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Study on Effect of Ground Motion Parameters on Seismic Responses of Multi-Layer Soil Deposits

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***Abstract*— Earthquakes have occurred for millions of years and will continue in the future as they have in the past. Some will occur in remote, undeveloped areas where damage will be negligible. Others will occur near densely populated urban areas and subject their inhabitants and the infrastructure they depend on to strong shaking. It is impossible to prevent earthquakes from occurring, but it is possible to mitigate the effects of strong earthquake shaking to reduce loss of life, injuries and damage. In recent situations, have been witnessed that there are many failures occurred during earthquake events in despite of scientific technology on structures. Based on the knowledge accretion over decades there is no effective scientific method estimate the origin and magnitude of the earthquake to date, the engineers have to do structures as seismic resistant as possible. During earthquakes, mostly the failure of the structures such as buildings, bridges etc. that leads to widespread destruction. Most soil deposits existing in nature are not purely homogeneous (single-layered) and are found in multi-layered stratum (two or more layers sandwiched in-between).**

It has been realized from the literature review that no significant studies are available on non-linear behaviour on multi-layered soil deposits. Therefore, the present study focuses on understanding the non-linear behaviour on multi-layered soils deposits against dynamic loads and estimate the effect of ground motion parameters on non-linear response of multi-layer deposits.

In this study, six multi-layer soil deposits are taken (i.e., homogenous sand, homogenous clay, sand & clay, clay & sand, sand & clay & sand, clay & sand & clay) and site response analysis were performed using equivalent linear and non-linear employing computer programming DEEPSOIL.

The obtained results will be presented in terms of peak ground acceleration (PGA), displacement and strains. The results will be analysed and may be used for providing recommendations to the design engineers planning for efficient earthquake resistant design of foundations in multi-layered soil deposits.

1. INTRODUCTION

In recent situations, have been witnessed that there are many failures occurred during earthquake events in despite of scientific technology on structures. Based on the knowledge accretion over decades there is no effective scientific method estimate the origin and magnitude of the earthquake to date, the engineers have to do structures as seismic resistant as possible. During earthquakes, mostly the failure of the structures such as buildings, bridges etc. that leads to widespread destruction. Fig 1.1 depicts the building due to the foundation failure during 2015 Gorkha earthquake in chautara, Nepal. Similarly, Fig 1.2 depicts the building due to foundation failure during 1995 Kobe earthquake in Japan.

Fig 1.1 Example of foundation failure during 2015 Gorkha earthquake in Nepal

Fig: Example of foundation failure during 1995 Kobe earthquake in Japan

Any effective earthquake resistant design should comprehensively consider the structural phenomenon as well as the underlying soil behaviour as it is not only the structure that proves to be volatile during seismic event, but also the underlying soil which dictates the seismic stability of overlying structure. During any seismic event, induced waves travel through the earth's crust before reaching ground surface and during the travel, waves interact with many layers of soil/rock and often get modified (amplify or attenuate). Such wave modification depends on the soil characteristics along with the ground motion parameters.

1.1 GROUND RESPONSE ANALYSIS (GRA)

The assessment of ground response, subjected to earthquakes of varying magnitudes, is an important task, as it governs the safety of structures located in seismically prone areas.1D GRA can be performed either in the time -domain (non-linear total & effective stress approaches) or in the frequency-domain (linear & equivalent total stress approaches).However, owing to the inherent non-linearity in soil behaviour a time-domain non-linear GRA can model the soil response, during an actual earthquake more accurately than any frequency domain GRA method. Ground motion parameters are crucial for describing the important characteristics of strong ground motion in compact, quantitative form. Many parameters have been proposed to characterize the amplitude, frequency content and during of strong ground motions; some describe only one of these characteristics, while others may reflect two or three.

1.2 GROUND MOTION PARAMETERS(GMP)

For the design of structures to resist earthquakes, it is necessary to have some knowledge of ground motions. Earthquake motion can be recorded in terms of ground displacement, velocity or acceleration. During earthquakes, producing translations in any general direction combined with rotations about arbitrary axes. Several earthquake parameters are reported in the literature for quantitatively describing the various characteristics of ground motion. There is intensity of motion, frequency of motion and duration of motion. Loading effect of earthquake ground motion at a site is generally represented by three ground motion parameters. The three ground motion parameters i.e., peak ground acceleration (PGA) value, response spectrum and acceleration time history of a site, commonly used in the design engineers of structure are known as design basis ground motion parameters (DBGM).

1.2.1 INTENSITY PARAMETERS:

a) PEAK GROUND ACCELERATION(PGA):

The earthquake time history contains several engineering characteristics of ground motion and maximum amplitude of motion is one of the important parameters among them. The PGA is a measure of maximum amplitude of motion and is defined as the largest absolute value of the acceleration time history. Generally, any distances several source dimensions away, vertical PGA are found to be less than horizontal PGA through at near source distances it could be equal to higher than the corresponding horizontal PGA. For engineering purposes, vertical PGA is assumed to be two thirds of horizontal PGA.

b) PEAK GROUND VELOCITY:

Peak velocity is the largest absolute value of velocity time history. It is more sensitive to the intermediate frequency components of motion and characterizes the response to structures that are sensitive to intermediate range of ground motion.

c) PEAK GROUND DISPLACEMENT:

Peak displacement reflects the amplitude of lower frequency components in ground motion. Accurate estimation of these parameters is difficult as the errors in signal processing and numerical integration greatly affect the estimation of amplitude of displacement time history.

1.2.2 FREQUENCY CONTENT OF MOTION:

Only the simplest of analysis are required to show that the dynamic response of compliant objects, be they are loaded. Earthquakes produce complicated loading with components of motion that span a broad range of frequencies. The frequency contents describe how the amplitude of a ground motion is distributed among different frequencies. Since the frequency content of an earthquake motion will strongly influence the effects of the motion. Several approaches have been proposed in the literature to quantitatively estimate these characteristics. Some of them are response spectra, Fourier spectra, power spectra.

A. FOURIER SPECTRA

A plot of Fourier amplitude versus frequency is known as a Fourier amplitude spectrum. The Fourier amplitude spectrum of a strong ground motion shows how the amplitude of the motion is distributed with respect to frequency.

B. POWER SPECTRA

The power spectra density function by itself can describe a stationary random process (i.e., one whose stationary parameters do not vary with time). Actual strong motion accelerograms, however frequency show that the intensity builds up to a maximum value in the early part of the motion, then remains approximately constant for a period of time and finally decreases near end of the motion.

C.RESPONSE SPECTRA

The response spectrum describes the maximum response of a single degree of freedom (SDOF) system to a particular input motion as a function of the natural frequency (or natural period) and damping ratio of the SDOF system. At low frequencies the average spectral displacement is nearly constant; at high frequencies the average spectral acceleration is fairly constant. In between lies a range of nearly constant spectral velocity. Because of this behaviour, response spectra are often divided into acceleration-controlled (high frequency), velocity-controlled (intermediate frequency) and displacement-controlled (low frequency) portions.

PREDOMINANT PERIOD

A single parameter that provides a useful, although somewhat crude representation of the frequency content of a ground motion is the predominant period Tp. The predominant period is defined as the period of vibration corresponding to the maximum value of the Fourier amplitude spectrum.

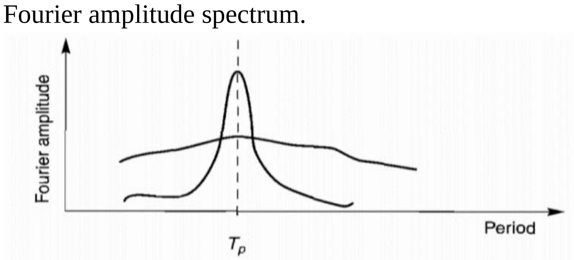


Fig: Two hypothetical Fourier amplitude spectra with the same predominant period but very different frequency contents. The upper curve describes a wideband motion and the lower a narrowband motion. To avoid undue influence of individual spikes of the Fourier amplitude spectrum; the predominant period is often. obtained from a smoothed spectrum. While the predominant period provides some information regarding the frequency content, it is easy to see (fig) that motions with radically different frequency contents can have the same predominant periods.

1.2.3 DURATION OF MOTION:

Earthquake duration is the total time of ground shaking from the arrival of seismic waves return to ambient conditions. Much of its time is at relatively low shaking levels which have little effect on seismic structural response and on earthquake damage potential. A motion of short duration may not produce enough load reversals for damaging response to build up in a structure, even if the amplitude of the motion is high. On the other hand, a motion with moderate amplitude but long duration can produce enough load reversals to cause substantial damage. An earthquake accelerogram generally contains all accelerations from the time the earthquake begins until the time the motion has returned to the level of background noise. For engineering purposes, only the strong-motion portion of the accelerogram is of interest. Different approaches have been taken to the problem of evaluating the duration of strong motion in an accelerogram. The bracketed duration (Bolt, 1969) is defined as the time between the first and last exceedances of a threshold acceleration (usually O.05g). Another definition of duration (Trifunac and Brady, 1975b) is based on the time interval between the points at which 5% and 95% of the total energy has been recorded. Boore (1983) has taken the duration to be equal to the corner period (i.e., the inverse of the comer frequency).

