Liquefaction Studies for Seismic Microzonation of Delhi Region

*Neelima Satyam D[1] and Rao K S[2]

[1] *Earthquake Engineering research Centre, International Institute of Information Technology Hyderabad, India*
[2] *Indian Institute of Technology Delhi, New Delhi, India*

[1]*neelima.satyam@gmail.com*

ABSTRACT

During earthquake, soil can fail due to liquefaction with devastating effect such as land sliding, lateral spreading, or large ground settlement. The phenomenon of liquefaction of soil had been observed for many years, but was brought to the attention of engineers after Niigata (1964), and Alaska earthquakes (1964). Historic large earthquakes throughout the world explain that the liquefaction related ground failure commonly causes extensive structural and lifeline damage in urban areas. Delineating areas that are susceptible to liquefaction hazards is important for evaluating and reducing the risk from liquefaction through appropriate mitigation. Because, liquefaction generally occurs in areas underlain by low density, saturated granular sediments, the liquefaction susceptibility can be mapped using specific, well established geologic and geotechnical criteria. Damages caused by liquefaction of saturated soil revealed that after liquefaction the ground failed, sand boiling occurred and the structure subsided unevenly causing tilting, cracking or even collapse. Since Delhi falls in the area with high seismic probability, there is a great need for the assessment of liquefaction potential. An attempt has been made to map the liquefaction hazard using the shear wave velocity database measured from Multichannel Analysis of Surface wave method.

INTRODUCTION

The state of Delhi occupies an area of 1485 sq. km spreading between latitude 28º24'01" and 28°53'00" and longitude 76°50'24" and 77°20'37". The historic Delhi is bound in the North, South and West by Haryana and in the East by Uttar Pradesh. The population of Delhi based on recent census is around 16 million. The Delhi is situated in highly earthquake prone belt near the very active Himalayan region. The heavily populated city with number of manmade structures could be prone to damage due to an earthquake of considerable magnitude (>6) from near field sources. India has experienced some of the strongest earthquakes viz. Assam 1897 (M=8.7), