail Mosque (Tablig Jamat), Dhaka (BH163) and Baitunnur lalmia mosque,Golakandail, Rupganj, Narayanganj (BH185)

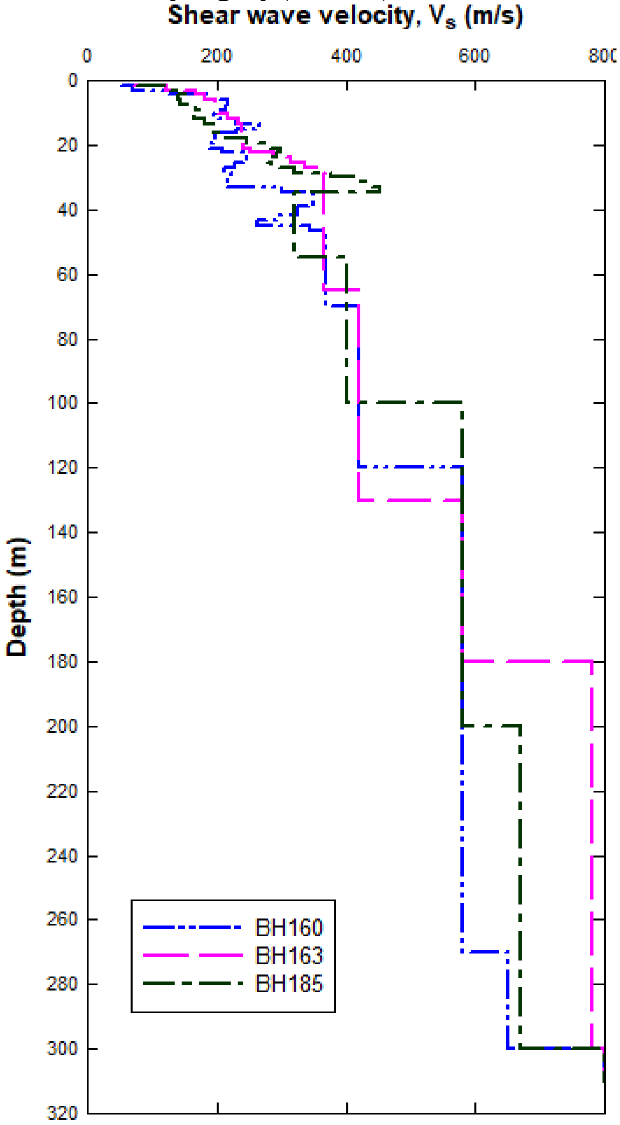


Figure B-8: Site- 11 No Mograkanda Govt. School, Savar, Dhaka (BH189), Ichakhali, Kaiup para, Rupganj, Narayanganj (BH195) and Rupayan Sity, Hamiyetpur, Savar, Dhaka (BH199)

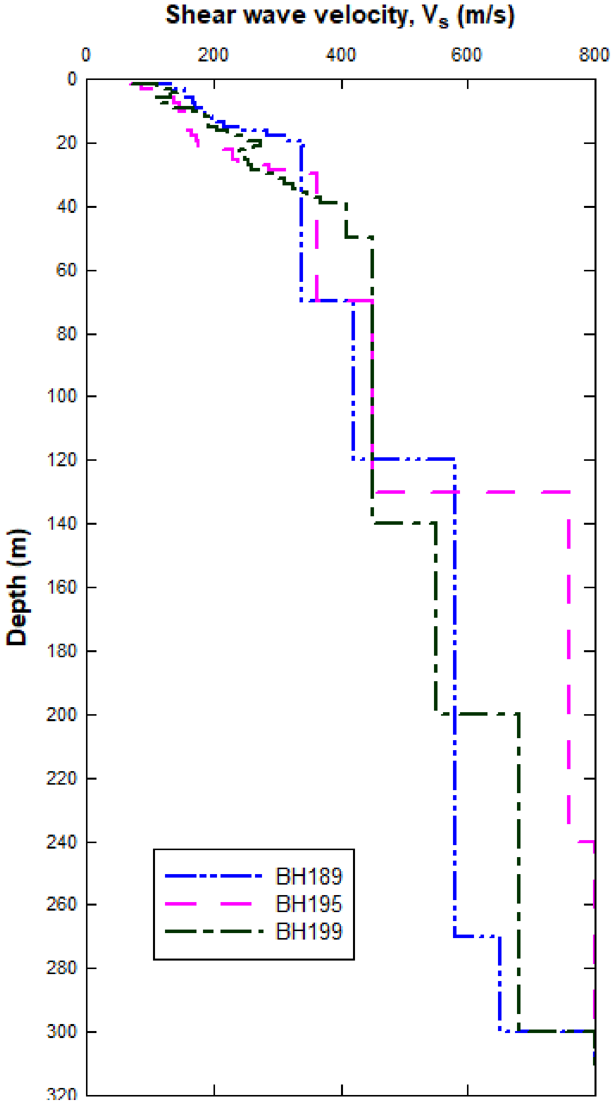


Figure B-9: Site- Golertek playground Darussalam , Mirpur, Dhaka (BH203), Moirabo, Bhulta, Rupganj, Narayanganj (BH213) and Purbo Gopalnagar Govt. Primary School, Purbo Gopalnagar, Fatullah, Narayanganj (BH074)

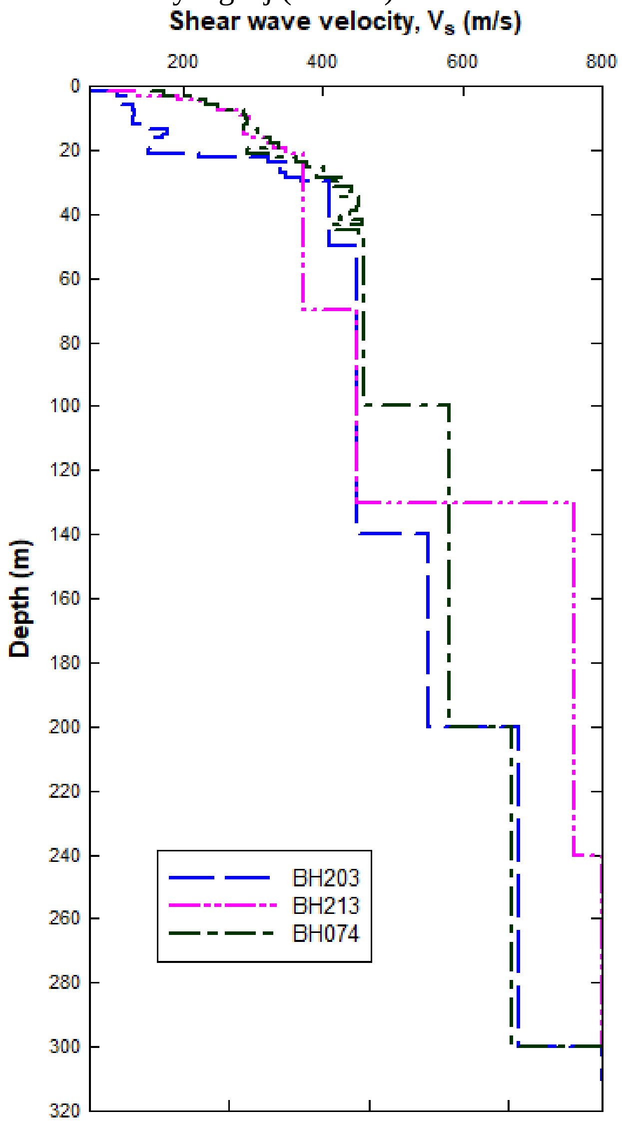


Figure B-10: Site- Kakabo, Birulia, Savar, Dhaka (BH253), Rajuk Land Area, Zinda Park, Gazipur (BH263) and Teromukh bridge, Uttarkhan, Dhaka (BH273)

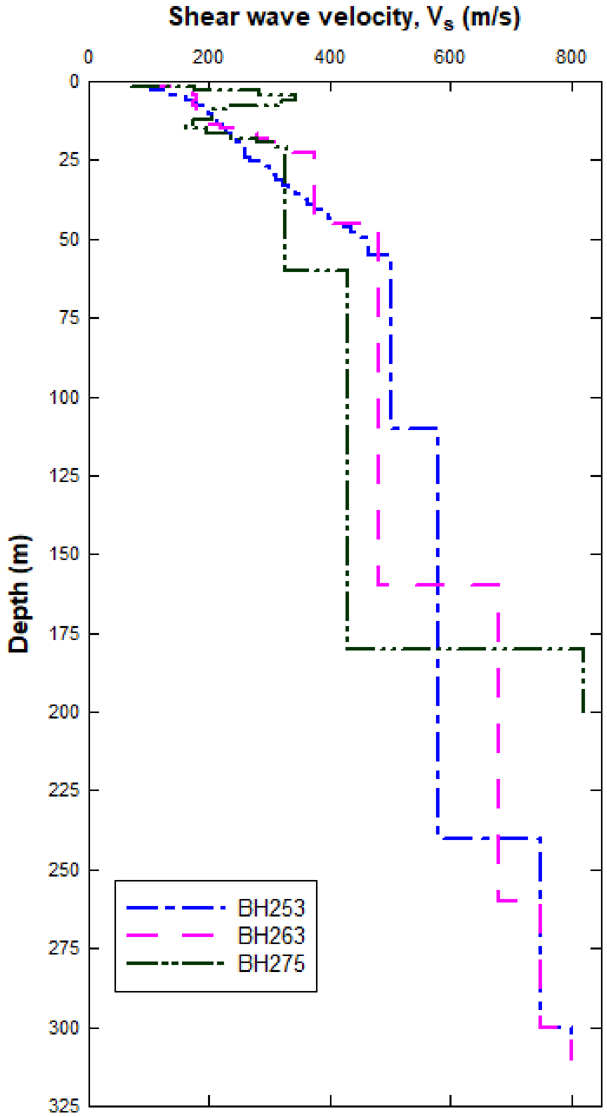


Figure B-11: Site- Awal Market, Sadupur, Kazipara, Bongayo, Savar, Dhaka (BH230), Barua (shilon para) khilkhet, Dhaka (BH245) and T Hossain Garden, Bandar, Narayanganj (BH085)