1.3 BROAD OBJECTIVES OF THE STUDY

The main objective of the study is to understand non-linear behaviour on multi-layer soil deposits subjected to earthquake loads. Total six multi-layer soil profiles (homogenous sand, homogenous clay, sand and clay, clay and sand, sand and clay and sand, clay and sand and clay) are taken to estimate the effect of ground motion parameters on non-linear response of multi-layer deposits.

2. LITERATURE REVIEW

2.1 STUDIES ON SEISMIC GROUND RESPONSE

Ground response studies can be categized based on the level of strains involved (linear elastic, equivalent linear and nonlinear analysis) as well as the dimensionality of the program (1D, 2D or 3D). Although 1D GRA studies are simplified in nature, they were effectively validated against field and laboratory tests and therefore, many researchers have been practicing such studies (Hashash and park 2001; Torabi and Rayhani 2017). Linear elastic analysis utilises only the low strain stiffness characteristics of soil and can only be adopted for analysis dealing with very small strains, such as low intensity seismic motions, etc. Equivalent linear (EQL) analysis is an approximation to full nonlinear analysis and cannot simulate the generation of pore water pressures and resulting plastic yielding of soils. Nonlinear analysis (NL) is a time domain analysis whereby all the possible dynamic characteristics of soil can be considered such as liquefaction, plastic yielding, etc. Kramer (1996) and Yoshida (2015) thoroughly describes the methodologies and associated background and corresponding literature.

2.2 STUDIES ON COMPARISON BETWEEN EQL & NL GRA

It was suggested to use EQL approach for low intensity motions where soil yielding is not expected, and in cases of high intensity motions with significant soil yielding, the NL analysis was recommended (Garala and Madabhushi 2018). Similar recommendations were proposed by Yee et al. (2013), Yoshida (2014), Kumar et al. (2018a), Mercado et al. (2018) and Basu et al. (2019). Basu et al. (2019) performed comparative studies on EQL and NL in Guwahati region of India with increased intensity of input motions and observed severe amplification for low intensity motions and attenuation for high intensity motions. This was attributed to the high damping at high strains, caused by the intense motions. Also, plastic soil deformations for NL analysis were observed which were absent in EQL analysis (Fig. 2.19). Plastic soil deformations in NL analysis can be understood by the stress-strain response adopted in the 1D program. For low amplitude motions (0.005g), the stress-strain response evaluated from both EQL and NL approaches yielded similar magnitudes, while the high amplitude motions (0.25g) produced differential response for both the approaches. This is again attributed to the soil yielding characteristics considered in NL analysis (Mercado et al. 2018).

2.3 GRA STUDIES IN INDIA

Some of the available literature are discussed in the below Table on GRA studies in India. The GRA studies that considered experimentally obtained G/G_{MAX} and D data highlighted the necessity of use of site-specific data in GRA studies. From the table 2.1 NL is almost rarely adopted and EQL is mostly used because of the lack of sufficient information on the large number of parameters required for the NL analysis.

Table 2.1 GRA studies in India

RESEARCHERS	APPROACH	PROGRAM	CONTRIBUTION
Raghu Kanth et al. (2008)	EQL	SHAKE91	Surface acceleration and liquefaction maps for Guwahati city were developed
Phanikanth et al. (2011)	EQL	DEEPSOIL	PGA and amplification maps for typical sites in Mumbai city were developed.
Govindaraju and Bhattacharya (2012)	EQL	SHAKE2000	Spectral accelerations and amplification ratios were developed for Kolkata city.
Kumar&Krishna (2013)	EQL	DEEPSOIL	PGA, amplification, FAR factors were developed for Guwahati city.
Desai and Choudhury (2015)	EQL	DEEPSOIL	Developed site-specific ground motions and seismic hazard maps in terms of pseudo-acceleration for port sites in Mumbai city
Basu et al. (2019)	NL	DEEPSOIL	Developed PGA, spectral acceleration maps for Guwahati; highlighted the need of NL effective stress analysis
Kumar et al. (2018a)	EQL	DEEPSOIL	High strain dynamic properties have been adopted in developing seismic response maps for Guwahati city

3. GROUND RESPONSE ANALYSIS

INTRODUCTION

Seismic ground response analysis (GRA) studies are performed to understand the response of soil deposits (in terms of accelerations, stresses, and strains) during earthquakes. The main aim of this chapter is to demonstrate the applicability of established strain dependent dynamic soil properties, obtained from the experimental programme in the seismic GRA studies. One dimensional nonlinear effective stress GRA studies are performed, using commercial ground response evaluation programme (DEEPSOIL v6.1).

4. TO DETERMINE THE EFFECT OF DYNAMIC SOIL PROPERTIES

INTRODUCTION

This chapter discuss about the effect of dynamic soil properties on ground responses analysis. As the stability of structures during earthquakes is dictated by the strength of underlying soil, investigation of the response of soils to seismic loading is essential. Understanding the dynamic response of soils is complex due to the significant number of parameters involved (Seed and Idriss 1970; Kumar et al. 2014). Traditionally, response of soils to dynamic loads is represented using strain dependent dynamic soil properties include maximum shear modulus (G_{MAX}), secant shear modulus (G) and hysteretic damping (D) of soil.

The rate of reduction of shear modulus with respect to G_{MAX} is called the normalized shear modulus reduction curve (G/G_{MAX}). In contrast, damping of the soil (measure of energy dissipated to stored) is minimum at low strains and increases with strains based on the stress-strain response (Kramer 1996). The variation of damping ratio with shear strain is termed as damping curve. The G_{MAX} combined with the variation of G/G_{MAX} and D over wide range of γ (from very low strains, 0.001% to strains beyond 5%) are traditionally termed as the strain dependent dynamic soil properties. Any seismic analysis study desirous of incorporating the realistic nonlinearity of the soil must consider these strain dependent dynamic soil properties.

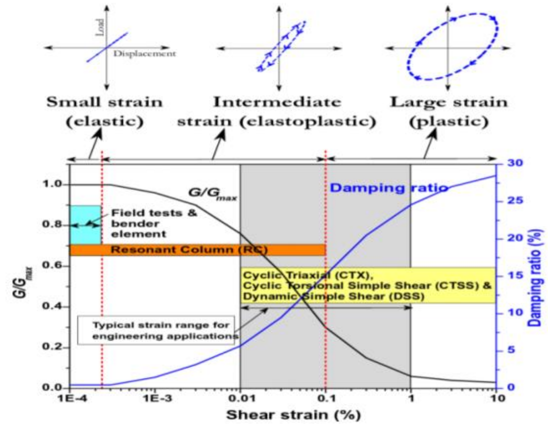


Fig. 4.1 schematically presents the typical variation of strain dependent dynamic soil properties (G/G_{MAX} and D with γ)

4.1 EFFECT OF DYNAMIC SOIL PROPERTIES ON GRA

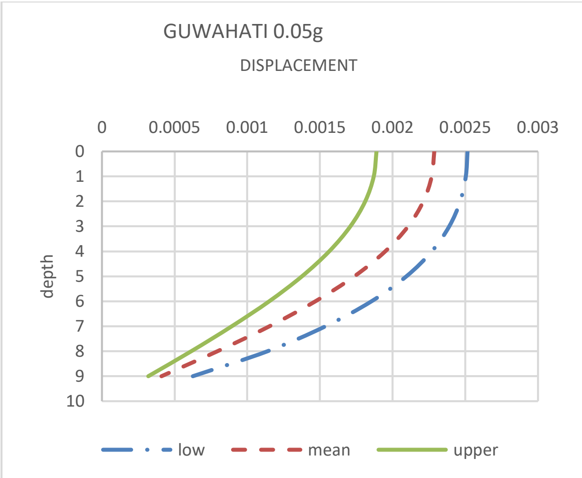
Table 4.1 SOIL PROFILES

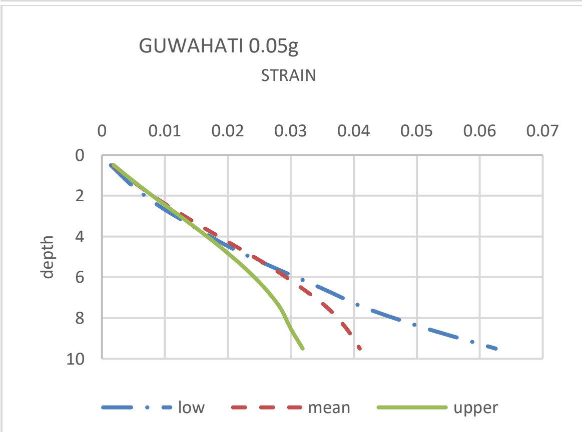
LAYER	LAYER NAME	THICKNESS (m)	UNIT WEIGHT (KN/m^3)	SHEAR VELOCITY (m/s)
1	SAND	1	18	200
2	SAND	1	18	200
3	SAND	1	18	200
4	SAND	1	18	200
5	SAND	1	18	200
6	SAND	1	18	200
7	SAND	1	18	200
8	SAND	1	18	200
9	SAND	1	18	200
10	SAND	1	18	200

