# Effect of Soil on Ground Motion Amplification of Kolkata City

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## ABSTRACT

*This paper presents the ground motion amplification factors at different time period bands and fundamental time period of soft sedimentary deposit in densely populated Kolkata city for seismic microzonation. 1D seismic wave propagation technique SHAKE2000 is used for ground motion amplifications at different locations of Kolkata city. Fundamental time period ($T_0$), amplification at fundamental time period, average amplification and amplification at different frequency band for soil columns are computed and corresponding contours are plotted for variety of end users. The study reveals that Kolkata may suffer severe damage even due to moderate earthquake.*

*Keywords: Amplification Factors, Ground Motion, Kolkata, Sedimentary Deposit, SHAKE2000*

## 1. INTRODUCTION

The assessment of local site effect on strong ground motion characteristics plays an important role in earthquake engineering. If seismic wave travels from high velocity soil media to low velocity soil media, velocity decreases and amplitude of wave increases (Narayan, 2008; Zeng, 1996; Tsuda et al., 2006). Therefore identification of soft alluvial deposit susceptible to ground motion amplification plays an important role for purpose of seismic microzonation. The damage pattern during several past earthquakes like 1985 Mexico Earthquakes, 1989 San Franscisko Earthquake, 1995 Los Angeles Earthquake, 2001 Bhuj Earthquake (Kayen & Mitchell, 1997; Zeevaert, 1991; Seed et al., 1988; Dary et al., 2000; Narayan et al., 2002; Govindaraju et al., 2004) have shown that local site effect especially soft soil plays important role in ground motion amplification.

Kolkata City has experienced shaking due to near and far source earthquakes in past. The intensity of 1964 Calcutta earthquake was VII and 1897 Assam earthquake was VIII in MMI scale. The city have suffered many distance earthquake like 1918 Srimangal Earthquake, 1930 Dubhri Earthquake, 1934 Bihar Nepal Earthquake, 2011 Sikkim Earthquake (Shiuly & Narayan, 2012; Mohanty & Walling, 2008, Jhingram et al., 1969; GSI, 2000). The unexpected shaking has raised a serious question

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about the safety of Kolkata during earthquake and needs seismic microzonation.

Seismic microzonation of Delhi was carried out by Mukhopadhyay et al. (2002) by H/V ratio method. Anbazhagan and Sitharam (2007) conducted seismic hazard analysis for Bangalore City using deterministic and probabilistic approach and also developed peak ground acceleration map and hazard curves. They developed 3-D subsurface modeling of the geotechnical data using SPT test and borehole information. Measurement of shear wave velocity and evaluation of dynamic properties of soil in Bangalore was done using multi channel analysis of surface wave (MASW). Site amplification was computed by both by MASW result and one dimensional wave propagation technique SHAKE 2000. Site specific analysis for a seismically vulnerable site near Ahmedabad, Gujarat was evaluated out by Boominathan and Krishna Kumar (2010). In this study the seismic hazard analysis was carried out by DSHA approach and the ground response analysis was carried out by equivalent linear approach using SHAKE2000. Peak Ground Acceleration (PGA) and response spectra considering the local site effects of Bangalore city was evaluated by Sitharam and Vipin (2010). Shear wave velocity investigation for ten representative sites of national capital territory, New Delhi was carried out by Mahajan et al. (2011). A new site classification for India, China and Australia based on average soil thickness, shear wave velocity up to engineering bedrock was proposed by Anbazhagan and Sheikh (2012). Seismic ground response analysis of some typical sites of Guwahati City using one dimensional equivalent–linear ground response analyses were performed by Kumar and Murali Krishna (2013).

Ground motion amplification scenario in Kolkata megacity was carried out by Shiuly et al. (2013) using 4th order finite difference algorithm. They evaluated ground motion amplification of soil column at 44 locations in the city due to soft deep sedimentary soil deposit. Deterministic seismic microzonation of Kolkata city has been carried out by Shiuly and Narayan (2012). The PGA at bed rock obtained was 0.077g. The amplification due to soil was computed by 2D fourth order finite difference method at 44 locations in the City. Large variations of PGA (0.12 g to 0.6 g) at surface level were obtained. Site specific ground motion parameter for seismic microzonation was computed by Roy and Sahu (2012). SMSIM was used for computing synthetic ground motion at bed rock level and SHAKE2000 was used for computation of site amplification due to soil. Site specific SH and SV wave was simulated by Vaccari et al. (2011) by neo-deterministic approach along metro rail soil profile. Govindaraju and Bhattacharya (2012) conducted site specific earthquake response study using wavelet based computer program WAVEGEN and SHAKE2000 for four locations in Kolkata city. All the previous studies indicate that the deep thick sedimentary soft soil deposit may cause high amplification during earthquake. So, to evaluate earthquake risk of low to high-rise buildings in Kolkata megacity, it becomes necessary to evaluate soil amplification at fundamental frequency and also amplification in different frequency band corresponding to buildings of different heights.

In this paper, site amplification due to soil above engineering bedrock has been obtained for 144 borehole locations (BH) in Kolkata city using 1D seismic wave propagation software SHAKE-2000. The bedrock (engineering) is considered at 50m depth below ground surface. Different kinds of maps like fundamental period of soil deposit, amplification at fundamental frequency, amplification in different frequency band (0.25-1 Hz, 1-2 Hz, 2-5 Hz, 5-10 Hz) have been generated by IDW method using ArcGIS packages.

## 2. GEOTECHNICAL DATA

144 borehole (See Figure 1) data collected from some unpublished report, like, Jadavpur University data bank project, ITD Cementation for Calcutta Metro, several soil testing agencies like C. E. Testing, S. Ghosh and Associates, R.C.E Group etc. were used in the present