IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 12, Issue 6 Ver. I (Nov. - Dec. 2015), PP 61-71
www.iosrjournals.org

A Study of Ground Surface Motion for Different Locations of Dhaka City

Abu Sayed[1], Md.Zilley Elahi Ibn Salam[2], Md. Ridwan Bin Alam[3] & Nurun Nahar Khan[4]

[1,2]*(Department of Civil Engineering,Bangladesh University of Engineering &Technology,Bangladesh)*
[3]*(Department of Civil Engineering,Ahsanullah University of Science &Technology,Bangladesh)*
[4]*(Department of Civil Engineering, Khulna University of Engineering & Technology, Bangladesh)*

Abstract: *One of the most frightening and destructive phenomena of nature is a severe earthquake and its terrible aftereffects.During 1869-1930, five earthquakes with magnitude M≥7 have affected parts of Bangladesh. Two of them had their epicenters inside Bangladesh. Now-a-days the topics Earthquake has become a matter of concern to the planners and decision makers. In the recent years no major earthquakes have been recorded in Bangladesh so using the earthquake data of Haity earthquake that was occurred on 10th January 2010, response of ground surface of Dhaka city has been proposed. Different soil samples have collected with their SPT values at different locations of Dhaka city. With the help of these particular N-values and using the data of ground surface response during the earthquake, logical prediction of the response of the ground surface can be obtained. From the different borehole data, it is noticed that impervious rocky layer of Dhaka city is situated beneath 70-80 feet from Existing Ground Llevel(EGL) where the impervious layer of Haiti is very near to this ground.*
Keywords: *Earthquake,Ground surface,Logical prediction,Response, SPT values*.

I. Introduction

People all over the world have been combating with various type of natural disaster for their existence from the beginning. Natural disasters like cyclone, flood etc can be predicted pretty earlier so that people can be aware about that. But earthquake is a different one. It comes without really giving time to get people prepared. It is related with the ongoing tectonic process and attack with sudden horror and damage. To minimize the damage the best way is to plan for the disaster earlier.Seismic hazard analysis can be the first step to mitigation and to develop building code for local condition of soil. In this paper response spectrum and idea of amplification is discussed.The Haity earthquake caused catastrophic ground failures in calcareous-sand artificial fills at the seaport, including liquefaction, lateral spreads, differential settlements, and collapse of the pile-supported wharf and pier [1].According to Cardona et. al, (1999), Dhaka is one of those cities which remains in highest relative earthquake disaster risk. Dhaka city has experienced a lot of historical earthquakes like 1897 Shillong Earthquake(Ms=8.1) due to its geological location. Tectonic boundaries between India plate and Eurasia plate to the north and the tectonic boundary between Indian plate and Burma plate to the east surround Bangladesh and produce a real great possibility of larger earthquake [2]. The seismic wave can be amplified that depends on the location of bedrock and types of soil layer. In this thesis, the consequences of Haity earthquake be analysed and correlation of this earthquake in Bangladesh especially in Dhaka city.

Due to different type of soil deposit every location has its own seismic response characteristics . From theory of wave its known that, if frequency of ground response get matched with the natural frequency of a structure, resonance takes place and maximum damage occurs. In Ahmedabad , heavy damage has been experienced during Bhuj Earthquake, 2001 which was situated upon young alluvial soil deposit at a great distance from the epicenter of earthquake just like Dhaka.Dhaka is a more over populated city than Ahmedabad and is the capital city of Bangladesh. It also lies in great earthquake damage risk (Cardona et. al, 1999). So seismic response analysis is needed for microzonation map and that will be very effective for future planning purposes.The main objectives of this paper are to estimate soil parameters that are vulnerable to cause earthquake in Dhaka city and to estimate spectral acceleration for different location in Dhaka city. This research was perfomed using some specific locations of Dhaka city.

1.1Overview of Haity earthquake

The 2010 Haiti earthquake was a catastrophic of magnitude 7.0 M_w, with an epicentre near the town of Léogâne, approximately 25 km (16 miles) west of Port-au-Prince, Haiti's capital [3]. The earthquake occurred at 16:53 local time (21:53 UTC) on Tuesday, 12 January 2010. By 24 January, at least 52 aftershocks measuring 4.5 or greater had been recorded. An estimated three million people were affected by the quake; the Haitian government reported that an estimated 316,000 people had died, 300,000 had been injured and 1,000,000 made homeless. International agencies, including the United States Agency for International Development, have suggested that the death toll is much lower at somewhere between 46,000 and 92,000 and 220,000, with around 1.5 million to 1.8 million homeless. The government of Haiti also estimated that 250,000 residences and 30,000 commercial buildings had collapsed or were severely damaged.

Fig.1 Region of Haiti earthquake.

1.2 Overview of Geological Characteristics of Dhaka city

Dhaka is situated between latitudes 23°42' and 23°54'N and longitudes 90°20' and 90°28'E. Dhaka is situated at the southern tip of a Pleistocene terrace, theModhupur an two characteristic geological units cover the city and surroundings, viz Madhupur Clay of the Pleistocene age and alluvial deposits of Recent age. The Madhupur Clay is the oldest sediment exposed in and around the city area having characteristic topography and drainage. The major geomorphic units of the city are the high land or the Dhaka terrace, the low lands or floodplains,depressions and abandoned channels. Low lying swamps and marshes located in and around the city are other major topographic features. The Dhaka city area does not show any surface folding. However, a large number of faults and lineaments have N-S, E-W. NE-SW, NW-SE trends recognised from air photo interpretation and the nature of the stream courses. All four sides of the city are bounded by major faults. Bangladesh is divided into 3 seismic zones based on the vulnerability to earthquakes and possible severity of damages. In all the classifications Dhaka city and its surroundings are shown to be situated in the seismic zone 2, the medium risk/hazard zone [4].