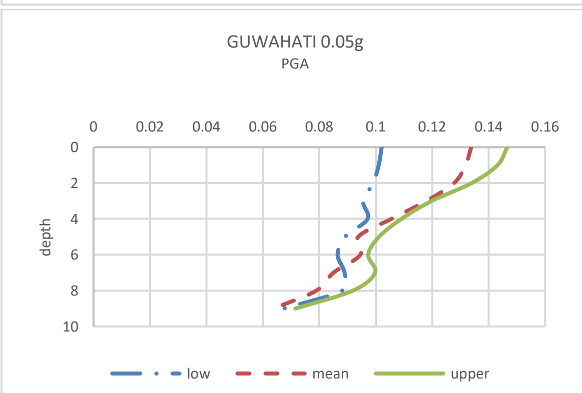
Table 4.2 LIST OF ANALYSIS TO DETERMINE THE EFFECT OF DYNAMIC SOIL PROPERTIES

SERIES	GROUND MOTION	G/Gmax	DAMPING
A	GUWAHATI 0.05g	LOW	LOW
	GUWAHATI 0.05g	MEDIUM	LOW
	GUWAHATI 0.05g	HIGH	LOW
B	GUWAHATI 0.138g	LOW	LOW
	GUWAHATI 0.138g	MEDIUM	LOW
	GUWAHATI 0.138g	HIGH	LOW
C	GUWAHATI 0.05g	LOW	LOW
	GUWAHATI 0.05g	LOW	MEDIUM
	GUWAHATI 0.05g	LOW	HIGH
D	GUWAHATI 0.138g	LOW	LOW
	GUWAHATI 0.138g	LOW	MEDIUM
	GUWAHATI 0.138g	LOW	HIGH

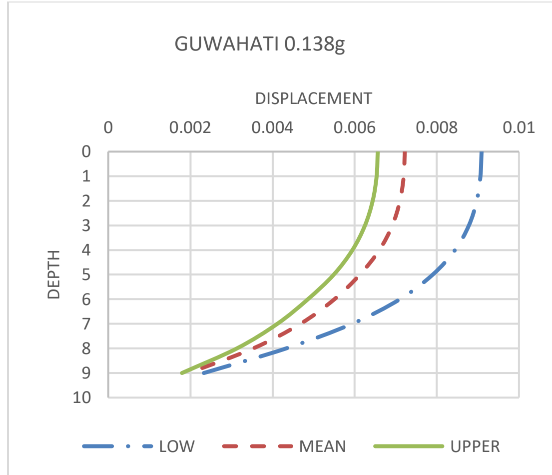
4.1.1 EFFECT OF NORMALIZED SHEAR MODULUS (G/G_{MAX})

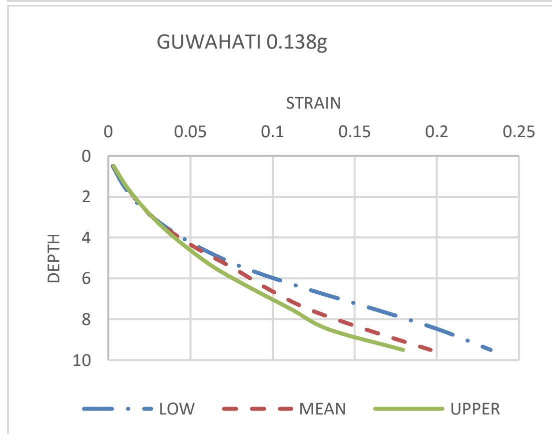


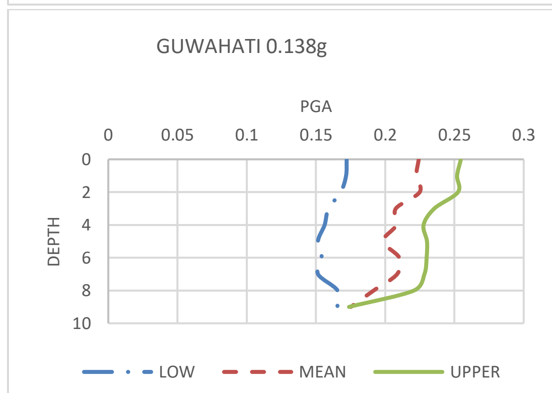




In the series A, input peak acceleration (GUWAHATI 0.05g) is applied to the 10m sand profile then the results are shown in displacements, strains and PGA. In displacement graph shows that where G/G_{MAX} are low their displacements are more similarly where G/G_{MAX} are more their displacements are less. In strain graph, results show as same as displacement results. But in PGA graph, at low G/G_{MAX} PGA is low and at high G/G_{MAX} PGA is high. finally, it concluded that below the depth 5m strains are more their displacement are less.

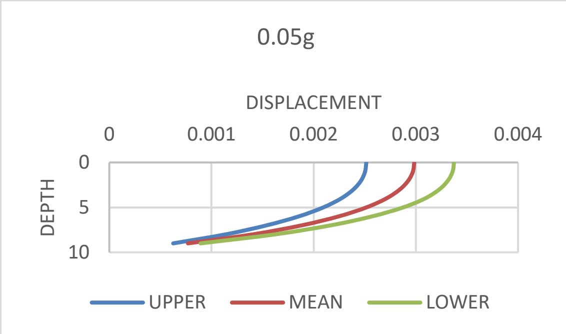


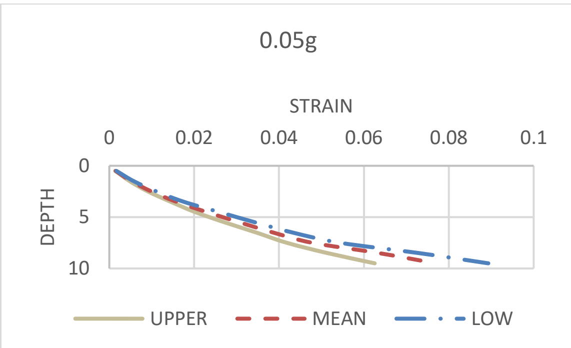


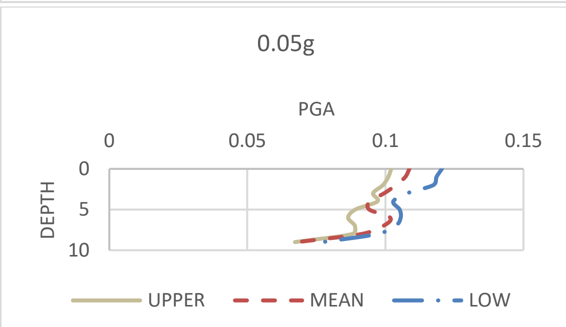


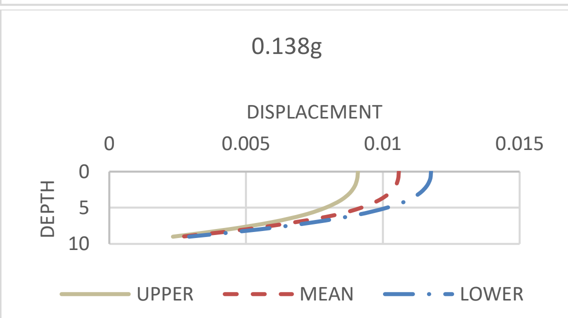
In the series B, input peak acceleration (GUWAHATI 0.138g) is applied to the 10m sand profile then the results are shown in displacements, strains and PGA. In displacement graph shows that where G/G_{MAX} are low their displacements are more similarly where G/G_{MAX} are more their displacement are less. In strain graph, results show as same as displacement results. But in PGA graph, at low G/G_{MAX} PGA is low and at high G/G_{MAX} PGA is high. finally, it concluded that below the depth 5m strains are more their displacement are less.