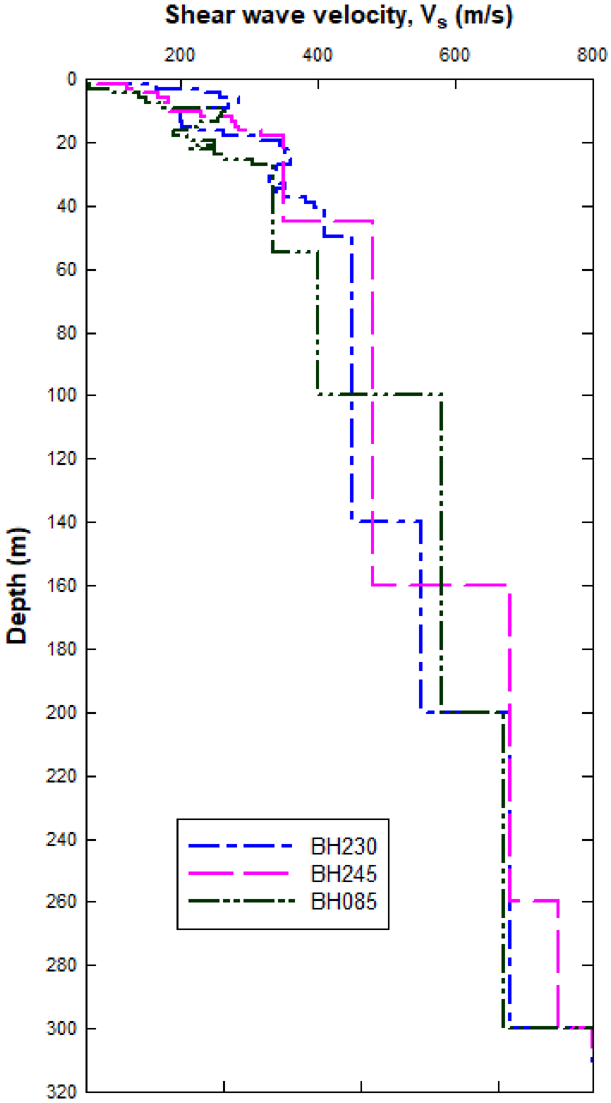


Figure B-12: Site- Ashulia, Savar, Dhaka (BH286), BTCL Tongi, Gazipur, Dhaka (BH289) and Bhasania Primary School, Gazipur (BH293)

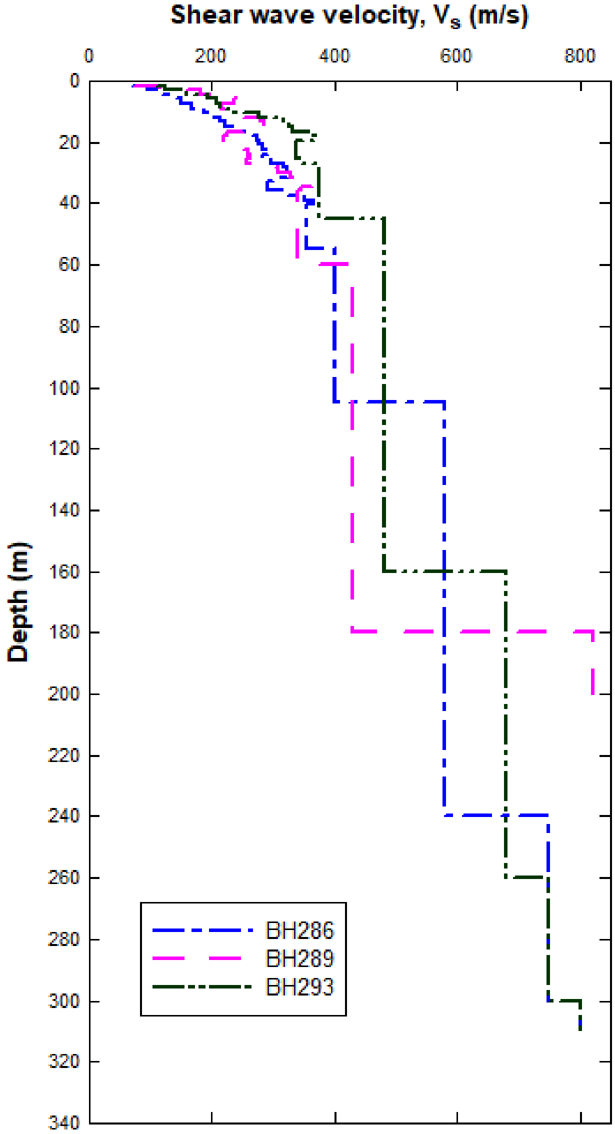
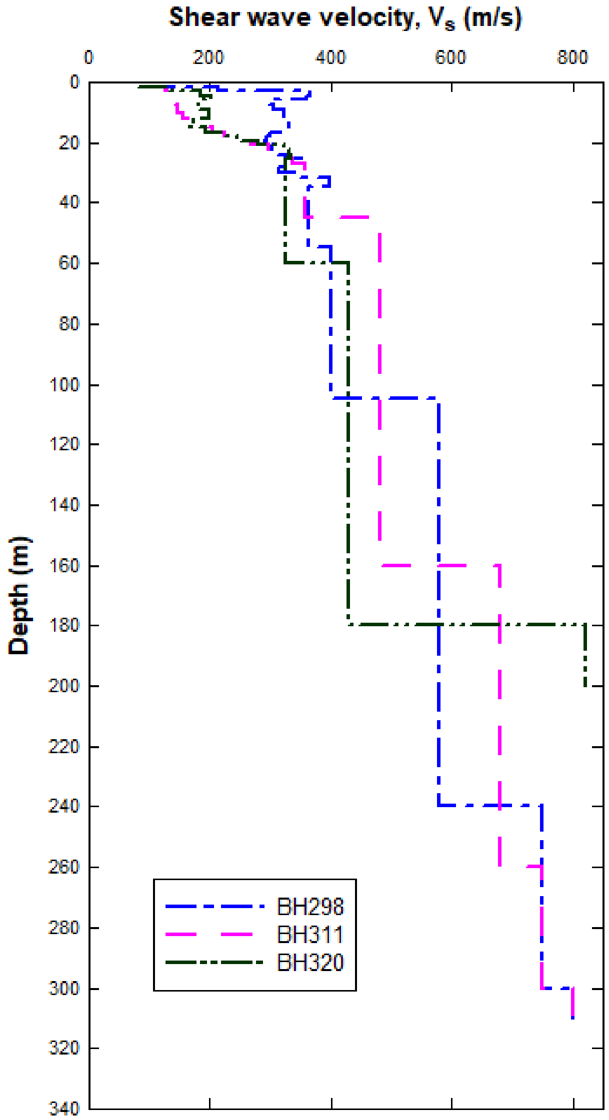