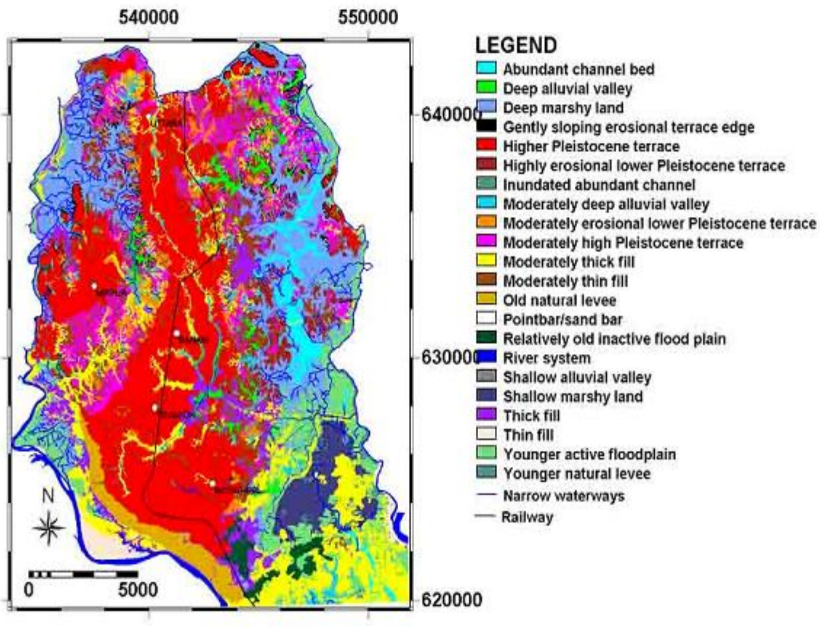

Fig. 2 Geological soil map of Dhaka.

1.3 Description of Study Area

Field investigations were carried out within 20m depth in all three sites.We used three bore hole data collected from Mirpur DOHS,Ashian City and Purbachal of Dhaka.

Bore hole 1: This is situated at Mirpur DOHS North South (fig 3).Ground Level R.L is to 0.6m from road level. Ground water level is to 4.5m from EGL. It contains grey loose silty Fine sand with trace mica (filling),Depth is to 3 m.(D-2),And it contains brown stiff clayey silt with fine sand medium compression,Depth is to 9 m (D-6).

Bore hole 2: This is situated at Ashiancity,Dhakkin khan (fig. 4).Ground Level R.L is to 0.6m from road level. Ground water level is to 1.5m from EGL. It contains grey loose silty Fine sand with trace mica (filling),Depth is to 1.5 m.(D-1),And it contains grey soft to medium stiffsilty clay with plastic clay.Depth is to 10.5 m (D-7).**Bore hole 3:**This is situated at Purbachal,Rupgonj,(fig 5).Ground Level R.L is to 1.5 m from road level. Ground water level is to 0.9m from EGL. It contains grey soft clay trace fine sand medium plastic,Depth is to 4.5 m.(D-3)And It contains grey medium dense silty fine sand trace mica.Depth is to 10.5 m (D-7).

Fig. 3 MirpurDOHS(Collected from google map)

Fig. 4 Ashian city(Collected from google map)

Fig. 5 Purbachal project(Collected from google map)

I.

II. Materials And Methods

2.1 Field investigation

Field investigations were performed in the form of SPT in the selected locations as discussed in below. Wash boring technique was used for SPT. Disturbed and undisturbed samples were collected from each bore-hole and SPT-N values were recorded at a depth of every 1.5m interval. The borings were conducted up to 20m depth in respect to Existing Ground Level(EGL). Collected soil samples were tested in the laboratory. Mainly Grain size distribution tests, Atterberg limit tests and specific gravity tests were carried out in Bangladesh University of Engineering &Technology (BUET) Geotechnical laboratory.Shear wave velocities were determined from the SPT-N values using equations

2.2 Standard Penetration Test

Out of many in situ penetrations based soil testing system in the field of geotechnical engineering SPT is characterized as one of the easy, user friendly, economical but reliable method soil tests. It readily determines the soil penetration resistance and various physical properties and characteristics of soil enabling interrelationship between them. SPTs have been conducted in all areas described above to utilize SPT-N values in estimating required static and dynamic properties of site soil, SPT was conducted according to ASTM D 1586(ASTM,2000).

2.3 Sieve analysis test

A sieve analysis or gradation test is a practice or procedure used to assess the particle size distribution of a granular material. It can be performed on any type of non-organic or organic granular materials including sands, crushed rock, clays, granite, feldspars, coal, soil, a wide range of manufactured powders, grain and seeds, down to a minimum size depending on the exact method. Being such a simple technique of particle sizing, it is probably the most common.The sieve analysis test are shown in Figure 6 to Figure 11 graphically.

2.4 Atterberg Limits Test

Atterberg Limits Test was performed on the clay samples collected from the bore holes. This test was performed according to ASTM d 4318-86 to determine liquid limit(w_L), plastic limit (w_P) and liquidity index(I_L). The plasticity index (PI) is a measure of the plasticity of a soil. The PI is the difference between the liquid limit and the plastic limit (PI = LL-PL). Soils with a high PI tend to be clay, those with a lower PI tend to be silt, and those with a PI of 0 (non-plastic) tend to have little or no silt or clay.The liquidity index (LI) is used for scaling the natural water content of a soil sample to the limits. It can be calculated as a ratio of difference between natural water content, plastic limit, and liquid limit: LI=(W-PL)/(LL-PL) where W is the natural water content .The result of atterberg limit test is shown in Table 1and result of grain size analysis is shown in Table 2.