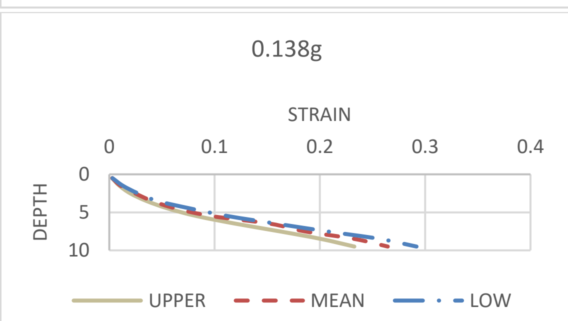
4.1.2 EFFECT OF DAMPING

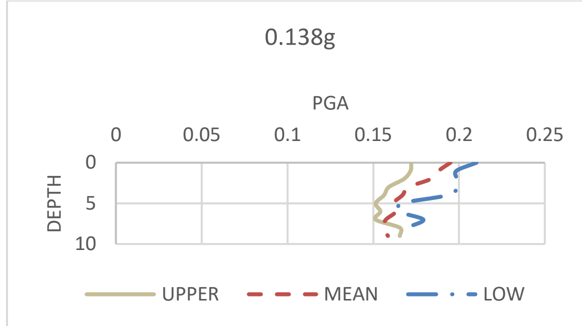












In the series C, input peak acceleration (GUWAHATI 0.05g) is applied to the 10m sand profile then the results are shown in displacements, strains and PGA. In displacement graph shows that where Damping are low their displacements are more similarly where Damping are more their displacements are less. In strain graph, results show as same as displacement results. But in PGA graph, at low Damping PGA is high and at high Damping PGA is low. finally, it concluded that below the depth 5m strains are more their displacement are less.

In the series D, input peak acceleration (GUWAHATI 0.138g) is applied to the 10m sand profile then the results are shown in displacements, strains and PGA. In displacement graph shows that where Damping are low their displacements are more similarly where Damping are more their displacements are less. In strain graph, results show as same as displacement results. But in PGA graph, at low Damping PGA is high and at high Damping PGA is low. finally, it concluded that below the depth 5m strains are more their displacement are less.

5. EFFECT OF GMP ON NON-LINEAR RESPONSE OF MULTI-LAYER SOIL DEPOSITS

5.0 INTRODUCTION

To analyse the effect of ground motion parameters (GMP) on non-linear response of multi-layer soil deposits, there are six soil profiles are subjected to seismic ground motion GUWAHATI (0.138g).

Six soil profiles are of same depth (20m) and arranged in following manner.

1) HOMOGENOUS SAND – 20m DEPTH [HS]
2) HOMOGENOUS CLAY – 20m DEPTH [HC]
3) SAND – 10m & CLAY – 10m DEPTH [SC]
4) CLAY – 10m & SAND – 10m DEPTH [CS]
5) SAND – 7m & CLAY – 6m & SAND – 7m DEPTH [SCS]

6) CLAY – 7m & SAND – 6m & CLAY – 7m DEPTH **[CSC]**

Ground response analysis was conducted at all the layers of these multi-layer soil profiles.

Table 5.1 SOIL PROFILS

HOMOGENOUS SAND (20m)

LAYER	LAYER NAME	THICKNESS (m)	Unit Weight (kN/m^3)	Shear Modulus (kPa)
1	sand	1	18	50000
2	sand	1	18	50000
3	sand	1	18	50000
4	sand	1	18	50000
5	sand	1	18	50000
6	sand	1	18	50000
7	sand	1	18	50000
8	sand	1	18	50000
9	sand	1	18	50000
10	sand	1	18	50000
11	sand	1	18	50000
12	sand	1	18	50000
13	sand	1	18	50000
14	sand	1	18	50000
15	sand	1	18	50000
16	sand	1	18	50000
17	sand	1	18	50000
18	sand	1	18	50000
19	sand	1	18	50000
20	sand	1	18	50000

HOMOGENOUS CLAY (20m)

LAYER	Layer Name	Thickness (m)	Unit Weight (kN/m^3)	Shear Modulus (kPa)
1	clay	1	18	50000
2	clay	1	18	50000
3	clay	1	18	50000
4	clay	1	18	50000
5	clay	1	18	50000
6	clay	1	18	50000
7	clay	1	18	50000
8	clay	1	18	50000
9	clay	1	18	50000
10	clay	1	18	50000
11	clay	1	18	50000
12	clay	1	18	50000
13	clay	1	18	50000
14	clay	1	18	50000
15	clay	1	18	50000
16	clay	1	18	50000
17	clay	1	18	50000
18	clay	1	18	50000
19	clay	1	18	50000
20	clay	1	18	50000

SAND (10m) & CLAY (10m)

LAYER	Layer Name	Thickness (m)	Unit Weight (kN/m^3)	Shear Modulus (kPa)
1	sand	1	18	50000
2	sand	1	18	50000
3	sand	1	18	50000
4	sand	1	18	50000
5	sand	1	18	50000
6	sand	1	18	50000
7	sand	1	18	50000
8	sand	1	18	50000
9	sand	1	18	50000
10	sand	1	18	50000
11	clay	1	18	50000
12	clay	1	18	50000
13	clay	1	18	50000
14	clay	1	18	50000
15	clay	1	18	50000
16	clay	1	18	50000
17	clay	1	18	50000
18	clay	1	18	50000
19	clay	1	18	50000
20	clay	1	18	50000

CLAY (10m) & SAND (10m)

LAYER	Layer Name	Thickness (m)	Unit Weight (kN/m^3)	Shear Modulus (kPa)
1	clay	1	18	50000
2	clay	1	18	50000
3	clay	1	18	50000
4	clay	1	18	50000
5	clay	1	18	50000
6	clay	1	18	50000
7	clay	1	18	50000
8	clay	1	18	50000
9	clay	1	18	50000
10	clay	1	18	50000
11	sand	1	18	50000
12	sand	1	18	50000
13	sand	1	18	50000
14	sand	1	18	50000
15	sand	1	18	50000
16	sand	1	18	50000
17	sand	1	18	50000
18	sand	1	18	50000
19	sand	1	18	50000
20	sand	1	18	50000

SAND 7m&CLAY 6m&SAND 7m

LAYER	Layer Name	Thickness (m)	Unit Weight (kN/m^3)	Shear Modulus (kPa)
1	sand	1	18	50000
2	sand	1	18	50000
3	sand	1	18	50000
4	sand	1	18	50000
5	sand	1	18	50000
6	sand	1	18	50000
7	sand	1	18	50000
8	clay	1	18	50000
9	clay	1	18	50000
10	clay	1	18	50000
11	clay	1	18	50000
12	clay	1	18	50000
13	clay	1	18	50000
14	sand	1	18	50000
15	sand	1	18	50000
16	sand	1	18	50000
17	sand	1	18	50000
18	sand	1	18	50000
19	sand	1	18	50000
20	sand	1	18	50000

CLAY 7m&SAND 6m&CLAY 7m

LAYER	Layer Name	Thickness (m)	Unit Weight (kN/m^3)	Shear Modulus (kPa)
1	clay	1	18	50000
2	clay	1	18	50000
3	clay	1	18	50000
4	clay	1	18	50000
5	clay	1	18	50000
6	clay	1	18	50000
7	clay	1	18	50000
8	sand	1	18	50000
9	sand	1	18	50000
10	sand	1	18	50000
11	sand	1	18	50000
12	sand	1	18	50000
13	sand	1	18	50000
14	clay	1	18	50000
15	clay	1	18	50000
16	clay	1	18	50000
17	clay	1	18	50000
18	clay	1	18	50000
19	clay	1	18	50000
20	clay	1	18	50000

5.1 EFFECT OF INTENSITY ON NON-LINEAR RESPONSE OF MULTI-LAYER SOIL DEPOSITS PGA

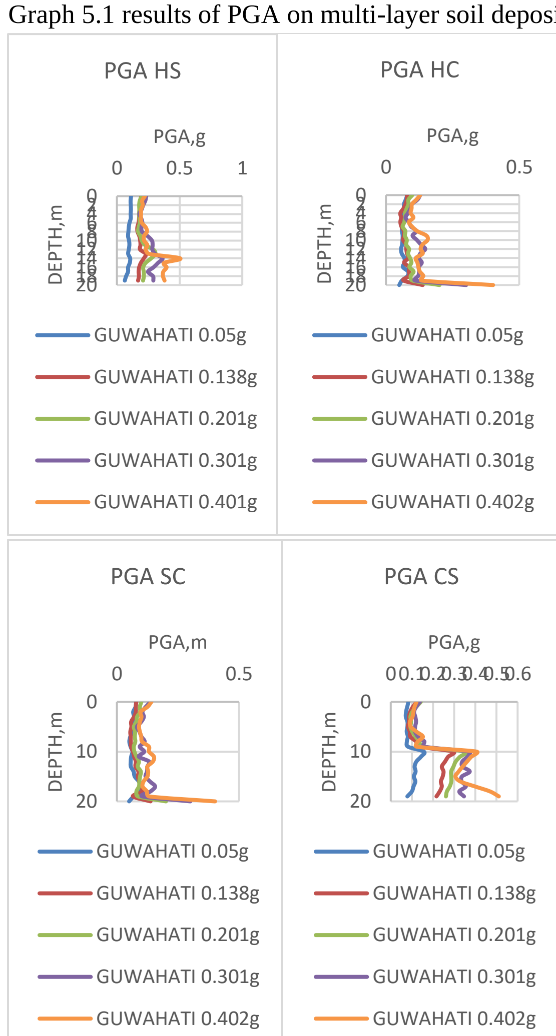
Peak ground acceleration (PGA) is corresponding to the maximum ground acceleration that occurred during earthquake shaking at a location. PGA is equal to the amplitude of the largest absolute acceleration recorded on an accelerogram at a site during a particular earthquake. Earthquake shaking generally occurs in all three directions. Therefore, PGA is often split into the horizontal and vertical components.