Figure B-13: Site- Madhobi Sheltech Project, Plot No. 63, Katgora, Ashulia (BH298), Victoria Hondachiam Interbita School, Kaliganj (BH311) and Kunia Moddho para Jame mosjid ,Gazipur (BH320)

Figure B-14: Site- Kudaba, Pubail, Gazipur (BH323), Stand Housing, Dehra, Ashulia (BH341) and 55 No Mograpara Govt. Primary School Sonagaon, Narayanganj (BH088)



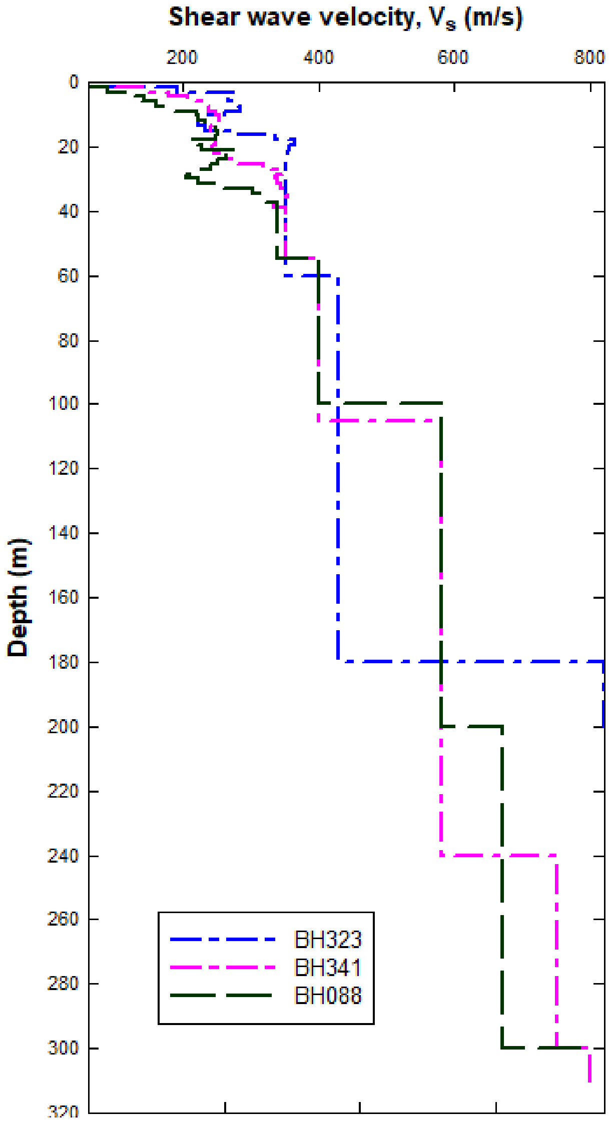


Figure B-15: Site- Tetultala, Eatahata, Kolabagan, Gazipur (BH369), Sonamia Market S.O Road Balurmath, Sumilpara (BH107) and Ambag Govt. Primary School, Konabari, Gazipur (BH376)