Table 1:Atterberg limit result

Plastic limit	Liquid limit	Shrinkage limit	Plasticity index	Flow index	Liquidity index
15	47.4	18	32.4	9.8	1.08
19	47.2	22.5	28.2	10.3	1.17
14	48	21.4	34	11.6	1.2

Table 2:Grain Size Distribution

Location	BH	Depth (m)	Soil type	Grain Size Analysis					
				D_{10}	D_{30}	D_{60}	C_U	C_C	F.M.
Mirpur DOHS	1	3(D2)	Fine sand	0.015	0.075	0.12	8.0	3.12	1.9
		9.0(D6)	Clayey silt	0.02	0.082	0.1	2.62	2.24	5.0
Ashian city	2	1.5(D1)	Fine sand	0.035	0.07	0.102	2.92	1.38	2.0
		10.5(D7)	Silty clay	0.025	0.075	0.14	5.6	1.6	2.22
Purbachal	3	4.5(D3)	Silty clay	0.015	0.075	0.12	8.0	3.12	1.9
		10.5(D7)	Fine sand	0.075	0.17	0.23	3.06	1.68	2.87

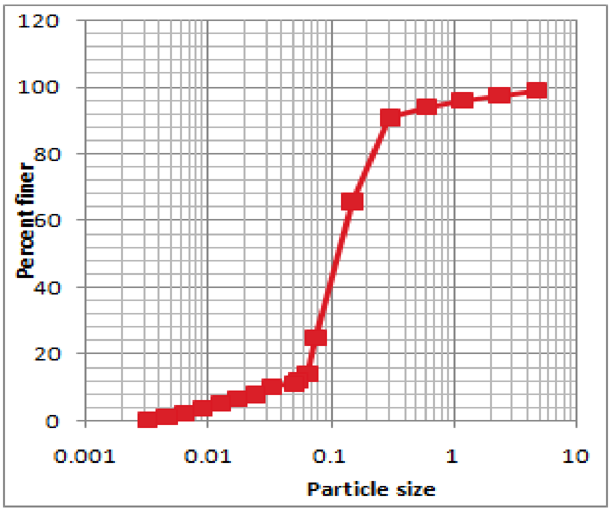

Fig. 6 Mirpur DOHS,(BH-1,Depth-3 ,D-2)

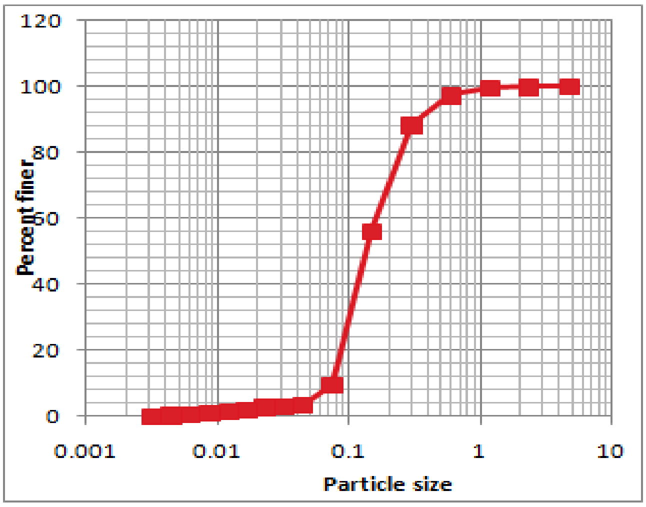

Fig.7 MirpurDOHS, (BH-1,Depth-9.0 ,D-6)

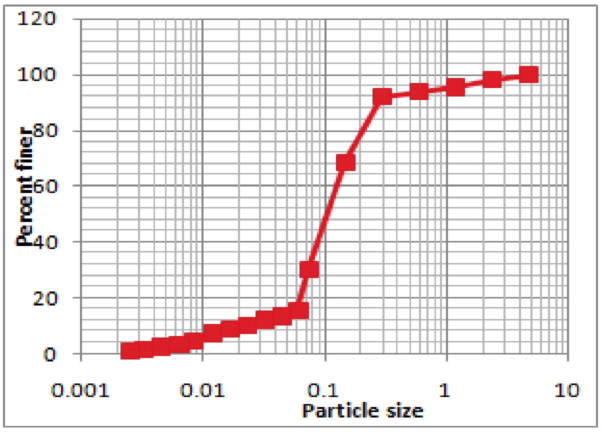

Fig.8 Ashian city.(BH-2,Depth-1.5 ,D-1)

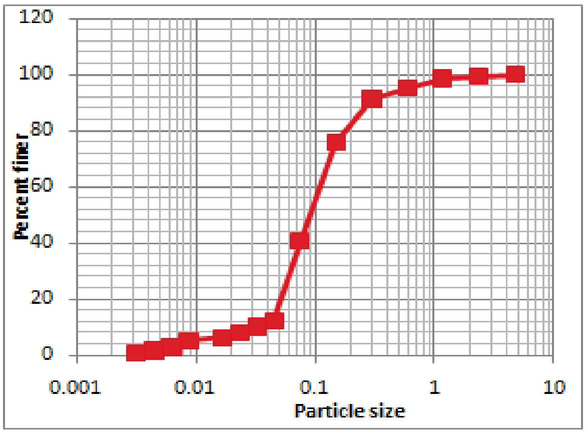

Fig. 9 Ashian city.(BH-2,Depth-10.5 ,D-7)

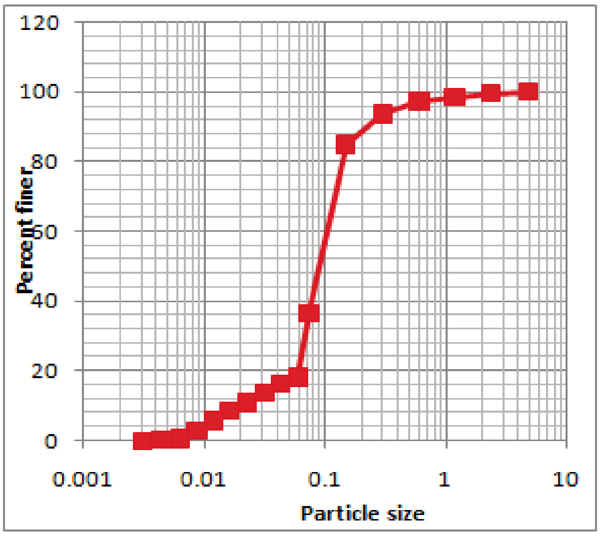

Fig. 10 Purbachal (BH-3,Depth-4.5 ,D-3)