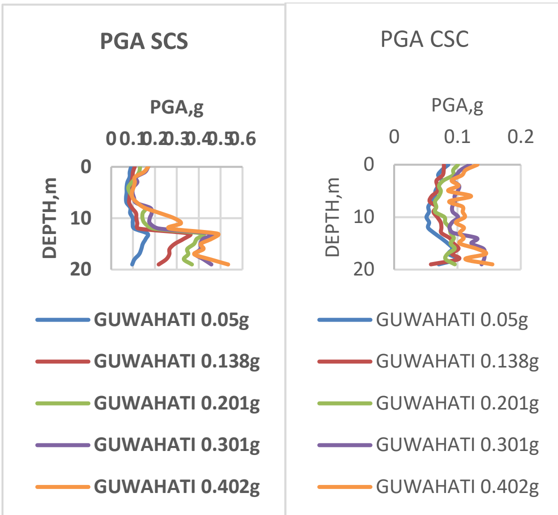
The input motions were applied at the bedrock level in all the soil profiles. The bedrock was considered rigid and dissipation of energy due to reflection of seismic waves at the bedrock soil interface was not accounted for. The soil layers were considered horizontal and extending till infinity while the ground surface was assumed to be level.

The intensity is a number describing the severity of an earthquake in terms of its effects on the earth's surface and on humans and their structures.

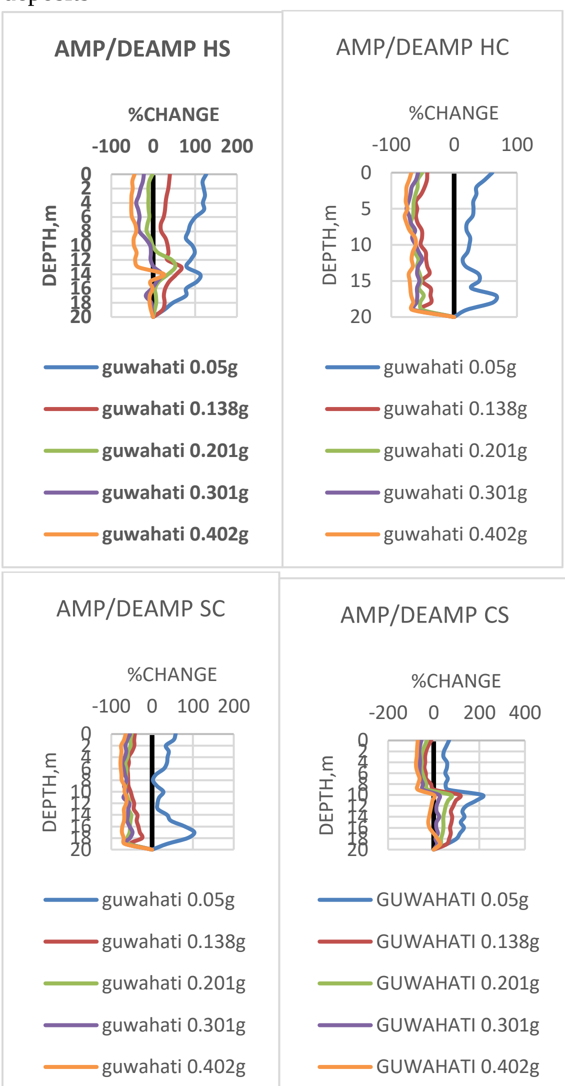
In this study, input peak acceleration changes from (0.05-0.401g) and applied to all the 6 soil profiles in the DEEPSOIL PROGRAM then obtained results are in the following graphs.

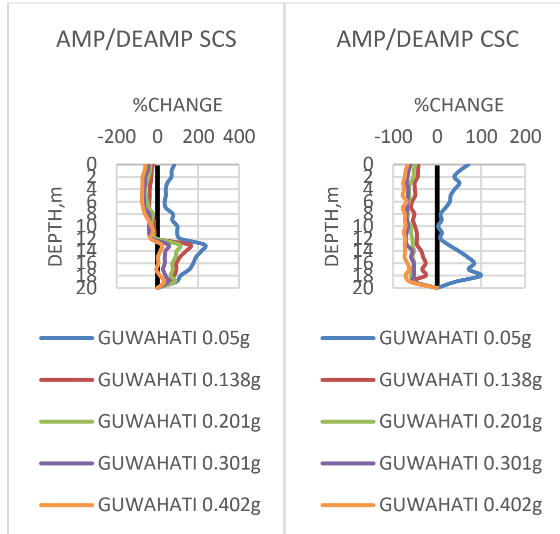
Graph 5.1 results of PGA on multi-layer soil deposits



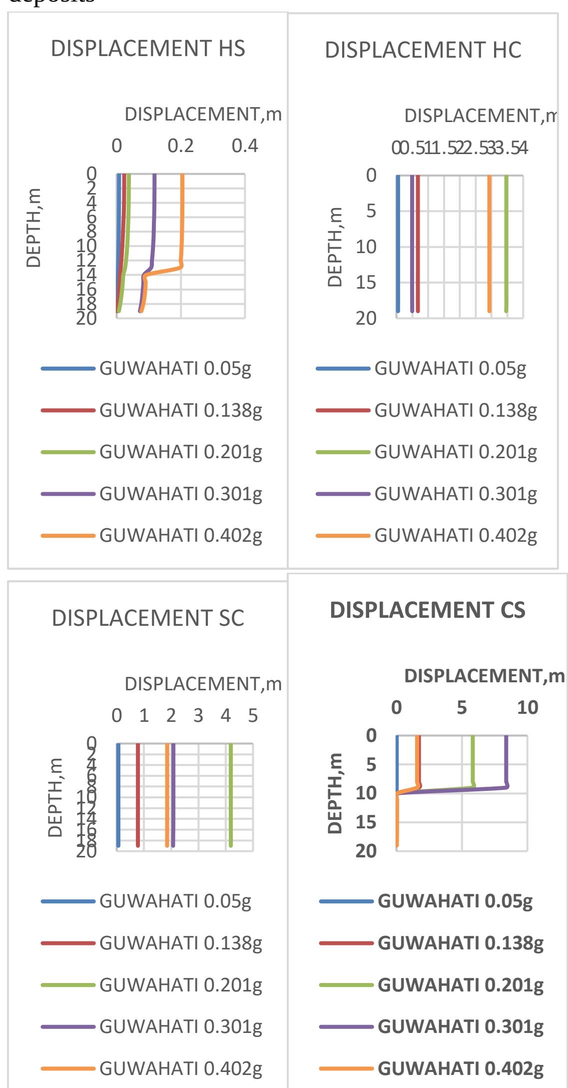


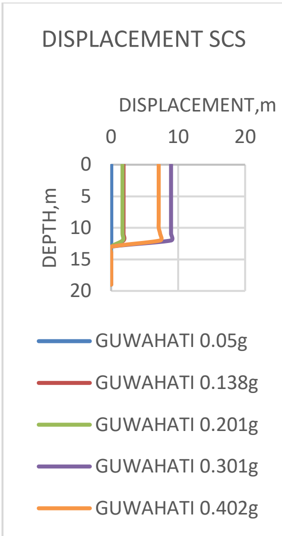
Graph 5.2 results of amp/de amp on multi-layer soil deposits

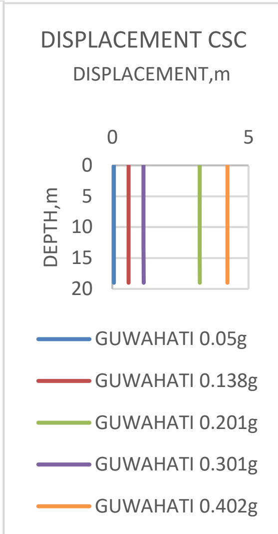




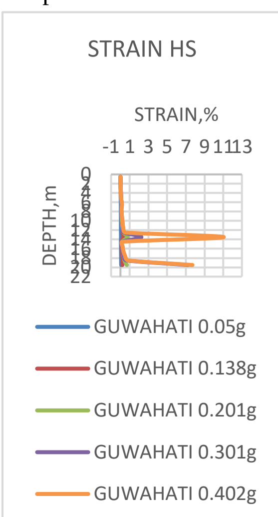
Graph 5.3 results of displacement on multi-layer soil deposits