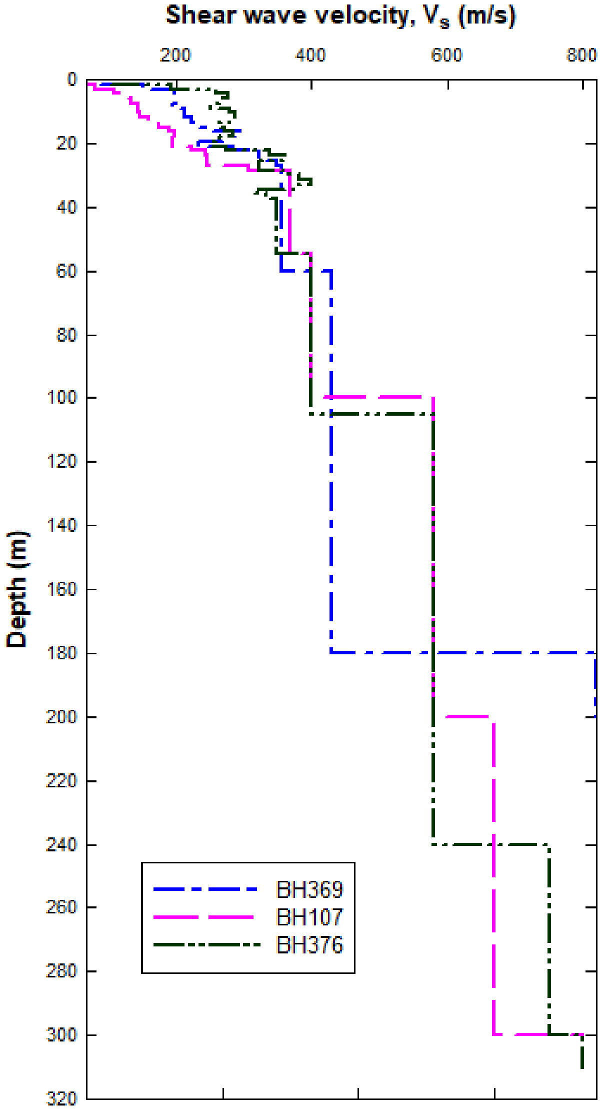


Figure B-16: Site- Samad Nagar, Jatrabari, Dhaka (BH146), Gazipur sadar upojilla, Gazipur (BH380) and Bagber, Rupganj, Narayanganj (BH236)

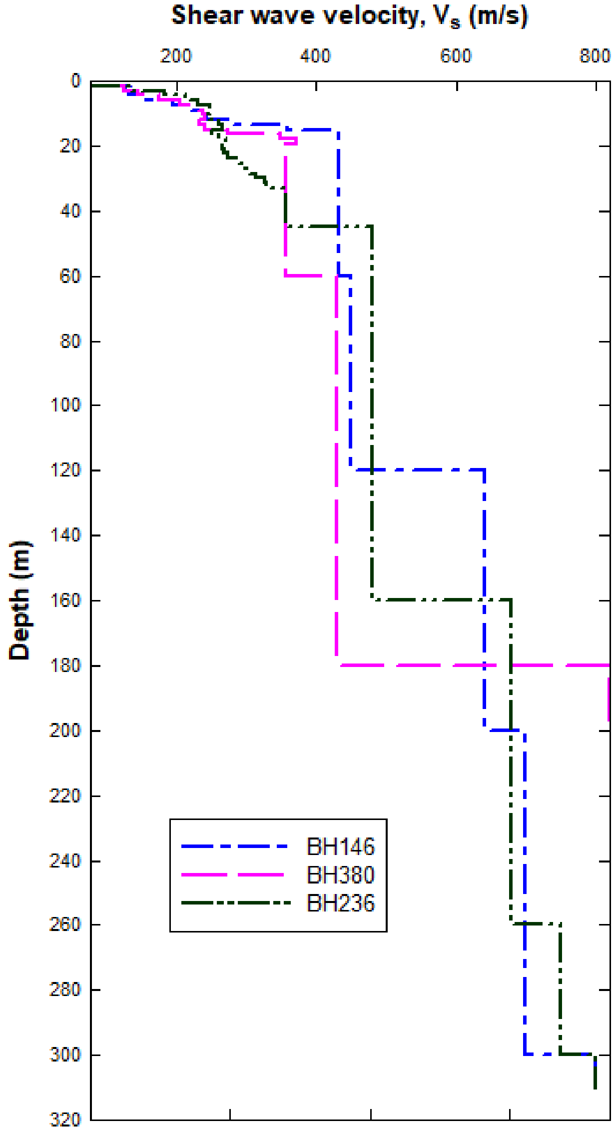
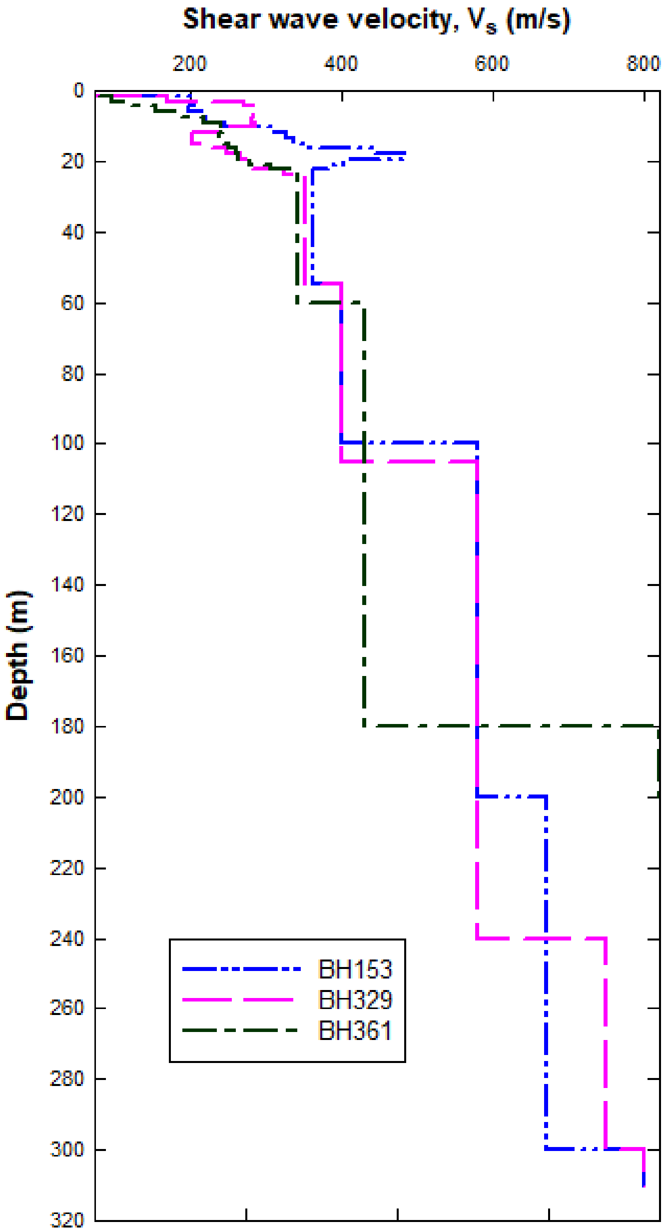