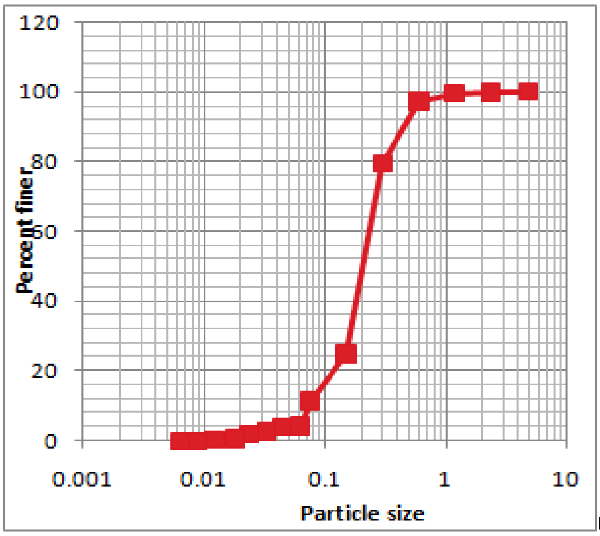

Fig. 11 Purbachal (BH-3,Depth-10.5 ,D-7)

2.5 Ground Motion Analysis

Ground motions parameters are commonly described with a time history. Acceleration, velocity, displacement or all of them can be displayed as motion parameter. Typically only one of this are measured directly and others are computed by basic relations between them. Acceleration time history is significant when frequency is high and displacement time history is dominant for low frequency motion.According to Kramer[5], Considering a soil deposit of N horizontal layers where N th layer is the bed rock, and assuming that each layer of soil behaves as a Kelvin-Voigt solid, the wave equation is,

$$\rho \frac{\delta^2 u}{dt^2} = G \frac{\delta^2 u}{dz^2} + \eta \frac{\delta^3 u}{\delta z^2 \delta t} \quad \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

The solution of the wave equation can be expressed in the form ,

$$u(z,t) = Ae^{i(\omega t + k^* z)} + Be^{i(\omega t - k^* z)} \quad \ldots\ldots\ldots\ldots\ldots(2)$$

Where A and B represents amplitude of wave traveling in the –z (upward) and +z(downward) direction respectively . The transfer function relating the displacement amplitude at layer i to that of layer j is given by,

$$F_{ij}(\omega) = \frac{|u_i|}{|u_j|} = \frac{a_i(\omega) + b_i(\omega)}{a_j(\omega) + b_j(\omega)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Because $\left|\ddot{u}\right| = \omega\left|\dot{u}\right| = \omega^2\left|u\right|$ for harmonic motion, equation (3) also describe the amplification of acceleration and velocities from layer i to layer j . Equation (3) indicates that motion at any layer can be determined from any other layers motion.Site Amplication: Site amplification is simply the ratio of acceleration at surface and acceleration at bedrock. It gives very important parameter for prediction of structure's behaviors in earthquake

2.6 Response spectrum analysis

Response spectrum is extensively used in earthquake engineering practice. It represents the maximum response of a single degree of freedom system (SDOF) to a particular input motion as a function of the natural frequency or natural period and damping ratio of the system. Response spectra can be plotted to arithmetic scale individually or combined. The spectral acceleration or velocities or displacement are plotted in vertical axis and natural period are plotted in horizontal axis. The response spectra indicate the maximum acceleration or velocity or displacement of a structure associated with different natural frequency or period (Kramer, 1996 [5]). The maximum value of these parameters only depends on natural frequency, period and damping ratio of the system. For the SDOF system of zero natural frequency is a rigid system and its spectral acceleration(S_a) would be the same as peak ground acceleration.Use of Duhamel integral to a linear elastic SDOF system produce expression for acceleration , displacement and velocities time histories that are proportional by factor ω, except for the phase shift. Because the phase shift does not significantly influence the maximum response values, the spectral acceleration(S_a),spectral vrlocity(S_v) and spectral displacement(S_d) can be approximately related to each other by the relations,

$$S_d = \left|u\right|_{\max}$$

$$S_v = \left|\dot{u}\right|_{\max} \approx \omega_0 S_d = PSV$$

$$S_d = \left|\ddot{u}\right|_{\max} \approx \omega_0^2 S_d = \omega_0 .PSV = PSA$$

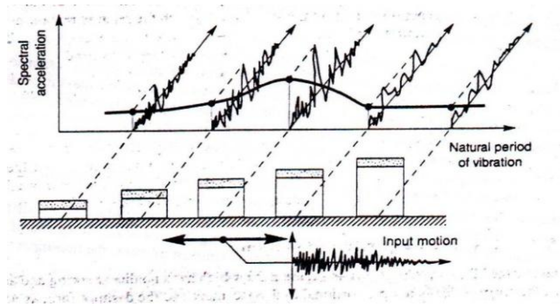

Fig.12 Procedure of developing Response spectra. (Kramer, 1996[5])

Where u and ω_0 are the displacement and natural frequency of SDOF system. Here PSV is Pseudospectral Velocity, PSA is Pseudospectral Acceleration which are not same as maximum values, but can be considered as maximum value.