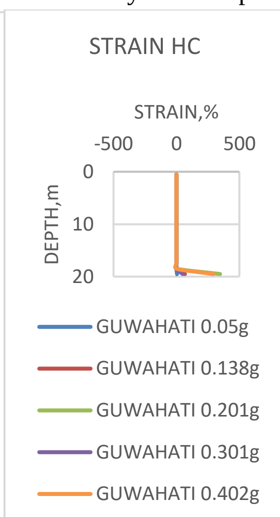


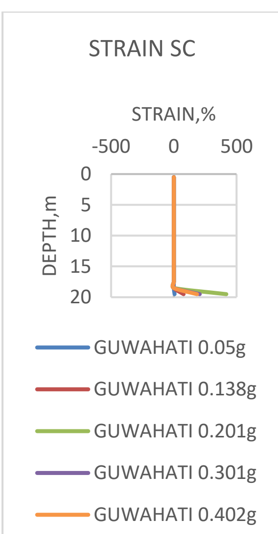


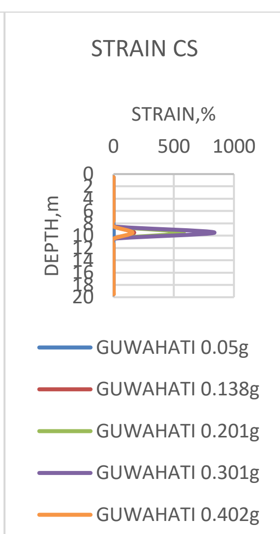


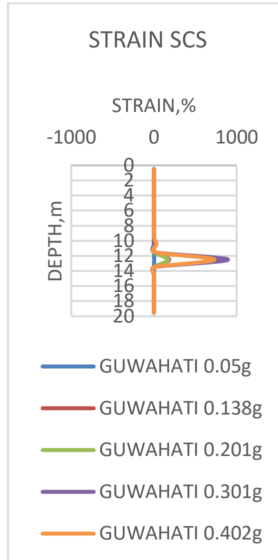
Graph 5.4 results of strain on multi-layer soil deposits

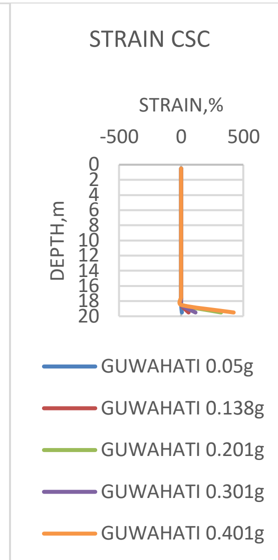












5.1.1 EFFECT OF INTENSITY ON EARTHQUAKE

From the graphs, [DEPTH Vs PGA] I observed that in homogenous sand maximum acceleration occurs in the 14th layer that is obtained 0.505g due to input motion which has a bedrock level acceleration of 0.402g.

In homogenous clay maximum acceleration occurs in the 10th layer that is obtained 0.156g.

In stratified soil deposits maximum acceleration occurs mostly in sand because sand is loosely packed and less stiff due to less cohesion.

From the graphs, [DEPTH Vs AMP/DEAMP] I observed that in any soil profiles the low intensity of ground motion amplifies than high intensity of ground motion.

5.1.2 EFFECT OF INTENSITY ON GROUND MOTION

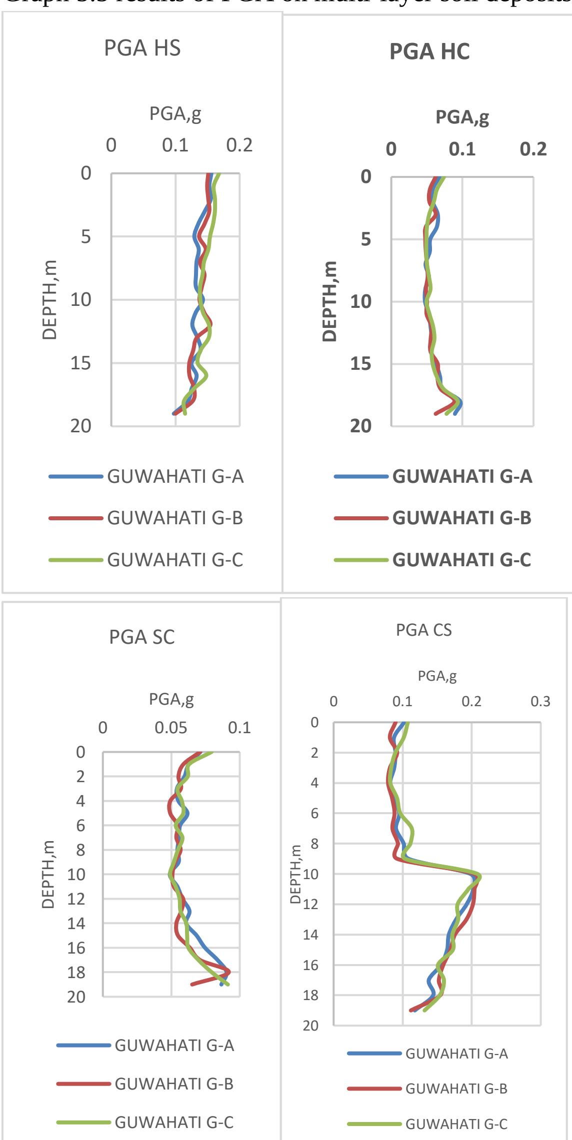
From the graphs, (DISPLACEMENT Vs DEPTH AND % OF STRAIN Vs DEPTH) I observe that in homogenous sand maximum displacement occurs in the 1st layer. While in clay displacement is constant throughout the soil deposit. In stratified soil deposits maximum displacement occurs mostly in sand due to less cohesion.

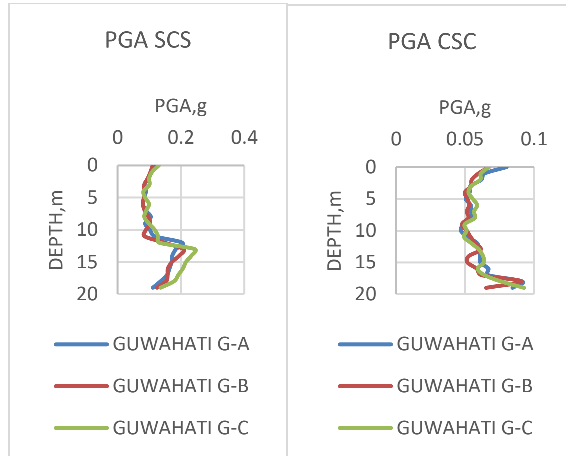
In stratified soils maximum displacement formed when the soil changes from sand to clay and when changing clay to sand it is constant. Maximum displacement and strain (%) occur in the same layers. And more intensity observed in sandy soils when compared to clay deposits.

5.2 EFFECT OF FREQUENCY ON MULTI-LAYER SOIL DEPOSITS

To determine the effect of frequency on multi-layer soil deposits input acceleration (GUWAHATI 0.138g). By using SESIMOMATCH program I change the frequency content then obtained results are GUWAHATI group-A, B&C. The predominant periods of GUWAHATI group-A, B&C are 0.28,0.26&0.62 sec respectively. After these values are uploaded into DEEPSOIL program to the multi-layer soil profiles and the results are obtained in PGA, displacement and strains. The results are shown below graphs.

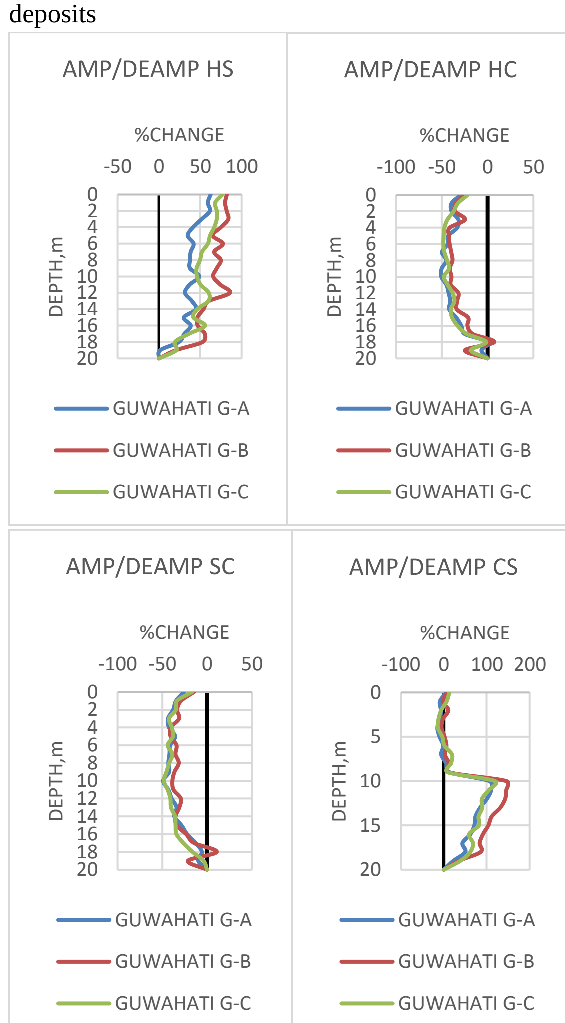
Graph 5.5 results of PGA on multi-layer soil deposits