Figure B-17: Site- Sommalon Math, Noyapur Bazar, Sadipur, Sonargaon, Narayanganj (BH153), Tajpur, Model High School, Ashulia, Savar, Dhaka (BH329) and Baluchakuli, Gazipur (BH361)



Appendix C

Shear wave velocity profile from CDMP data

Figure C-1: Site- Dhaka University (MMT-1)

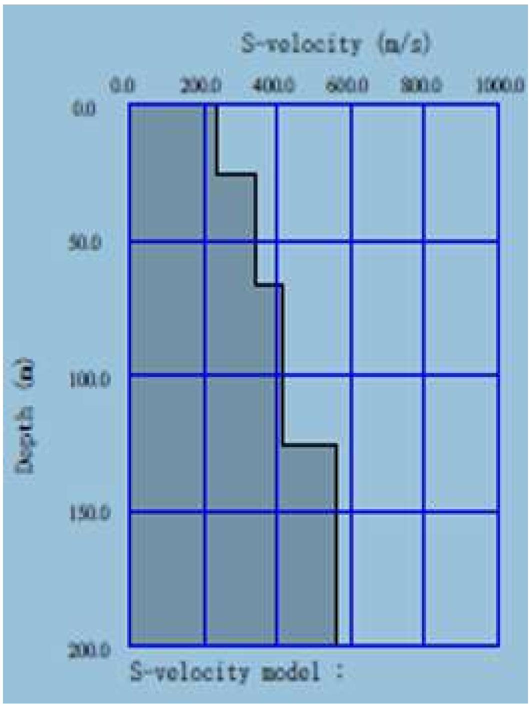


Figure C-2: Site- Green Model Town (MMT-2)

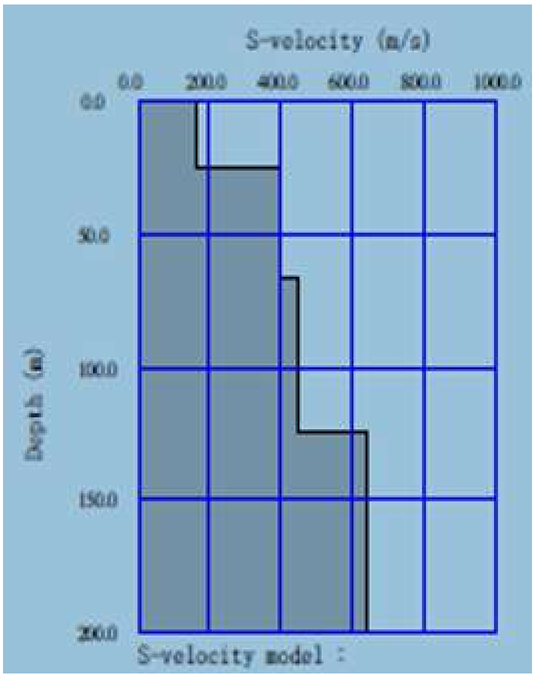


Figure C-3: Site- United City (MMT-3)

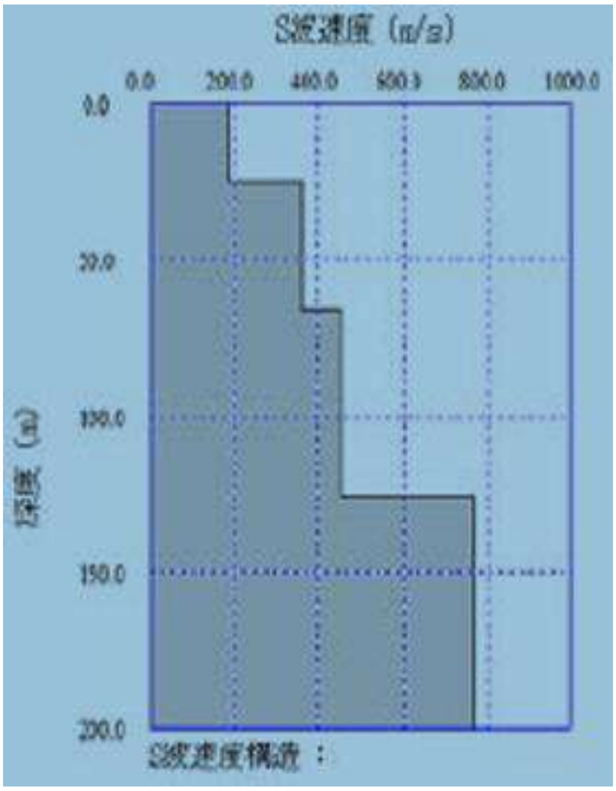


Figure C-4: Site- Uttara Phase 3 (MMT-4)