2.7 Procedure of Data Analysis

For accurate prediction of ground motion in thick soil layer shear wave velocity of different depth of soil layer is necessary. Within many methods of ground motion response analysis, one dimensional analysis is used in this research. This one dimensional analysis is done by using SHAKE, which is a ground motion analysis software developed by Schnabel et al, 1972[6]. For ground motion analysis two Text file is needed as input. One will give the soil data and damping ratio (h) and shear modulus ratio (G/G_0) with respect to shear strain and another Text file will give the ground motion of outcrop and it is shown at Figure 13. An example is given in Figure 14,Here in soil type, 1 – Clay,2 – Sand,3 - Dense sand,0 –rock.The damping ratio and shear modulus ratio are taken from cyclic triaxial shear test data for different type of soil. Those data was collected from Ansary et al, 2010 [4]. Those data has given as an input as Figure 15.

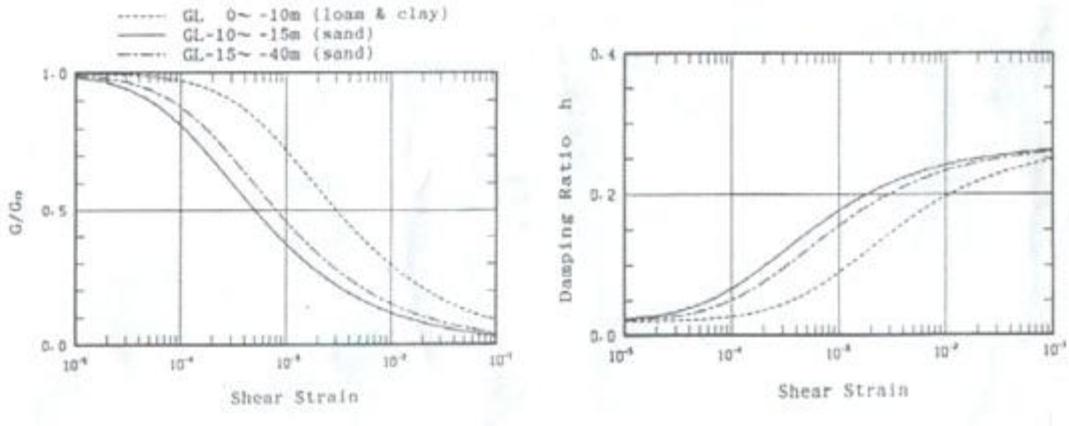

Fig.13: Assumed strain dependent soil properties (Ansary et al, 2010[4])

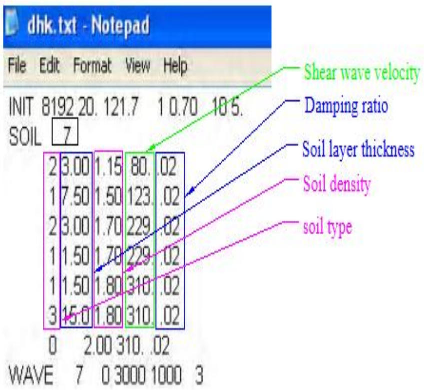

Fig.14 Input data of soil properties. **Fig.15** Input data of dynamic properties

In Figure 15, it can be seen that there are three different carve for three type of soil. They are used as input consequently in the first text file.In another text file only time history is only input value. In this research each value is given in a interval of 0.02 sec.It can be seen that the total time of 1985 Mexico City Earthquake is 60 second and from data it can be found that total time of 1989 Loma Prieta earthquake is 40 second[7]. So total (60/0.02 =) 3000 values are used in Mexico earthquake and (40/.02 =) 2000 values are used in Haity earthquake.Than the executive file has run and output file of ground motion at surface and bedrock are generated. Than the values from output file are used for plotting ground motion by MS Excel. To calculate the Response Spectra this output file is used in another executive file of SHAKE. It generates response spectra of acceleration, velocity and displacement against natural period of structure at a given interval of 0.01 sec from 0.1 sec to 10 seconds which is normally considered as time period of a one story building to hundred stories building roughly. For Dhaka city no more value for time period of more than 10sec is required apparently. Dynamic soil property of different locations are given below in Table 3.These data were used as input data.

Table 3:Dynamic soil property of different location

Location	Layer no	Soil type	Soil type code	Layer Thickness (m)	Soil density (Tcf)	Sear wave velocity	Damping ratio
Mirpur DOHS	1	Fine Sand	2	2.5	1.15	175	.02
	2	Fine Sand	2	3.0	1.5	185	.02
	3	Stiff clay	1	3	1.5	195	.02
	4	Clayey Silt	1	2.5	1.5	200	.02
	5	Fine Sand	2	3.5	1.5	240	.02
	6	Silty clay	1	5.5	1.5	255	.02
	7	Rock	0		2	310	.02
Ashian City	1	Fine Sand	2	3.5	1.15	160	.02
	2	Clay Soil	1	2.0	1.5	150	.02
	3	Clay Soil	1	1.5	1.5	110	.02
	4	Clay Soil	1	5.5	1.5	300	.02
	5	Fine Sand	2	4.5	1.5	175	.02
	6	Silty clay	1	3.0	1.5	310	.02
	7	Rock	0		2	310	.02
Purbachal	1	Clayey Silt	1	2.0	1.15	150	.02
	2	Clay Soil	1	6.0	1.5	160	.02
	3	Sandy Soil	2	2.0	1.5	165	.02
	4	Sandy Soil	2	2.5	1.5	210	.02
	5	Sandy Soil	2	3.0	1.5	175	.02
	6	Sandy Soil	2	4.5	1.5	185	.02
	7	Rock	0		2	310	.02

2.8 Input Ground Motion

Ground motion response for 90^0 East-West direction using Presa de Sabenta ,Haity station is shown at Figure 16 .Ground motion response for 360^0 North-South direction using Presa de Sabenta ,Haity station is shown at Figure 17.

