Study of Local Site Effects for Strong Motion Recording Stations of Delhi

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ABSTRACT: Effects of local site conditions on strong ground motion characteristics is a well-known phenomenon studied by many researchers. Similar studies were also carried out in past for Delhi to understand the amplification of ground motion in various locations using different methods. In this study an attempt is made to study the amplifications in 8 locations of Delhi where strong motion recording stations are located. For this study shear wave velocity profiles were used for performing ground response analysis using equivalent linear approach. For input motion, response spectra compatible motion was used, compatible to response spectra for Rock sites as per IS 1893:2002. Transfer functions from available earthquake records and ambient vibration records were also calculated for comparison. The results obtained were presented in the form of response spectra and amplification functions for all the sites. The results suggests an amplification of the order of 2 – 3 with respect to actual motion at sites coming under site class D of NEHRP. No amplification was found at IMD site which suggest that it can be used as a reference site for Delhi. Other two sites with NEHRP site class C found to have amplification of the order of 1 – 2. Similarly output response spectra, at surface, for all the sites except IMD and Kalkaji were found to be amplified with respect to the corresponding response spectra of IS 1893:2002.

Keywords: Site Amplification, Local Site Effects, Response Spectra, Reference Site, HVSR, Strong Ground Motion

1 INTRODUCTION

It is a well-known fact that Earthquakes pose a real threat to Northern and North-Eastern part of the country. Most of the areas of Northeast region, Northern Bihar, Northern Uttarakhand, Himachal Pradesh, Jammu & Kashmir and some parts of Kutch are mapped in seismic zone V as per IS 1893-2002. Similarly most of the regions adjacent to Zone V such as, entire Gangetic plains, southern region of Uttarakhand and some parts of Rajasthan are in seismic zone IV (IS 1893-2002).

Himalayan region being one of the most seismically active regions of the world has experienced several earthquake disasters in past. Indian peninsula has experienced several earthquakes more than magnitude 8.0, such as, Kutch Gujarat, 1819; Assam earthquake, 1897; Kangra earthquake, 1905; Bihar–Nepal earthquake, 1934; Assam earthquake, 1950 in last 200 years. Also, very recent Nepal earthquake of 7.9M in Nepal on 25th April, 2015 cannot be overlooked. This earthquake was followed by more than 100 aftershocks with the largest being the one with a magnitude of 7.3 (as per Indian Meteorological Department website www.imd.gov.in) on 12th May, 2015. These earthquakes continuously remind us to improve our preparedness for future earthquakes so that a large number of valuable lives can be saved.

Learning from past earthquakes, Indian agencies are continuously working on the methods and technologies to improve our preparedness for any large earthquake in future.

Delhi, the National Capital of India, confronts a high seismic threat, as it is very close to the seismically active regions of Himalyas. Along with that there are other tectonic features close to Delhi which may be a cause of medium intensity earthquakes in Delhi region. Delhi sits in the Seismic Zone IV as per IS-1893:2002. Delhi's high population density and proximity to various tectonic features warrants us to be more proactive in our preparedness for any future seismic event.

Thickness of the alluvium is variable in Delhi and seeing such varieties is critical in evaluating site amplification. Various studies had been carried out in Delhi region related to site amplification. These studies are based on (a) Micro-tremors (e.g. Mukhopadhyay et al., 2002), (b) Earthquakes (Singh et al., 2002; Nath et al., 2003; Mittal et al., 2013a, 2013b), (c) Standard penetration test (Iyengar et al., 2004), and (d) Numerical modeling of wave propagation (e.g., Parvez et al., 2006).

Mukhopadhyay et al., 2002 worked on estimation of fundamental frequency and corresponding amplification factors at various locations of Delhi using micro-tremor data. Singh et al., 2002, and Mittal et al., 2013a, 2013b used standard spectral ratio (SSR) method for estimation of amplification. They reported high amplifications at different sites in Delhi which were of the order of 10-20. Iyengar et al., 2004 evaluated amplification at 17 sites in Delhi by using Standard Penetration Test (SPT) to obtain shear wave velocity profiles which were further used to obtain local site effects. They reported amplification of the order of 2 to 3 at the natural frequency of the sites. Singh et al., 2010 studied implications of Delhi earthquake of 25/11/2007 on seismic hazard and concluded that the recorded PGA values at different locations were poorly explained by the estimates provided by previous studies.

