Liquefaction Hazard Mapping of Lucknow: A Part of Indo-Gangetic Basin (IGB)

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ABSTRACT

Even though the size of the earthquake is moderate, presence of soft soil near the surface can cause devastating damage due to local site and induced effects like liquefaction. Evidence of liquefaction due to past Indian earthquakes was highlighted in many Paleo-seismic studies, particularly in the Himalayan region. The objective of this paper is subsurface characterization of part Indo-Gangetic Basin (IGB) and estimation of liquefaction hazards for the possible surface ground motions based on the region seismic study. Drilling of boreholes and measurement of standard penetration N values are carried out at selected locations for subsurface characterization. Possibility of liquefaction for soil deposits are assessed by comparing the grain size distribution curves obtained from laboratory tests with the range of grain size distribution curves of potentially liquefiable soils. The minimum factor of safety values has been identified for each location and presented in the form of maps showing FOS against liquefaction for average and maximum amplified peak ground acceleration (PGA) values. These maps have highlighted that the northern, western and central parts of Lucknow fall under very critical to critical for liquefaction while southern parts shows moderate to low critical area.

Keywords: Cyclic Resistance Ratio (CRR), Cyclic Stress Ratio (CSR), Factor of Safety (FOS), Ground motion, Indo-Gangetic Basin (IGB), Liquefaction, Liquefaction Potential Index (LPI), Soil, Subsurface

INTRODUCTION

Ground shaking induced during an earthquake causes large amount of vibrations for buildings and for the subsoil as well. Subsoil shaking results in differential settlement of the building foundations, sinking of pavements, railway lines etc. Failure of soil during an earthquake usually happens due to loss in the in-situ shear strength of soil. This phenomenon is termed as Liquefaction where the shear resistance of the soil is reduced significantly in comparison to shear stresses induced by an earthquake. This reduction in shear strength causes the soil to behave

DOI: 10.4018/jgee.2013010102
almost like a liquid. Further, such subsoil cannot withstand any overcoming load on it resulting in tremendous settlements, failures of foundation of buildings and bridge abutments, slope failures etc. The terminology of liquefaction came into existence after the occurrence of the Good Friday earthquake of 1964 with Mw (moment magnitude) of 9.2 in Alaska followed by Nigata earthquake with Mw of 7.5 in Japan. These two earthquakes caused failure of slopes, sinking of bridge piers, tilting of houses, embankments, foundations, pavements and exposure of the buried structures. After 1964, the numerous examples are available where liquefaction had caused massive destruction. These may include the 1971 San Fernando earthquake (Mw-6.6), 1977 Argentina earthquake (Mw-7.4), 1989 Loma Prieta earthquake (Mw-6.9), 1995 Great Hanshin earthquake (Mw-6.8), 1999 Chi-Chi earthquake (Mw-7.6), 2001 Bhuj earthquake (Mw-7.6), 2004 Niigata-ken Chuetsu earthquake (Mw-6.8) and 2011 Sendai earthquake (Mw-8.9), 2011 Sikkim earthquake (Mw-6.8) and many more. In India, damages due to liquefaction on a large scale were noticed during 26 January 2001 Bhuj earthquake (Mw-7.6). Historically ground failure due to liquefaction was not well reported in India. However, a few case studies on paleoliquefaction show evidence of liquefaction in India in historic times. Sand blows were evident during 1819 Bhuj earthquake and sand dykes at Beltaghat site during 1897 Shillong earthquake (Rajendran & Rajendran, 2001). Paleo-liquefaction studies in Assam also confirm liquefaction failures during Assam earthquake (Sukhija et al., 2011). The above case studies are the classical examples where the damages due to liquefaction were reported far away from the epicenter during an earthquake. Such examples clearly highlight the presence of the softer medium at the shallow depth which had caused the scenario more catastrophic even at distant regions. Considering the possible seismic vulnerability of Lucknow, the estimation of liquefaction potential for Lucknow is important for seismic microzonation which has been presented in this chapter. Boreholes are drilled at selected locations in Lucknow and Standard Penetration Test N (N-SPT) values are measured. These have been used to evaluate the in-situ soil cyclic resistance ratio. Detailed seismic hazard analysis and site response study were carried out and the surface PGA are mapped for maximum amplification. The maximum amplified surfaces PGA has been used to estimate the cyclic stress ratio. These values have been used to estimate the factor of safety against liquefaction and also evaluation of the liquefaction potential index for Lucknow region has been attempted.

THE STUDY AREA AND NEED FOR THE STUDY

The Indo-Gangetic Basin (IGB) covers an area about 2, 50, 000 sq km extending between the latitude 24° N to 30° N and longitude 77° E to 88° E. Approximately 200 million live in the IGB which defines the area as one of the most densely populated regions of India. Ganga is the main river of the basin which flows from the Himalayas in the north to the Bay of Bengal in the northeast. The study region of Lucknow city has an area of about 370 km² and with latitude 26° 51.6’ N and longitude 80° 54.6’ E is located in the central part of IGB. Figure 1 shows the study area of Lucknow with Himalayan belt and IGB. The elevation difference in the entire study area is about 29 m from its highest elevation of 129 m in the area of the Sarda canal and its lowest elevation of 100 m in the southeastern region of Dilkusha garden. The River Gomati flows from the middle of Lucknow in northwest-southeast (Husainabad-Dilkusha garden). The study area covers most part of River Gomati in the Lucknow city. Regional lateral slopes are toward the River Gomati from north-west towards south-east through the heart of the city. The rise in water level during the monsoon season has brought flooding in and around the River Gomati in the years 1923, 1960, 1971, 1985, and 1998. This had caused the level to rise up to a maximum of 111.5 m in 1960, 110.85 m in 1971 and 106.30 m in 1998. As per Geological Survey of India (DRM, 2001)
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*International Journal of Geotechnical Earthquake Engineering* (pp. 1-22).
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