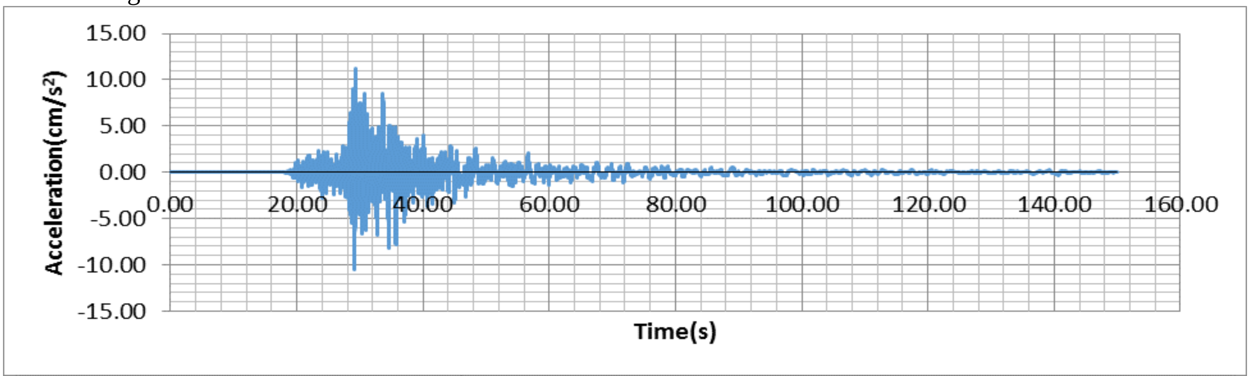

Fig.16 : Ground motion history for 90^0 E-W direction of Haity Earthquake.(Used as input ground motion)

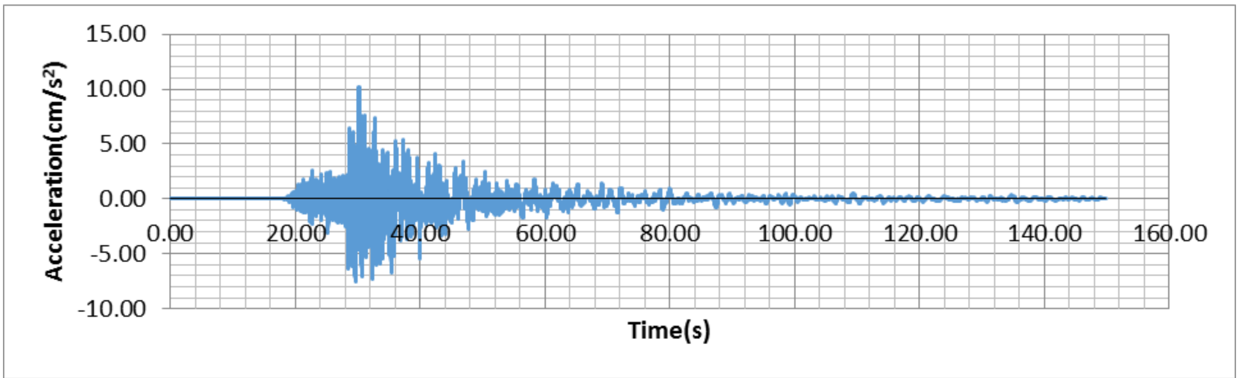

Fig. 17 Ground motion history for 360^0 N-S direction of Haity Earthquake.(Used as input ground motion).

III. Results And Discussions

3.1 Output Ground motion for Dhaka soil

Using ground motion history of Haity earthquake ,We found output ground motion history of Mirpur DOHS for 90^0 E-W direction and 360^0 N-S direction that is shown at Figure 18 and Figure 19 respectively.Similarly output ground motion history of Ashian city for 90^0 E-W direction and 360^0 N-S direction is shown at Figure 20 and Figure 21 respectively. And output ground motion history of Purbachal project for 90^0 E-W direction and 360^0 N-S direction is shown at Figure 22 and Figure 23 respectively.

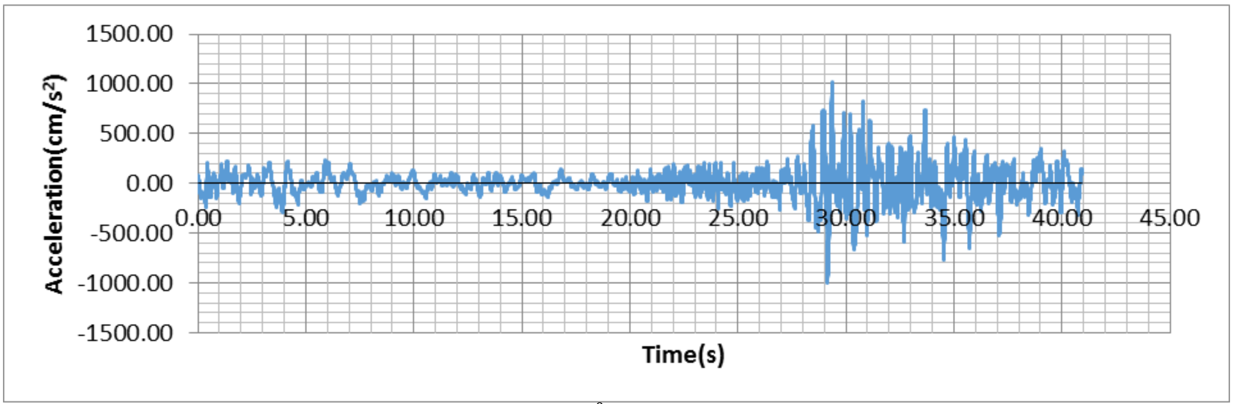

Fig.18 Ground motion history for 90^0 E-W direction in Mirpur DOHS.

