Soil Amplification Studies for Ahmedabad Region

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Abstract-- **The present paper is primarily concerned with identifying the areas in Ahmedabad region in which soil formations are prone to amplifying ground motions, as well as evaluation of amplification of peak ground accelerations due to soil using computer program ProShake for earthquake site response analysis. Based on the soil formation summary in Ahmedabad, a qualitative approach was employed to determine locations in Ahmedabad that are prone to ground motion amplification due to their soil formations, and a tentative map showing these areas was prepared. Acceleration amplification factors were obtained as the ratio of spectral accelerations at the top to those at the bottom of the soil formation. Amplification factors are presented for firm and weak sites. It was found that while for the firm sites, amplification factors reach only maximum values of 1.69, amplification factors in the weak sites may very well reach 4.26. This finding clearly confirms the effect of soil formation on amplification of ground motion.**

Index Terms**—Peak ground acceleration, equivalent linear ground response analysis, soil amplification.**

I. INTRODUCTION

Soil formations at one site may have a great influence on ground motion characteristics. Specifically, peak ground accelerations (PGA) values as affected by the site soil formations and their amplification, or deamplification, need to be determined. As is evidenced by observations of earthquake-induced damage, buildings on rock or compact soils might be subjected to lower lateral forces as compared to neighboring structures on deep soft soil strata. Apart from rigorous analytical studies, it is common to account for the soil amplification of ground motions either by specifying site-dependent response spectra or by specifying amplification coefficients for different soil formations.

The main objectives of the present paper are: (i) to identify the areas in Ahmedabad in which soil formations are prone to amplifying ground motions and (ii) to analytically evaluate amplification of PGAs due to soil using ProShake computer program for earthquake site response analysis.

Under ideal conditions, a complete ground response analysis would model the rupture mechanism at the source of an earthquake, the propagation of stress waves through the earth to the top of bedrock beneath a particular site, and would then determine how the ground surface motion is influenced by the soils that lie above the bedrock. In reality, the mechanism of fault rupture is so complicated and the nature of energy transmission between the source and the site so uncertain that this approach is not practical for common engineering applications. In practice, empirical methods based on the characteristics of recorded earthquakes are used to develop predictive relationships. These predictive relationships are often used in conjunction with a seismic hazard analysis to predict bedrock motion characteristics at the site. The problem of ground response analysis then becomes one of determining the response of the soil deposit to the motion of the bedrock immediately beneath it. Despite the fact that seismic waves may travel through tens of kilometers of rock and often less than 100 m of soil, the soil plays a very important role in determining the characteristics of the ground surface motion (Kramer, 2003).

Site specific ground response analysis is required to determine the response of a soil deposit to the motion of the bedrock immediate below the soil and also determining the effect of local soil conditions on amplification of seismic waves and hence estimating the ground response spectra for future design purposes.

II. SOIL FORMATIONS IN AHMEDABAD

The city of Ahmedabad, a leading industrial and commercial city of Gujarat, lies on 23.01° N Latitude and 72.61° East Longitude, on the bank of river Sabarmati. Extensive borehole data is collected from various public and private organizations such as Ahmedabad Municipal Corporation, Ahmedabad Urban Development Authority, and private soil testing laboratories. The data of more than 1400 boreholes from several locations in Ahmedabad region is collected. The information so collected include, the particle size distribution, Attergberg's limits, Standard Penetration Test values, moisture content at different depths, density values, specific gravity, etc. Major soil strata observed in the area are:

1) Filled up soil layer at a few locations
2) Clayey Silt as upper layer from existing ground level to about 2.0 m. to 3.0 m. depth (with SPT varying between 4 to 14)
3) Silty Sand, mainly occurring as next layer (2nd) layer from about 3.0 m. to 6.0 m. to 10 m., or even more (SPT ranging from 8 to 24)

4) Sandy Silt at a few locations
5) Clayey Sand
6) Gravelly Sand near the river banks and in the river bed as upper layer.

III. ONE DIMENSIONAL GROUND RESPONSE ANALYSIS

A. Equivalent Linear Approximation of Nonlinear Response

Since the nonlinearity of soil behavior is well known, the linear approach must be modified to provide reasonable estimates of ground response for practical problems of interest. The actual nonlinear hysteretic stress—strain behavior of cyclically loaded soils can be approximated by equivalent linear soil properties. The equivalent linear shear modulus, G, is generally taken as a secant shear modulus and the equivalent linear damping ratio, ξ, as the damping ratio that produces the same energy loss in a single cycle as the actual hysteresis loop.