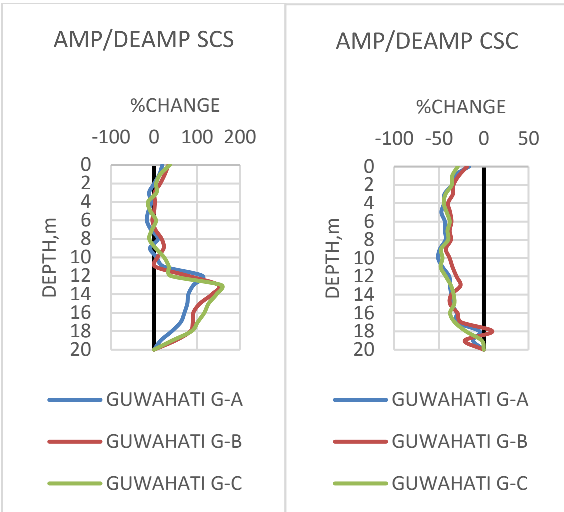




From above graphs, in homogenous sand the PGA is about 0.1g when it comes to clay it below 0.1g and in sand over clay PGA is about 0.1g when it comes to clay over sand PGA below 0.1g up to interface then increases.

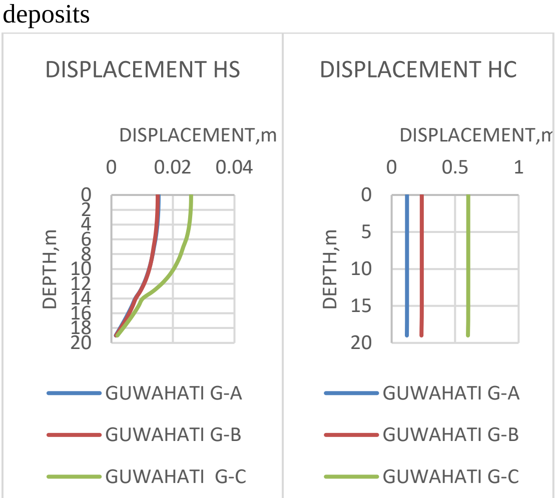
Graph 5.6 results of amp/ de amp on multi-layer soil deposits

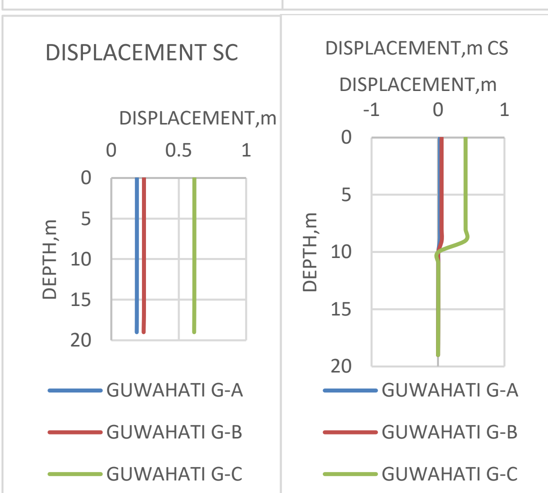


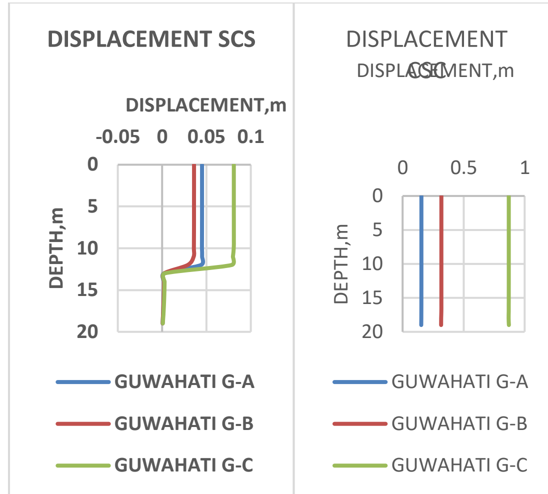


From above graphs, in homogenous sand it amplifies, when comes to homogenous clay it de amplifies. Sand over clay de amplifies and clay over sand it de amplifies up to interface after that it amplifies.

Graph 5.7 results of displacement on multi-layer soil deposits

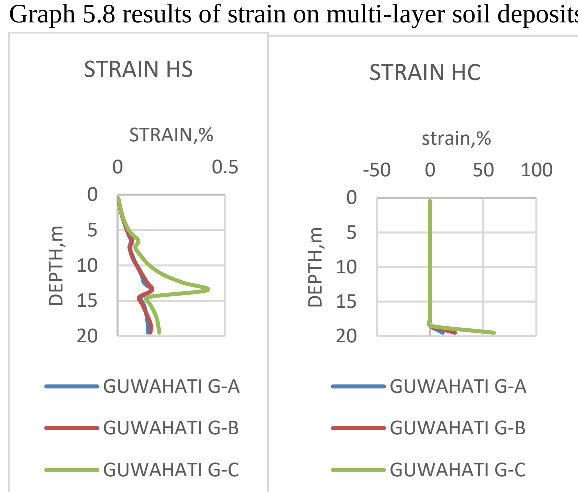


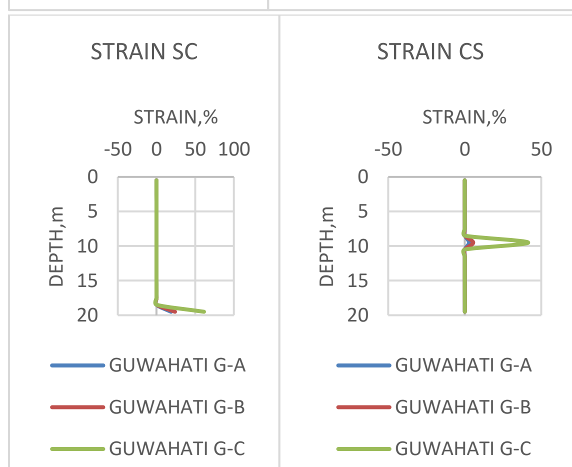


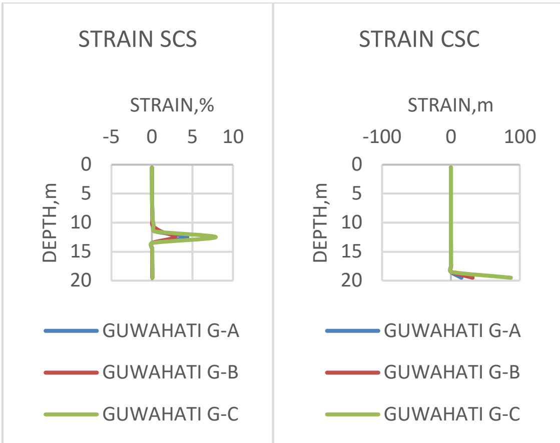


From above graphs, in homogenous sand, displacement decreases with increases in depth; when comes to homogenous clay, displacement is constant throughout the depth. Sand over clay, displacement is constant throughout the depth; when comes to clay over sand, displacement decreases up to interface then it becomes constant.