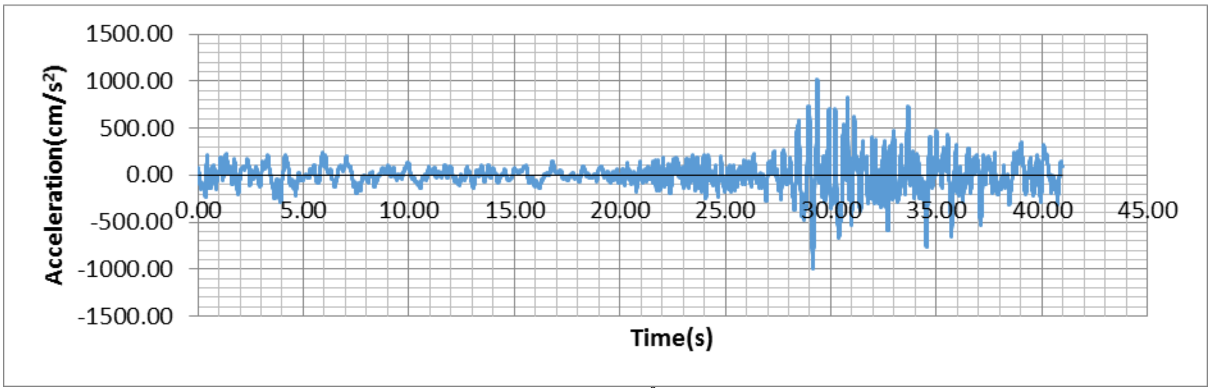

Fig. 19 Ground motion history for 360^0 N-S direction in Mirpur DOHS.

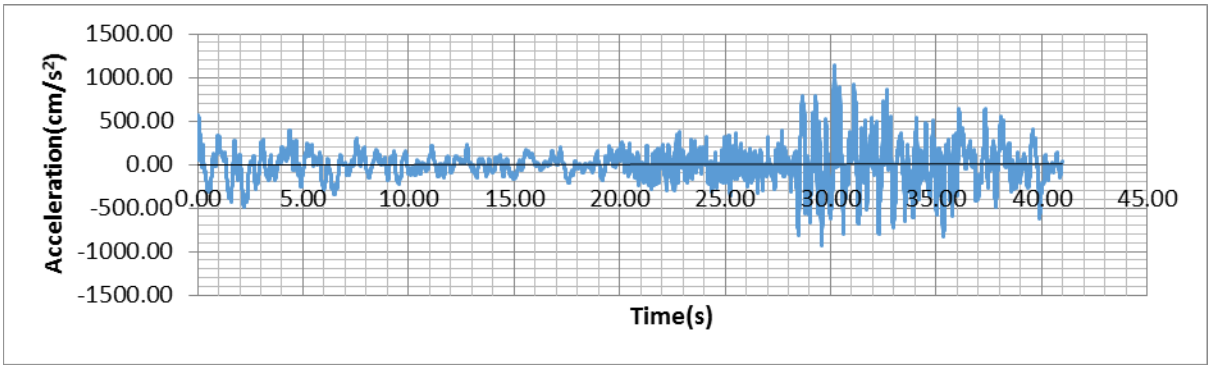

Fig. 20 Ground motion history for 90^0 E-W direction in Ashian city.

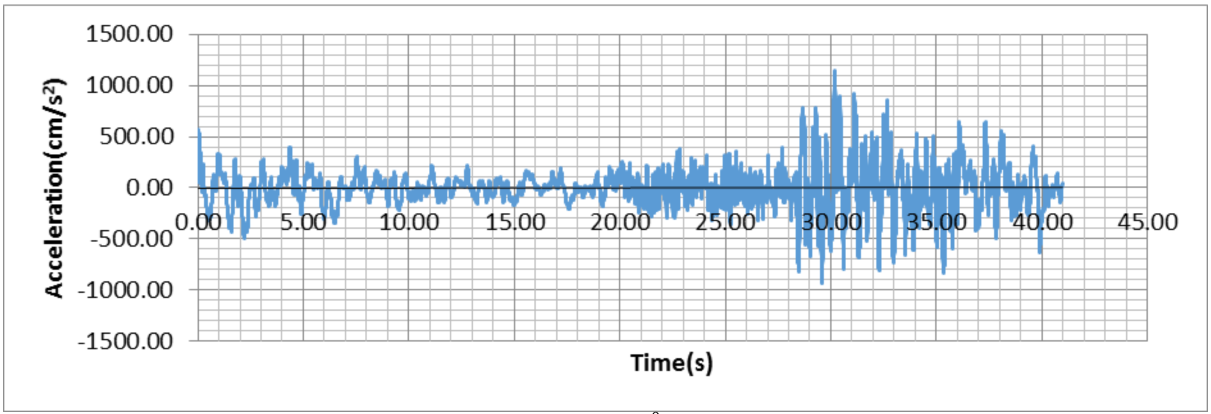

Fig. 21 Ground motion history for 360^0 N-S direction in Ashian city.

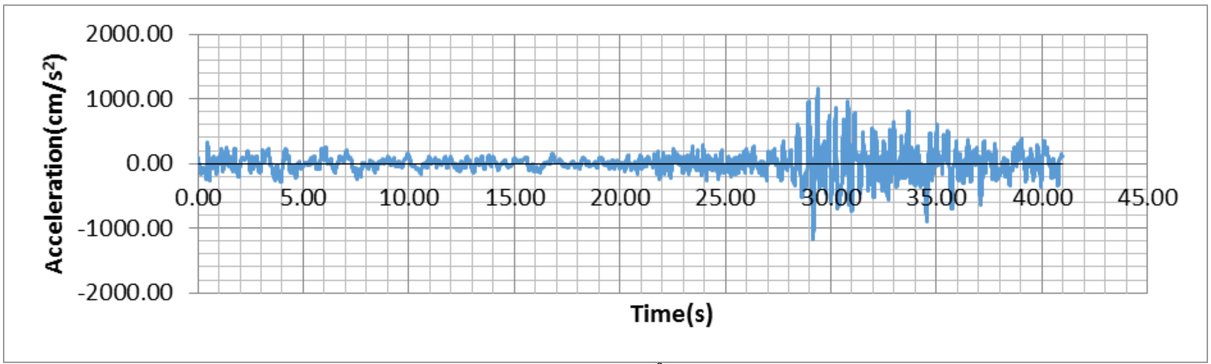

Fig. 22 Ground motion history for 90^0 E-W direction in Purbachal.