The equivalent linear approach to one-dimensional ground response analysis of layered sites has been coded into a widely used computer program called SHAKE (Schnabel et al., 1972), the professional version of the same is now available in the name of ProSHAKE. This programme has been used in the present analysis.

B. Deconvolution

Because the equivalent linear approach utilizes a linear analysis, the response at any point can be related to the response at any other point. Although the transfer functions developed related to the computation of free surface motion from bedrock motion, transfer functions relating motions at other depths can also be derived without difficulty. An important problem of practical interest involves the computation of bedrock motion from a known free surface motion. This process known as deconvolution, is particularly useful in the interpretation of actual ground motions recorded on the surfaces of soil deposits. Fig.1 and Fig.2 are showing the deconvolution process.

This approach has been used for ground response analysis and development of peak ground acceleration for 54 locations in Ahmedabad region. The time history recorded at the Passport office is transferred to 30 m depth, using ProSHAKE software, through the process of Deconvolution.

IV. SELECTION OF ROCK MOTIONS

It is necessary to estimate the potential ground motion at each site after the characterization of the site. Appropriate rock motions i.e. natural acceleration time histories or synthetic acceleration time histories are selected to represent the design rock motion for the site. For the present study acceleration time history recorded at Passport office of Ahmedabad during Bhuj 2001 earthquake, in longitudinal, transverse and vertical directions are considered.

The depth of layers of soil is 30 m., beyond this depth, the hypothetical bedrock is considered. The damping ratio considered is 5%. The graphs are obtained for 3 input motions, at ground surface, which are specified in 3 directions (longitudinal, transverse and vertical) and are shown in Figure. 1.

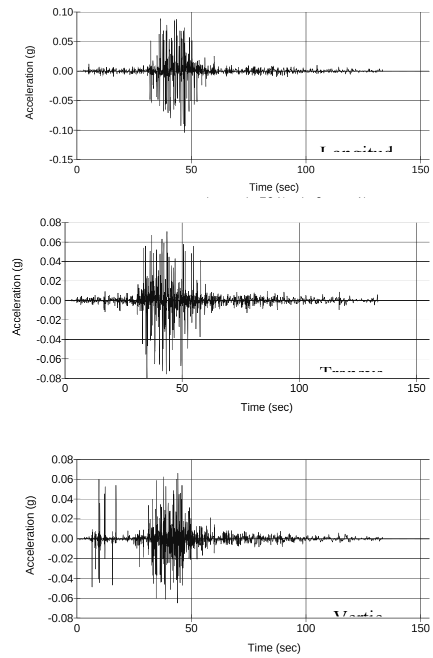


Fig. 1 Acceleration Time History Plots - Ground Surface

The graphs of time history, after deconvolution for 30 m. depth, are shown in Figure 2. These time history motions are used as input motions at all locations for getting the site-specific reponse spectrum and acceleration depth plots.

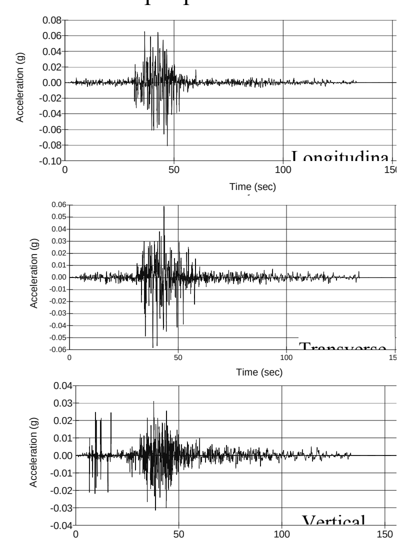


Fig. 2 Acceleration Time History Plots – 30 m depth

V. ANALYSIS WITH PROSHAKE SOFTWARE

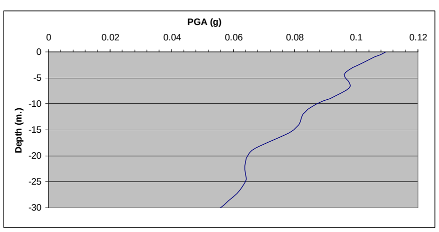
For One-dimensional ground response calculations, ProSHAKE software is used. ProSHAKE is a computer program for seismic ground response analysis of horizontally layered soil deposits developed by EduPro Civil Systems, Inc., Washington (U.S.A).

ProSHAKE is organized into three main modules - an Input Manager, a Solution Manager, and an Output Manager. In addition, a utility for editing or creating new modulus reduction and damping curves is available. The appropriate modulus reduction and damping curves, based on the types of soils encountered at the sites were chosen.