Graph 5.8 results of strain on multi-layer soil deposits



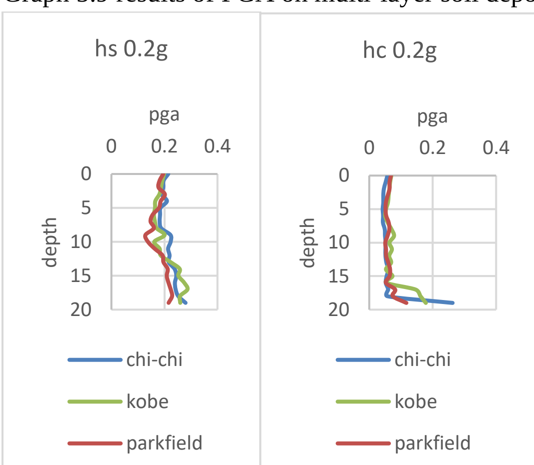


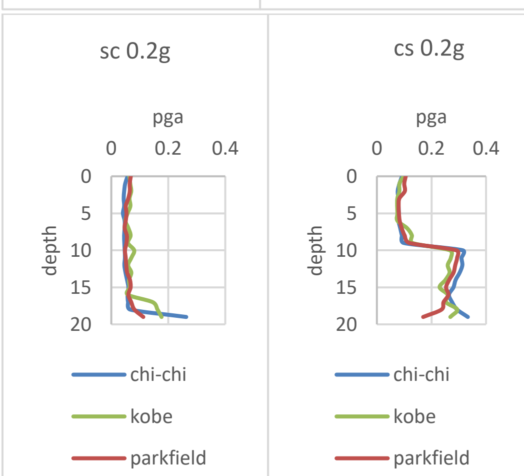


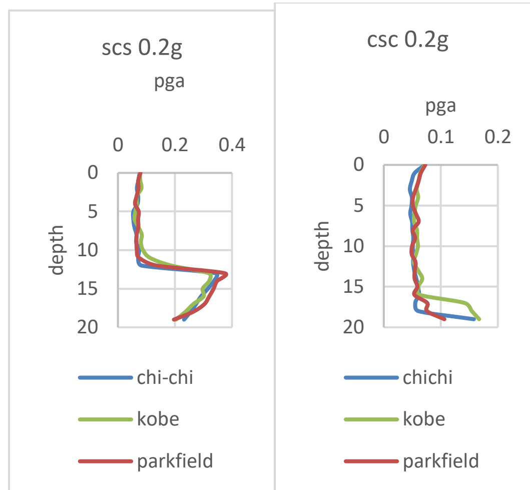
From above graphs,in homogenous sand, maximum strain occurred at 13.5m depth and in homogenous clay strain is constant throughout the depth. Sand over clay strain is constant throughout the depth and clay over sand maximum strain occurred at interface.

5.3 EFFECT OF DURATION ON MUILTI LAYER SOIL DEPOSITS

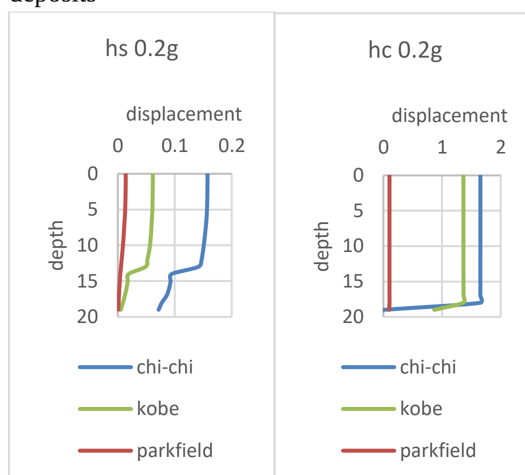
Graph 5.9 results of PGA on multi-layer soil deposits

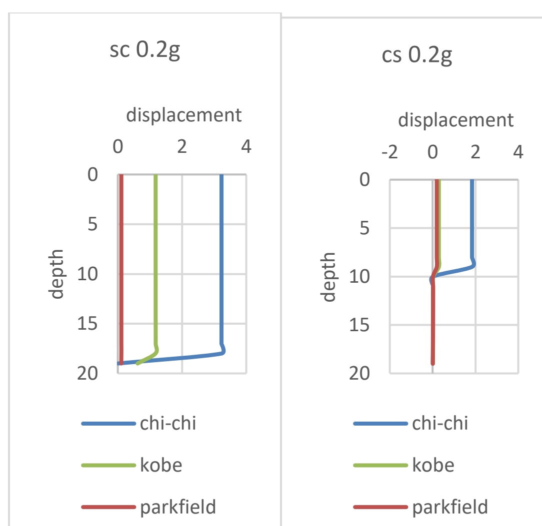


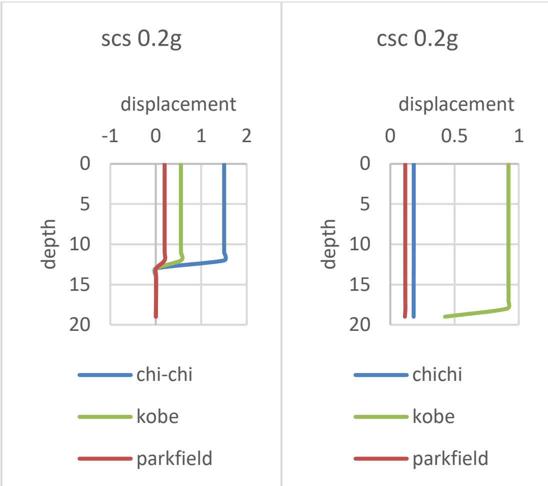




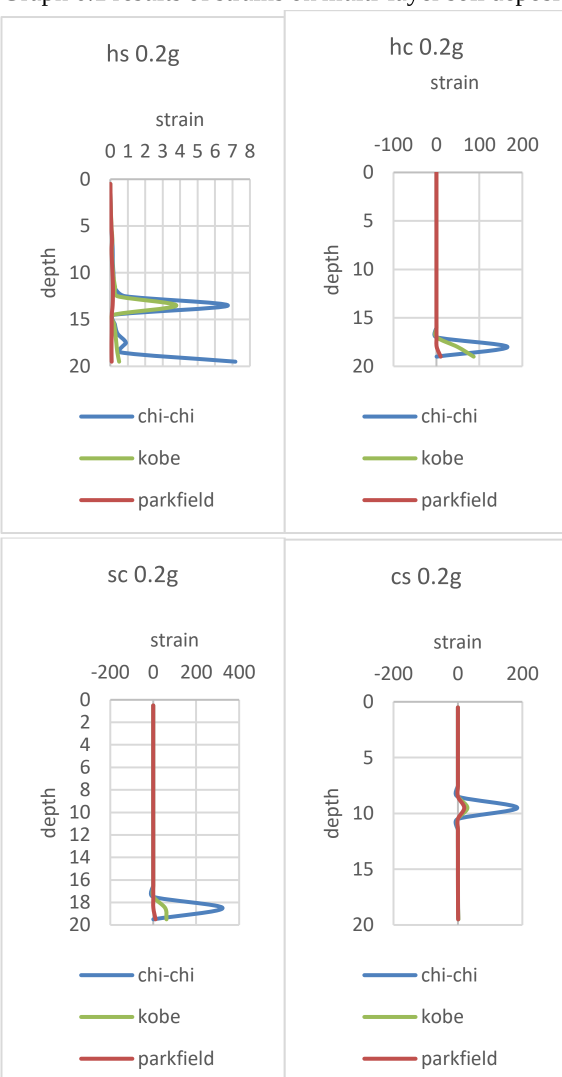
Graph 6.0 results of displacement on multi-layer soil deposits

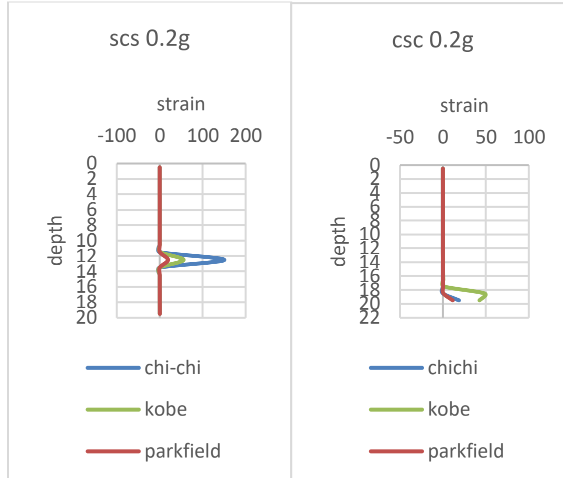






Graph 6.1 results of strains on multi-layer soil deposits





In this study, the durations of chi-chi, kobe and parkfield earthquakes are 60s, 50s and 30s respectively are taken. From the above graphs it is observed that with increases of duration of earthquakes displacement and strains also increases. In sand over clay, PGA, displacement and strain are constant but clay over sand, at intersection displacement and strains are decrease.

6. CONCLUSIONS

The following conclusions are made based on the graphs obtained by the DEEPSOIL program.

- Response of soils to dynamic loads is represented using strain dependent dynamic soil properties include maximum shear modulus (G_{MAX}), secant shear modulus (G) and hysteretic damping (D) of soil. Generally, where the normalized shear modulus ($G\backslash G_{MAX}$) is high their strains are low and vice versa. In this study, the obtained results are also same i.e. $G\backslash G_{MAX}$ is high at low strains and where $G\backslash G_{MAX}$ is high their damping is low.
- Ground motion parameters on seismic ground response analysis of multi-layer soil deposits is carried out. From the result of the detailed study, conclude that maximum displacement occurs when the soil changes from sand to clay. Maximum percentage of strain and maximum displacement occurs at same layer and the mare intensity occurs in sandy layers when compared to clay deposits.
- The effect of frequency on multi-layer soil deposits concluded that displacement is constant throughout the depth, but maximum displacement occurs when the soil changes from clay to sand.

- The effect of duration on multi-layer soil deposits concluded that if duration of earthquake increases, displacement also increases. Maximum displacement occurred at clay over sand.

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