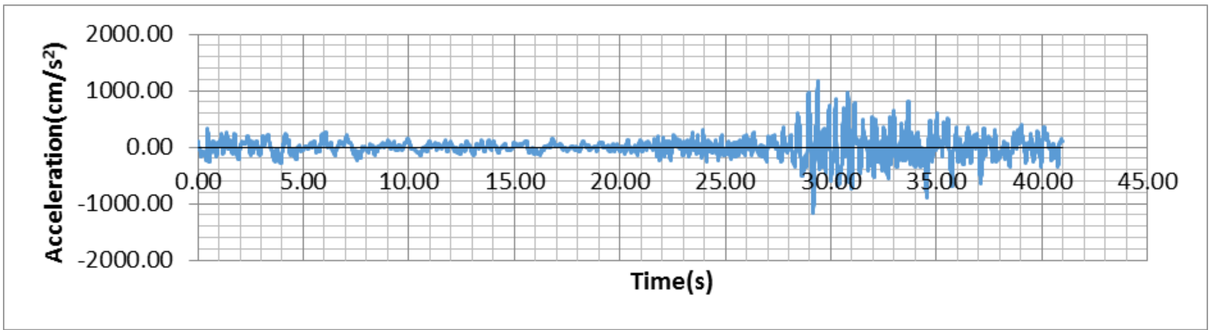

Fig.23 Ground motion history for 360^0 E-W direction in Purbachal.

3.2 Comparision of results

The maximum amplification of acceleration was found in Purbachal project.At that place the top 20.0 meter soil is found as soft clay and sandy soil with shear wave velocity of only 210 m/s. The maximum acceleration was found 1200 cm/s^2 at north south direction.The minimum amplification was found at Mirpur DOHS. The shear wave velocity at that location is maximum 255 m/s to minimum 175 m/s.From the outputs ,the maximum acceleration and the ratio which have obtained from data of different location of Dhaka city using the Haity earthquake data are given below.

Table 4: Chart for Peak acceleration and Site amplication ratio

Location	Presa de Sabenta station			
	Maximum Acceleration at 90^0 E-W direction(cm/s^2)	Site amplification Ratio	Maximum Acceleration at 360^0 N-S direction(cm/s^2)	Site amplification Ratior
Mirpur DOHS	1020	9.44	1020	8.44
Ashian city	1150	8.40	1180	8.57
Purbachal project	1170	8.55	1200	9.45

Dhaka, the capital of Bangladesh is the most important and densely populated city of this country. According to 2001 census there are more than 1000 people live in every square Kilometer area. This city also has the history of large earthquakes within previous 150 years (1897 Shillong Earthquake and 1950 Assam Earthquake) [8]. This whole country is surrounded by several tectonic boundaries where earthquake occurrence probability is very high. Dhaka city is formed by alluvial deposits which thickness is around 10 Km. Two earthquakes are used in this analysis to find the amplification characteristics and variability. On those two earthquakes its observed that the damages were larger on those locations where alluvial deposit remains overlying like Dhaka city. The ground motions recorded from Yerba Buena Island were used for 1989 Presa de Sabenta Haity earthquake and data recorded from UNAM were used as ground motion for Haity 2010 earthquake[8].The main objective of this research was to estimate site response and response spectra based on soil dynamic property data (shear wave velocity) collected from Comprehensive Disaster Management Programme(CDMP) project.

IV. Conclusions

In this research the main objective was to estimate the soil ground motion. From that ground motion the amplification of different location of Dhaka city was found. For different type of location it is found that maximum acceleration occurs with the building of natural period of 30 to 40 second which indicate 3 story building to 10 story buildings are in maximum risk. The location where an upper soil stratum is younger and looser is subjected to maximum amplification and on the other hand the location where upper soil strata is formed by over consolidated clay and very stiff clay is subjected to less acceleration.

References

[1]. Geotechnical Aspects of Failures at Port-au-Prince during the 12 January 2010Haiti Earthquake,Russell A. Green, Scott M. Olson, Brady R. Cox, Glenn J. Rix, Ellen Rathje, Jeff Bachhuber,JameFrench,SamuelLasley,andNathanielMartin pp. S43-S65
[2]. Center for engineering strong motion data ,http://www.strongmotioncenter.org/ Accessed on June,2011
[3]. Seismic Hazard Maps for Haiti
[4]. Arthur Frankel, Stephen Harmsen, Charles Mueller, Eric Calais, and Jennifer Haase pp. S23-S41
[5]. Ansary, M.A.,Rahman, S., Murad, E.M., Chowdhury, S.A. and Shuvra, D.P., (2010)
[6]. "Proposed time history and response spectrum for Dhaka, Chittagong and Shylet cities",
[7]. Kramer, S. L., (1996),Geotechnical Earthquake Engineering (Low Price Edition,1996).
[8]. Algermissen, S., T. and Perkins,D.M., (1976)."A Probablistic Estimate of Maximum Acceleration in Rock in the Contiguous United States." U.S. Geological Surve
[9]. Recent earthquake teachable moments, http://www.iris.edu/hq/retm,Accessed on june, 2011
[10]. Shear Wave Velocity- and Geology-Based Seismic Microzonation of Port-au-Prince, Haiti
[11]. R. Cox, Jeff Bachhuber, Ellen Rathje, Clinton M. Wood, RanonDulberg, AlberKottke,RussellA.Green,andScottM.Olson pp. S67-S92.