Liquefaction Hazard Scenario of Imphal City for 1869 Cachar and a Hypothetical Earthquake

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ABSTRACT

In the present article liquefaction potential of Imphal city is reported in the form of two indices, i.e., LPI (Liquefaction Potential Index) and LSI (Liquefaction Severity Index), for 1869 Cachar earthquake (M_w 7.5) along the Kopili fault and probable future great earthquake (M_w 8.1) in the Indo-Burma subduction zone. The Factor of Safety (FS) against liquefaction has been computed by using modified procedure given by Idriss and Boulanger (2006) for all depths of 122 boreholes. The computed FS have been used as input parameters for evaluating LPI and LSI indices for Imphal City. Based on these LPI and LSI indices, liquefaction potential hazard contour maps of Imphal city is prepared. It is observed that over a large area of Imphal city is highly vulnerable to liquefaction failure in the events of the selected earthquake. The liquefaction hazard obtained at each site exhibits a good agreement with the damages documented for 1869 Cachar earthquake. This contour map can be served as a guideline for engineer and planner in site selection for upcoming projects and helps city administration in mitigating the city from future hazards.

Keywords: *Cachar Earthquake, Imphal City, Liquefaction, Liquefaction Potential Index (LPI), Liquefaction Severity Index (LSI)*

1. INTRODUCTION

Imphal city (24.8ºN 93.9ºE), the capital of Manipur state, is situated at the extreme end of Northeastern (NE) India and adjacent to Myanmar. Past earthquake histories of NE India show that the region is seismically most active as compared to other parts of India. As a result, the NE region has been assigned Zone V (most severe seismic hazard zone) in the seismic zoning map of India (Bureau of Indian Standard, 2002). Liquefaction is a common cause of ground failure and structural damage in any earthquake (*e.g.*, Kramer, 2008; Nandy, 2001; Madabushi & Heigh, 2005) *viz.,* NE-India (1869, 1897, and 1950 Assam), Alaska (1964), Nigata (1964), Kobe (1985), Loma Prieta (1989), Turkey (1999) Adana-ceyhan (1999) Kocali, Taiwan (1999 Chi-Chi) and India (2001 Bhuj). In all these cities partial or complete

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bearing failures of shallow-founded structures occurred at sites due to liquefaction-type damages. Ambraseys (1988) studied worldwide earthquakes and liquefaction data and concluded that an earthquake of magnitude as low as 5 can produce liquefaction. It may be noted that since 1897, this NE region has experienced more than 1500 earthquakes of magnitudes ≥ 5. In seismic prone areas like Imphal city liquefaction potential must be evaluated during site selection and planning stages of engineering structures. In order to compute the liquefaction potential of soil, many methods have been developed by engineers and researchers (Seed & Idriss, 1971; Iwasaki *et al.,* 1982; Seed & Idriss, 1982; Liao *et al.,* 1988; Bartlett & Youd, 1995; Harder, 1997; Youd & Idriss, 1997; Youd & Noble, 1997; Chen & Juang, 2000; Cetin *et al.,* 2002; Juang *et al.,* 2003; Sonmez, 2003; Lee *et al.,* 2003; Sonmez & Gokceoglu, 2005; Idriss & Boulanger, 2006; Moss *et al.,* 2006).

In the present work, liquefaction potential status of Imphal city has been evaluated by means of two indices, *i.e.,* deterministic index LPI (Liquefaction Potential Index) and probabilistic index LSI (Liquefaction Severity Index), for 1869 Cachar event (M_w 7.5, PGA=0.16g) which occurred along the Kopili fault and probable future great earthquake (M_w 8.1, PGA=0.3g) in the Indo-Burmese subduction zone. PGA values estimated by Raghukanth *et al.* (2009) and Pallav *et al.* (2010) based on stochastic finite fault model proposed by Motazedian and Antkinson (2005) are used for finding the liquefaction hazard of Imphal city. Computation of LPI and LSI requires Factor of Safety against liquefaction of each soil layer as an input. The *FS*s have been obtained based on SPT-N values using the procedure (discussed in Section 6.1) proposed by Idriss and Boulanger (2006). The computed values of *FSs* for each borehole are then used as input for evaluating the LPI and LSI indices. Liquefaction potential hazard contour maps for Imphal city have been developed based on the LPI and LSI indices.

2. ABOUT IMPHAL CITY AND ITS DEVELOPMENTS

Imphal city is located on the bank of three rivers *viz.,* Imphal, Kongba and Nambul. The city is below the high flood level of these rivers. In the past, Imphal city has experienced several earthquakes of large magnitudes. However there are insufficient records of damages incurred by these earthquakes prior to 1869. Probably the earliest documented earthquake is that of 10th January 1869 which caused widespread damages in Imphal city (details are discussed in the next section). In the literature this is referred to as the '1869 Cachar earthquake' (Oldham, 1882). The 6th August 1988 earthquake which occurred in Indo-Burma region also caused notable damages in Imphal city. These events occurred at a time when the population as well as infrastructure facilities in Imphal were limited in nature. Compared with other cities of India, the developmental growth rate of Imphal city has been very slow for various political (unstable law and order) and geographical (limited connectivity) reasons. However, in the last few years, an increase in population density in and around Imphal has been observed. As per the 2011 census the population of Imphal city is about 0.27 million (10% of the entire state's population). It has been estimated that the population will continue to grow in Imphal with a decadal growth rate stabilizing at around 10% for the next few decades and estimated to be 0.37 million in 2021 (Imphal Municipal Council, n. d.) (Imphal agglomerate population is still awaited). The population density in Imphal city is registered at 7,202 persons per sq. km which is much higher than the State's population density of 97 persons per sq. km. Due to increase in the population in recent times, the local government has taken up several important infrastructural building programmes *viz*., construction of BT flyover (Bir Tikendrajit), ongoing construction of city sewerage system, city convention centre, capitol

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