It can be seen clearly that none of the study comes to a consensus, hence an attempt is made in this study to estimate site amplification factors for 8 locations of Delhi. 5 locations viz. Shivaji College, NPTI, Vikaspuri, Jamia Milia Islamia University and GEC Jaffarpur are situated on over deep alluvium and are in site class D of NEHRP (Pandey et al., 2016). Another set of sites were IMD, Kalkaji and JNU which are shown as site class D of NEHRP as per the site characterization study conducted by Pandey et al., 2016. Site class and respective Vs30 values, calculated as per site characterization study of Pandey et al., 2016, for these sites were shown in Table 1.

2 METHODOLOGY

There are various methods which can be used for estimation of site amplification. There are methods which uses earthquake records or ambient vibration records from the sites of interest such as Standard Spectral Ratio technique, Horizontal to Vertical Spectral ratio technique. Other than this there are theoretical methods such Theoretical Ground Response analysis. For this study theoretical ground response analysis (GRA) using equivalent linear approach has been used. For conducting GRA a software STRATA (Kottke et al., 2013) has been used in this study.

Figure 1: Figure showing locations of 8 strong motion recording stations considered in this study.

For GRA two kinds of input is required one is information regarding soil strata and another is input motion. All the sites chosen for this study are having strong motion recording stations (Mittal et al., 2012) and site characterization report for these sites is available (Pandey et al., 2016). This gives us the benefit of having details of underlying soil strata of the location and availability of earthquake records at the same location. The available records from these sites were used for comparison of transfer functions from GRA and HVSR (Nakamura, 1989). Along with this response spectra obtained from GRA and response spectra from recorded motion were also compared with response spectra in IS 1893:2002. For input ground motion response spectra compatible motion was generated compatible with response spectra for Rock sites. As IS 1893:2002 provides response spectra for outcrop/surface motion hence the response spectra compatible motion was corrected for free surface effect and then was applied at top of the layer having shear wave velocity more than 750 m/s. The location of sites is shown in Figure 1.

3 RESULTS

Results of this study was compiled in two forms one is transfer function comparison and another is response spectra comparison. For ease of comparison the results were divided in two groups as per their NEHRP site class.

For transfer function comparison (Figure 2 & 3), 4 kinds of transfer functions were generated. a) Transfer function between surface and half space (top of the layer having velocity greater than 750 m/s) from GRA, b) transfer function between surface and bedrock outcrop (top of the layer having velocity greater than 750 m/s), c) transfer function obtained from HVSR of earthquake records available from these stations and d) transfer function from HVSR using ambient vibration records.

For response spectra comparison Figure (4 & 5), normalized response spectrum obtained at surface from GRA and normalized response spectrum obtained from earthquake records were compared with response spectrum as per IS 1893:2002.

For sites of site class D (Figure 1) it can be clearly seen that all the four kinds of transfer functions are very close to each other in respect to frequency. Also amplification function between surface/half space and surface/outcrop are similar in terms of frequency although amplitude is very low for surface/outcrop amplification function which is of the order of 2 – 3.

Table 1: Table showing Vs30 and NEHRP site class.

S.No.	Site Name	Vs30 (m/s)	NEHRP Site Class
1	GEC Jaffarpur	338	D
2	Jamia	346	D
3	Kalkaji	564	C
4	Shivaji college Raja Garden	346	D

5	Vikaspuri	360	D
6	IMD Ridge	543	C
7	NPTI, Badarpur	322	D
8	JNU	565	C

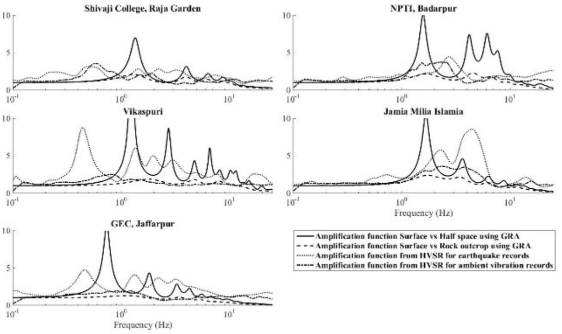

Figure 2: Comparison of transfer functions for sites in Class D of NEHRP.

Similarly, for site class C sites (Figure 2) amplification functions matches very well with each other in terms of frequency. Here also remarkable difference can be seen between surface/half space function and surface/outcrop function. Another interesting observation which can be easily made from Figure 2 is surface/outcrop transfer function for IMD is almost flat with value 1, which means there is no amplification between surface motion obtained after GRA and original response spectra compatible motion. The same thing is also evident from response spectra comparison in Figure 5 where response spectra obtained for surface motion after GRA is almost matching with response spectra from IS 1893:2002 for

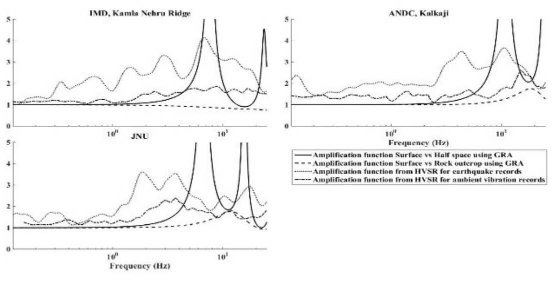

Figure 3: Comparison of transfer functions of sites belonging to NEHRP site class C.

