SITE-SPECIFIC GROUND RESPONSE ANALYSIS AT DIFFERENT LOCATIONS IN LUDHIANA USING DEEPSOIL

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Abstract :Earthquakes occur all over the world each second but of varying intensity and duration. Some of these earthquakes can cause huge loss of life due to inadequate resources to accurately predict earthquake occurrence time as well as due to faulty designed structures. In the recent years it has been studied by various scholars/researchers that soil overlying rocky strata of earth can hugely affect the properties of shear waves originated from earthquake like surface acceleration, surface velocity of shear waves. There is vast variety of soil lying in layers over hard bedrock strata of earth. Each layer of soil has its own property like Density, Shear Modulus, Shear strength etc. that can influence various ground motion parameters on occurrence of earthquakes in different regions. Due to relatively new field of research, Ground Response Analysis (GRA) of only few sites in different cities in India has been carried out till date. In the current research, attempt has been made to analyze the effect of soils on various ground motion parameters at different locations in Ludhiana namely Hero Bakery Chowk (LDN1), Hampton Plaza (LDN2) and Village Jhande (LDN3) using Accelerograms of Loma Gilroy Earthquake (PGA 0.17g), Uttarkashi Earthquake (PGA 0.253g) and Artificial Accelerogram (PGA 0.392g generated from SeismoArtif computer program) by carrying out One-Dimensional Equivalent-Linear GRA with the help of DEEPSOIL computer program. It has been observed that for different sites under consideration, Peak Ground Acceleration varies from 0.2824g to 0.7083g, Peak Spectral Acceleration varies from 1.3448g to 2.5817g and Amplification Ratio varies from 1.119 to 2.085. The current research can help the engineers extensively in designing earthquake prone structures in region of Ludhiana with the help of values of spectral accelerations obtained from GRA. The current variation of PGA values obtained after carrying out GRA from the value given by Bureau of Indian Standards for Zone IV in India proves the necessity of carrying out GRA at other regions in state of Punjab in Northern India too.

***IndexTerms* - Amplification Ratio, Equivalent-Linear, Ground Response Analysis, Ludhiana, Peak Ground Acceleration (PGA), Peak Spectral Acceleration.**

I. INTRODUCTION

Geotechnical Earthquake Engineering is the latest field of Engineering that deals with the study of effect of soil properties on surface motion due to seismic waves that originate from earth's crust on occurrence of earthquakes. In the recent research it has been observed by researchers that different soils at different regions can extensively affect the ground motion parameters like Peak Ground Acceleration, Peak Spectral Acceleration and Amplification Ratio (Ratio of Peak Ground Acceleration at surface to Peak Ground Acceleration of earthquake at bedrock level). Since different regions have different types of soils so it is better to use the term Site-Specific Ground Response Analysis instead of Ground Response Analysis (GRA). Being a relatively new subject vast research is yet to be carried out in India due to which GRA of very few cities like Delhi, Kanpur, Kolkata, Mumbai, Goa, Guwahati etc. has been completed. Talking about state of Punjab in India, GRA of only Jalandhar city has been carried out (Bhardwaj et al. 2017). In the current research, attempt has been made to carry out Equivalent Linear Ground Response Analysis at three different locations in Ludhiana City with the help of DEEPSOIL computer program. Ludhiana city is one of the main cities of Punjab state in Northern India also known as Manchester of Punjab lies in Zone IV category as per IS 1893 published by Bureau of Indian Standards. As per IS 1893, whole country is divided into four different categories ranging from Zone II to Zone V with Zone II having least severity and Zone V having maximum severity of earthquake hazard..