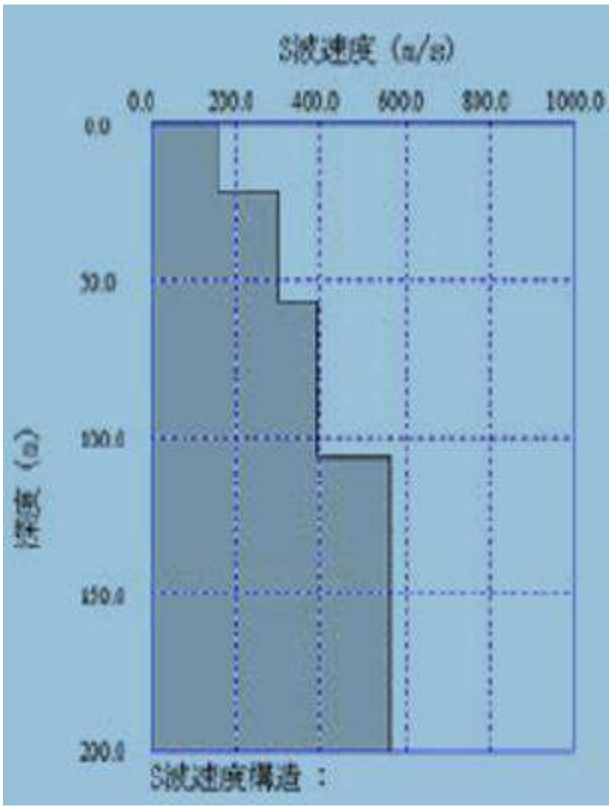


Figure C-5: Site- Agargaon Trade Fair Area (MMT-5)

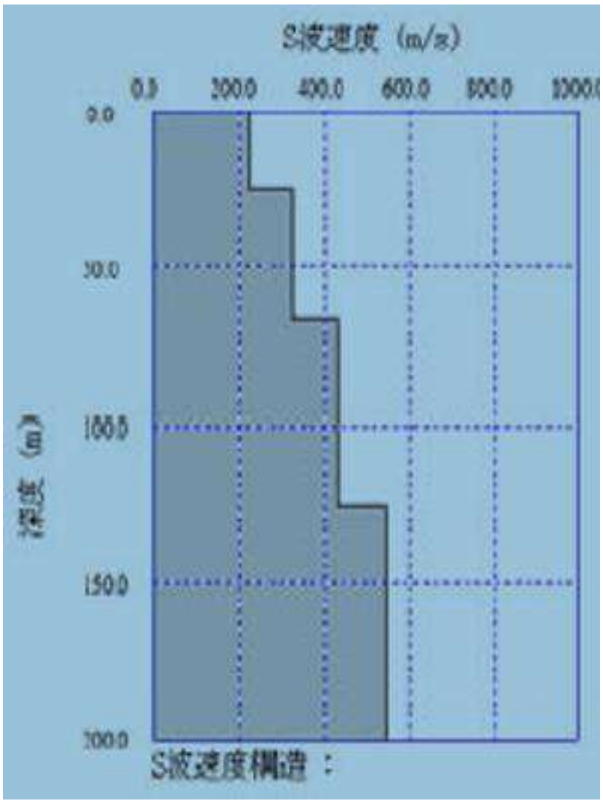


Figure C-6: Site- Pallabi, Mirpur (MMT-6)

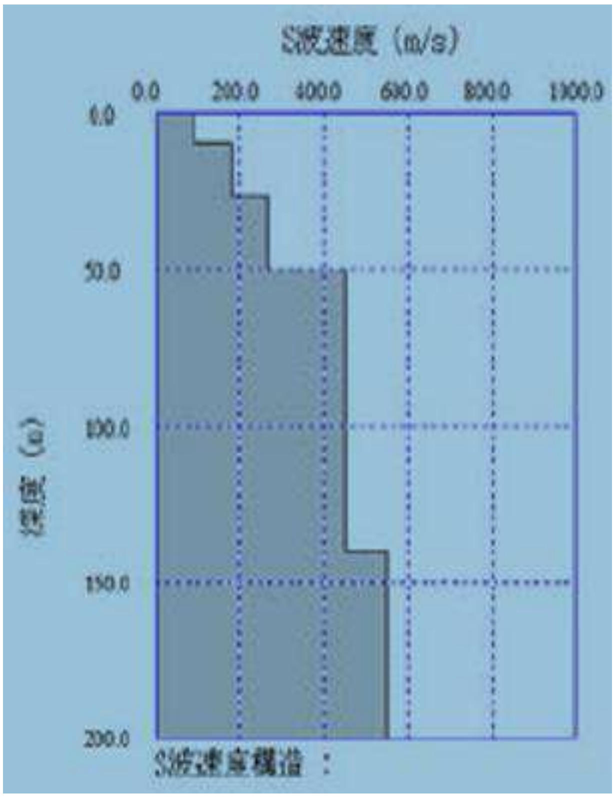


Figure C-7: Site- Uttra Khan (MMT-7)