Rock sites. It will be interesting to note that almost similar results were obtained for Kalkaji site (Figure 3 and 5) except at higher frequency (or lower period) where some amplification of 1.7 was found. For third site in class C group i.e. JNU, amplification of 1.8 is found in surface/outcrop transfer function at 10Hz frequency. The similar kind of amplification is also evident in response spectra plotted for JNU. These results clearly shows that IMD can comfortably be used as a reference site for earthquake engineering studies but Kalkaji can only be used for such studies at lower frequencies. Another inference which can be made from this analysis is even though a site looks like a rock outcrop, as is the case with JNU, and have high Vs30 value still care should be taken in considering any site as reference site.

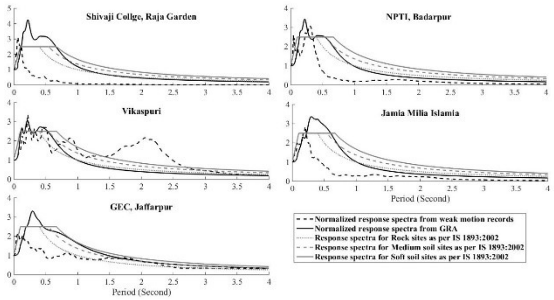

Figure 4: Response spectra comparison for sites of NEHRP site class D.

Comparing the response spectra of all the sites shows that all the response spectra are amplified. Hence, by observing amplification of response spectra it can be clearly said that expected acceleration would be much higher than response spectra proposed in IS 1893:2002 for the maximum considered earthquake. Also the mismatch between response spectra obtained from earthquake records and GRA is due to the huge difference between intensity of recorded motion and input motion for GRA as the recorded motion have very low PGA values.

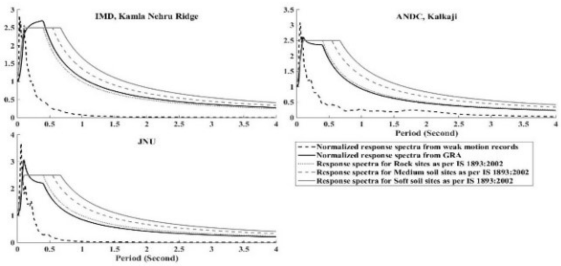

Figure 5: Response spectra comparison for sites belonging to NEHRP site class C.

4 CONCLUSION AND DISCUSSION

Lots of variations were found in amplification ratios of different transfer function for each site. Hence it can be concluded from this study that amplification ratios must be chosen with care whenever any analysis for seismic hazard assessment is to be. However, not much difference is observed in fundamental frequency estimated by different transfer functions. Also the amplification function obtained from surface/outcrop seems to be more realistic for engineering purposes as normally we tend to compare to amplification of a site with reference to other site location. Surface/ half space transfer function can be very useful for studies related to attenuation studies as bedrock motion is very important for such studies.

Another inference from this study is that, sites which look like rock outcrop may not be an actual rock outcrop as it was shown from the result of amplification function and response spectra of JNU in Figure 3 & 5. Also it can be concluded that IMD can be used as a reference rock outcrop site for motion with PGA of order of .24g. Kalkaji can also be used as reference outcrop if study deals with low frequency range. Using IMD as a reference site it can be suggested that an amplification of the order of 2 to 3 can be expected at sites having site class D with respect to ground motion at IMD for a ground motion of intensity as used in this study.

Comparison of response spectra also conforms the amplifications observed through transfer functions. This study also suggest higher acceleration values for soil sites at almost all the periods. Hence provision must be made in response spectra provided in IS 1893:2002 for amplification as well. Currently, the difference in response spectra provided in IS 1893:2002 for Rock sites and Soil sites is just in frequency bandwidth and it does not provide any provision for amplification

AKNOWLEDGEMENT

The authors wish to thank Ministry of Earth Sciences (MoES), Government of India, for providing financial support for carrying out the research on this topic (Project Grant No. MoES/P.O.(Seismo)/1(263)/2015). We are also thankful to Mr. Subodh Jain (Technical Superintendent) and Mr. Prem (Sr. Attendant) of Soil Dynamics Laboratory and other technical staff of Department of Earthquake Engineering, IIT Roorkee, for their help in testing and field work.

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