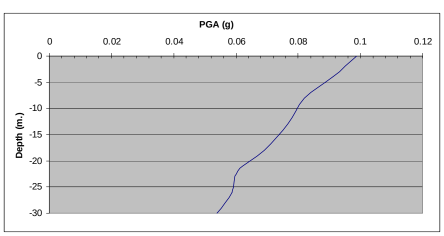
With the help of computer programme ProSHAKE, site-specific ground response spectrum analysis for 54 sites of Ahmedabad city is obtained. ProSHAKE provides the import of input parameters and the estimation of output response values (acceleration, velocity).

A. Computation of peak ground acceleration (PGA)

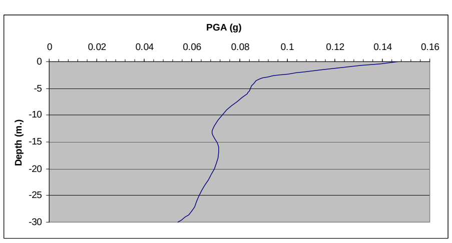
The site-specific acceleration depth plots are generated for all locations using ProSHAKE software, and the PGA values are obtained at ground surface. Figure 3 shows a few depth plots so obtained. PGA values calculated for all locations are shown in Table 1.



(a) Gomtipur



(b) Memnagar



(c) Isanpur

Fig.3 Depth Plots Indicating Varation of PGA with Depth

Depth plots are useful to examine the variation of ground motion amplitudes with depth. These plots have been used to get the amplified peak ground acceleration (PGA) at the ground surface.

B. Soil Amplification Factor (SAF)

The soil amplification factor describes how the soil strata can amplify or attenuate the ground motion during an earthquake. Estimation of soil amplification factor is very important in any seismic microzonation study. In this study, the PGA at ground level has been computed using the ProSHAKE software by plotting the depth plot for variation of peak ground acceleration (PGA). This is obtained for site-specific input data for actual measured soil properties for each of the sites. The ratio between the actual time history at the hypothetical engineering bed rock (at 30 m) at site to the amplified site response at the ground for soft soil sites give the amplification factor. This is estimated at various soil sites in Ahmedabad and a soil amplification map is generated. The soil amplification factor (SAF) is ranging from 1.69 to 4.26 for Ahmedabad region. The soil amplification map generated from the values, is shown in Figure 4.

Table I
PGA and Soil Amplification Factors for Different Locations

Sr. No	Location Name	PGA at 30 m	PGA at Ground surface	Soil Amplification Factor
1	Inside Ringroad, Bopal	0.054	0.1141	2.11
2	Ratnadeep appts, Isanpur	0.054	0.221	4.09
3	Near GIDC - Vatwa	0.054	0.132	2.44
4	Vatva	0.054	0.129	2.39
5	Sarkhej Cross roads	0.054	0.132	2.44
6	Near Odhav Cross road	0.054	0.098	1.81
7	AMAN Party Plot	0.054	0.184	3.41
8	Vasana Barrage	0.054	0.192	3.56
9	Changodar	0.054	0.133	2.46
10	Dastan Farm, Kathwada	0.054	0.132	2.44
11	Shilpgram-II, Lapkaman Village	0.054	0.135	2.50
12	Gota	0.054	0.135	2.50
13	Maninagar-Sukhipura	0.054	0.23	4.26
14	Memnagar-Naranpura	0.054	0.132	2.44
15	NERF SCHOOL -	0.054	0.165	3.06
16	SETU BUNGLOWS	0.054	0.16	2.96
17	Gandhinagar-1 near Remote sensing centre	0.054	0.163	3.02
18	Gandhinagar-II, Ground Opp. New Sachivalaya	0.054	0.148	2.74
19	Gandhinagar Akshardham Temple	0.054	0.148	2.74

20	NIT Campus	0.054	0.1022	1.89
21	Hari Om-IV, Sabarmati	0.054	0.141	2.61
22	Karnavati School of Dentistry	0.054	0.107	1.98
23	SG Highway-1 R. Farm	0.054	0.091	1.69
24	Ground near Adalaj Bus stand	0.054	0.144	2.67
25	Mann Party Plot	0.054	0.106	1.96
26	BimaNagar Society Ground,	0.054	0.134	2.48
27	GMDC Ground,	0.054	0.091	1.69
28	SrinandNagar, Vejalpur	0.054	0.195	3.61
29	RTO office, near Subhash bridge	0.054	0.162	3.00
30	Navrangpura BusStop	0.054	0.135	2.50

The PGA values are ranging from 0.098g to 0.198g for the entire region. In the western Ahmedabad region, the areas like Sabarmati, Adalaj, Motera, Thaltej, Hebatpur, parts of Sola, Vejalpur, and Bopal, have lower range of PGA, between 0.098g to 0.12g. The areas like Paldi, Vasana, Shahwadi, Maktumpura have PGA values on higher side, i.e. 0.164g to 0.195g. The other areas in western Ahmedabad, have PGA in between 0.12g to 0.164g.