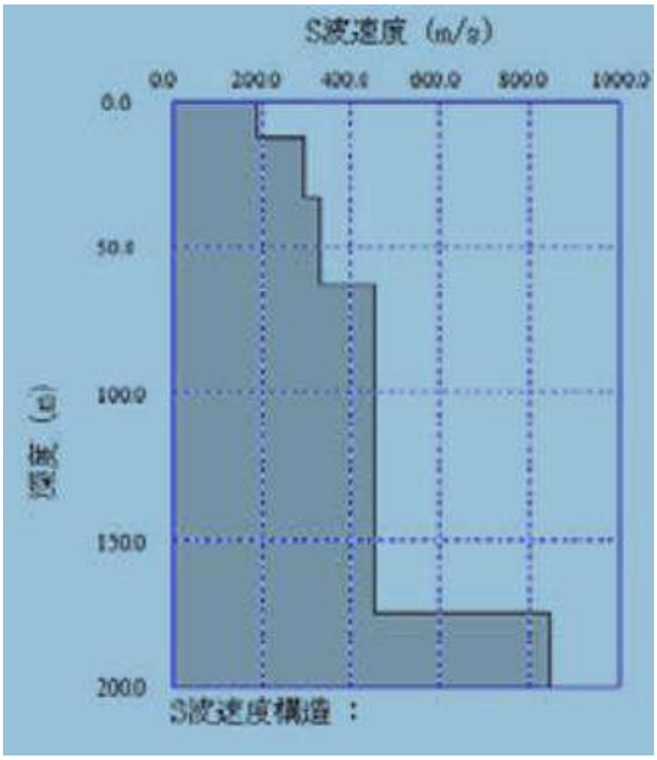


Figure C-8: Site- Aftab Nagar Housing Project, Dhaka (MMT-8)

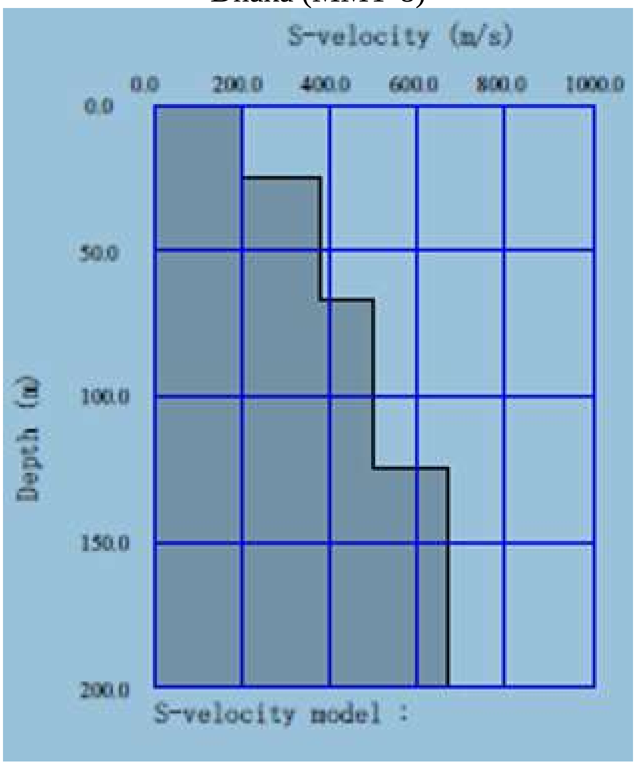


Figure C-9: Site- Sapnali Housing Project, Dhaka (MMT-9)

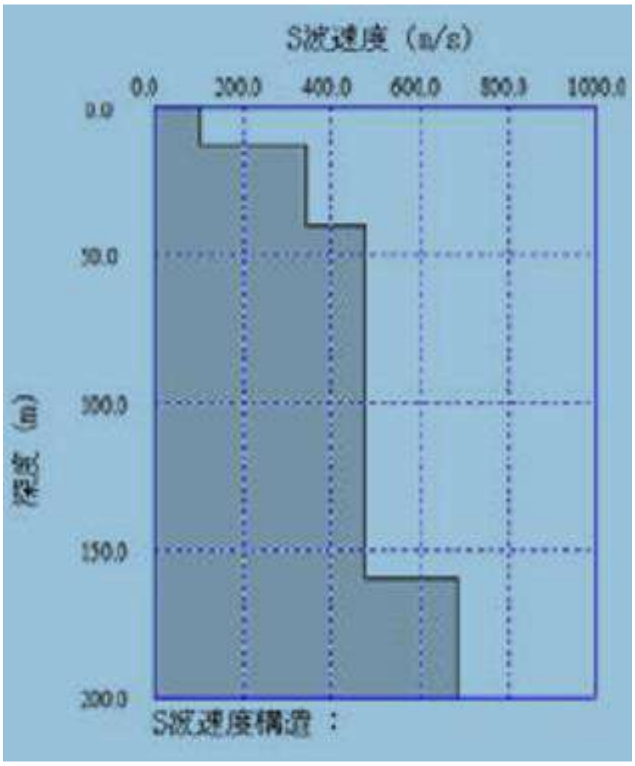


Figure C-10: Site- Matuail, Demra, Dhaka (MMT-10)