II. LITERATURE REVIEW

Ground Response Analysis requires soil properties beneath the surface of earth as well as input motion of earthquake that can occur in the region. Seismic Hazard Analysis is the process of determining the magnitude of earthquake that can potentially hit the region based upon the seismic sources present around the region. For the region of Ludhiana city, Deterministic Seismic Hazard Analysis was carried out by Naval, Sanjeev et al. (2017) and it was observed that the maximum value of PGA that can strike the region is 0.392g which is on much higher side in comparison to the value of 0.24g given by BIS in IS 1893. Equivalent –linear Ground Response Analysis at 77 different locations of Haryana state in Northern India was carried out by Puri, Nitish et al. (2018) using the input motions of Chamoli, Uttarkashi and Sikkim Earthquakes after which amplification factors were determined from 0.702 to 2.339 and consequently mapping of Haryana state was done. Similarly in year 2017, 1-D nonlinear as well as equivalent-linear ground response analysis was carried out for different sites in Chandigarh city by Joseph T.M. et al. (2017) under the input motions of Chamoli and Sikkim Earthquake motions and PGA values on surface for both nonlinear and equivalent-linear GRA were compared. Bhingarde, Nika S. et al. (2016) carried out one-dimensional equivalent-linear ground response analysis of Mormugao port located in Goa state of India under the influence of 8 different bedrock motions and response spectra, amplification spectra, surface acceleration time history and ground motion parameters were determined. In the process of research in the field of Geotechnical Earthquake Engineering Kumar, Shiv Shankar et al. (2012) carried out the one-dimensional equivalent-linear ground response analysis in Guwahati city using input motions of Bhuj Earthquake, Kobe Earthquake, Sikkim Earthquake and Loma Preita Earthquake to determine various ground motion parameters. Similarly at three different sites in Mumbai 1-D equivalent linear GRA was carried out using Kobe, Bhuj and Loma Gilroy Earthquake motions by Phanikanth V.S. et al. (2011) to evaluate various ground motion parameters like PGA, Amplification Factor etc. It was observed in all the research conducted so far that most of the researchers used DEEPSOIL software to carry out 1-D GRA at various sites throughout Indian sub-continent.

III. METHODOLOGY

From the research conducted so far it can be concluded that the process of Microzonation of India based upon ground motion parameters obtained from Ground Response Analysis is in pipeline. Seismic Hazard Analysis of Ludhiana city has already completed that gives the maximum PGA value of 0.392g in contrast to 0.24g value given in IS 1893. For generating artificial accelerogram of PGA value 0.392g, computer program SeismoArtif is used which is further used in carrying out GRA of different locations in Ludhiana. In this research, borehole log data of three different locations namely Hero Bakery Chowk (LDN1), Hampton Plaza (LDN2) and Village Jhande (LDN3) in Ludhiana city was collected and Equivalent Linear Ground Response Analysis is carried out considering soft bedrock conditions under the influence of Loma Gilroy Earthquake Motion (PGA 0.17g), Uttarkashi Earthquake Motion (PGA 0.253g) and Artificial Earthquake Motion generated from SeismoArtif (PGA 0.392g) with the help of DEEPSOIL computer program considering soft bedrock conditions having density of 2500 kg/m^3 and shear wave velocity of 760 m/sec. According to NEHRP (National Earthquake Hazard Reduction Program), the category of all the three sites under consideration based upon average SPT N-value is given in Table 1.

Table 1: Categorization of sites under consideration as per NEHRP

Site	Average SPT N-value	Category as per NEHRP
LDN1	19.696	D
LDN2	16.939	D
LDN3	13.696	E

DEEPSOIL uses density of soil, Shear Modulus of soil and input motion at bedrock level as input to carry out Equivalent-Linear GRA. For determining Shear Modulus of soil, correlation between SPT N-value and Shear Modulus given by Anbazhagan et al. (2016) which is used is given in Table 2.

Table 2: Correlations used to determine Shear Modulus of soil from SPT N-value

Correlations	Soil Type	Units	Author(s) Name
$G = 11.96 (N^{0.62})$	Clay	MN/m^2	Ohba and Toriumi (1970)
$G = 6.374 (N^{0.94})$	Sand	MN/m^2	Ohsaki and Iwasaki (1973)
$G = 11.59 (N^{0.76})$	Intermediate Soils	MN/m^2	Ohsaki and Iwasaki (1973)

IV. RESULTS

After carrying out Equivalent-Linear Ground Response Analysis, the PGA vs Depth graph for different sites in consideration is shown in Figure 1 ad the values of Maximum PGA obtained at surface is shown in Table 3. Similarly Maximum Surface PGA values for different locations under different input motions are depicted in Figure 2.

Table 3: Maximum Surface PGA values for different sites under consideration

SITE	LOMAGILROY SOFT ROCK (0.17g)	UTTARKASHI SOFT ROCK (0.253g)	ARTIFICIAL SOFT ROCK (0.392g)
LDN1	0.3365	0.4044	0.4385
LDN2	0.2824	0.5275	0.7083
LDN3	0.3252	0.4192	0.4487