In the eastern Ahmedabad region, the areas like Madhupura, Kajipura have lower range of PGA, between 0.098g to 0.12g. The areas like Maninagar, Khokhra, Isanpur, and Danilimda have PGA values on higher side, i.e. 0.164g to 0.195g. The other areas in eastern Ahmedabad, have PGA in between 0.12g to 0.164g.

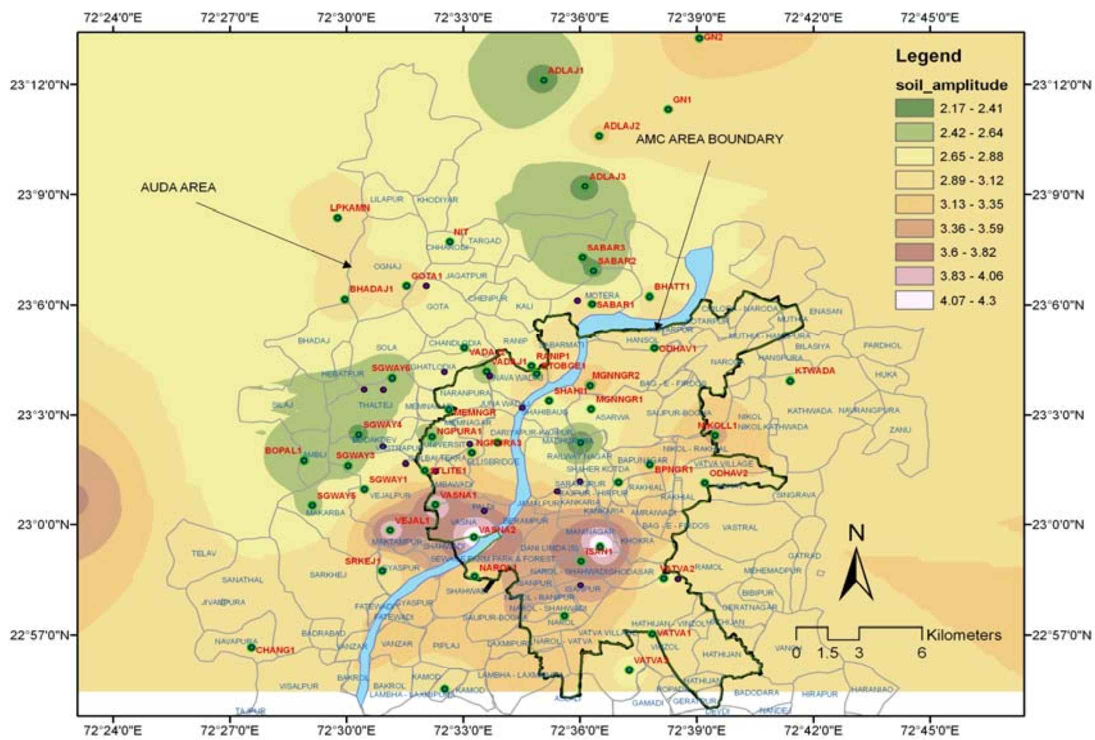


Fig. 4 Soil Amplification Map for Ahmedabad Region

VI. CONCLUSIONS

Following conclusions have been derived from the study.

1) Site specific ground response analysis is required to determine the response of a soil deposit to the motion of the bedrock immediate below the soil and also for determining the effect of local soil conditions on amplification of seismic waves.
2) Soft soil deposits amplify (increase) certain frequencies of ground motion thereby increasing earthquake damage. Thus local soil conditions have significant role to play, on amplification of seismic waves.
3) The one dimensional equivalent linear ground response analysis for 54 sites is carried out, using ProSHAKE software, and PGA values at ground surface for all locations have been established, taking into consideration the actual soil profiles at all locations.

4) The PGA values are ranging from 0.098 g to 0.198 g, and the soil amplification factor is ranging from 1.69 to 4.26

VII. REFERENCES

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