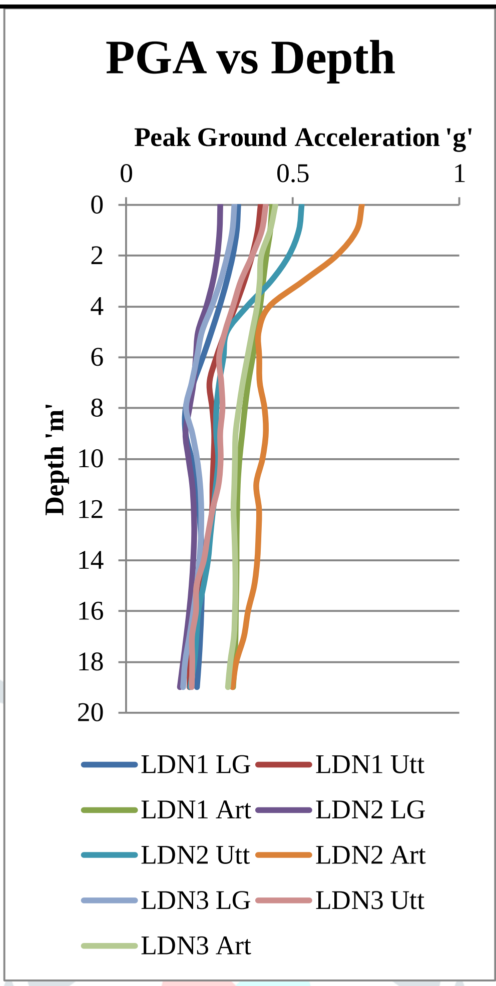

Fig. 1: PGA vs Depth for different locations under different Earthquake motions

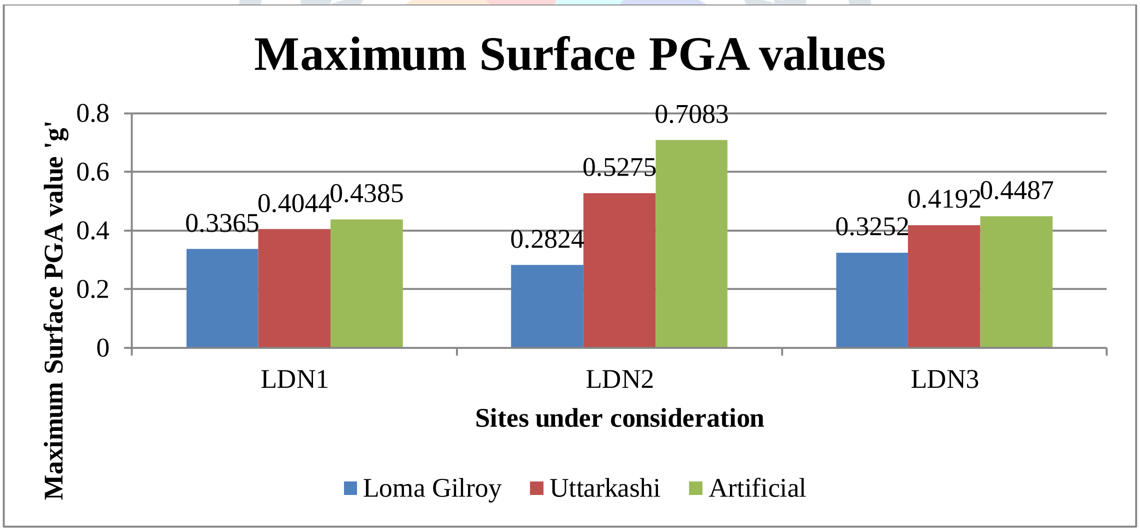

Fig. 2: Maximum Surface PGA values for different sites under different Earthquake motions

The Amplification Ratio i.e. the ratio of PGA value at surface to PGA value of Input motion at bedrock level is obtained for different locations in consideration is mentioned in Table 4 and same is depicted in Figure 3.

Table 4: Amplification Ratio for different sites under consideration

SITE	LOMAGILROY SOFT ROCK (0.17g)	UTTARKASHI SOFT ROCK (0.253g)	ARTIFICIAL SOFT ROCK (0.392g)
LDN1	1.979	1.598	1.119
LDN2	1.661	2.085	1.807
LDN3	1.913	1.657	1.145

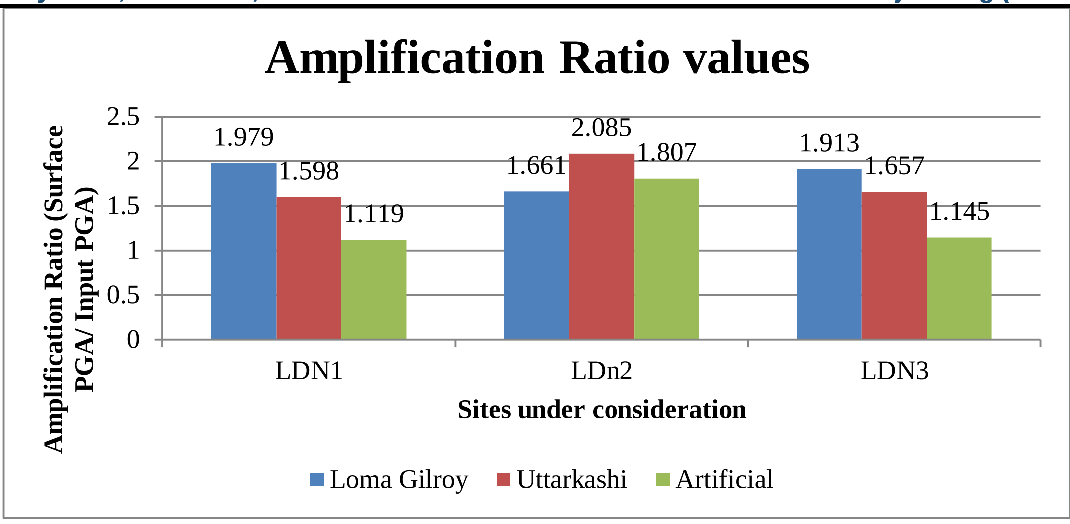

Fig. 3: Amplification Ratio values for different sites under different Earthquake motions

The values of Peak Spectral Acceleration obtained after carrying out GRA are mentioned in Table 5 and are depicted in Figure 4.

Table 5: Peak Spectral Acceleration values for different sites under consideration

SITE	LOMAGILROY SOFT ROCK (0.17g)	UTTARKASHI SOFT ROCK (0.253g)	ARTIFICIAL SOFT ROCK (0.392g)
LDN1	1.6233	1.3448	1.6562
LDN2	1.3963	1.666	2.5817
LDN3	1.3523	1.5353	1.819

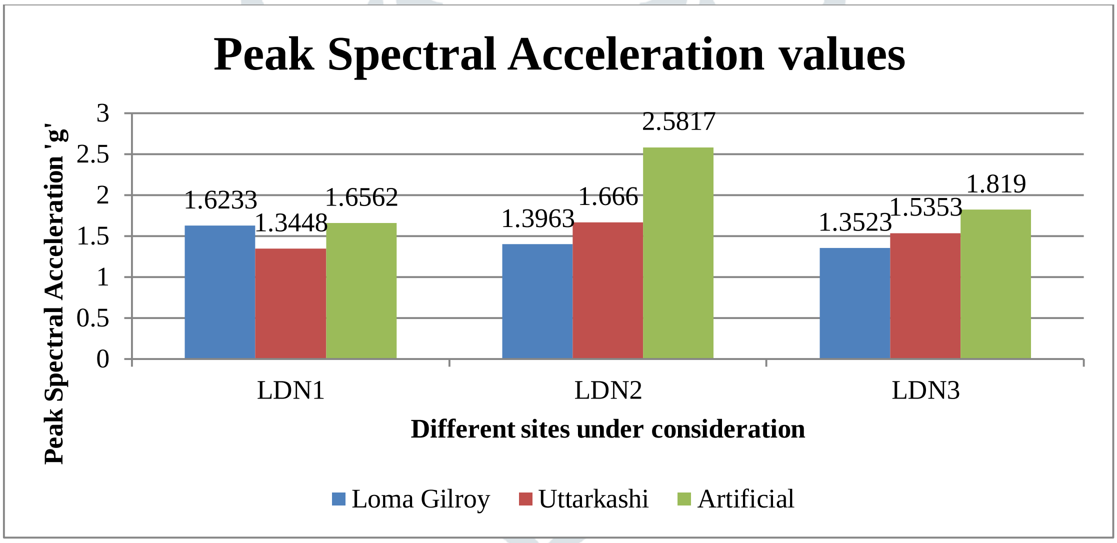

Fig. 3: Peak Spectral Acceleration values for different sites under different Earthquake motions

V. DISCUSSION

The current research concludes that the Peak Ground Acceleration values at surface varies from 0.2824g to 0.7083g at LDN2 with minimum value occurring under effect of Loma Gilroy Earthquake motion and maximum value under Artificial Earthquake motion. It can be observed from results that the values of PGA obtained after GRA are on much higher side against the value of 0.24g given by Bureau of Indian Standards in IS 1893 for Zone IV category regions. Similarly the value of Amplification Ratio varies from 1.119 to 2.085 with minimum value arising at LDN1 under Artificial Earthquake motion and maximum value at LDN2 under effect of Uttarkashi Earthquake motion. The Peak Spectral Accelerstion obtained after carrying out Equivalent-Linear GRA on different sites under consideration varies from 1.3448g to 2.5817g with minimum value arising at LDN1 when subjected to Uttarkashi Earthquake motion and maximum value arising at LDN2 when subjected to Artificial Earthquake motion using DEEPSOIL computer program.

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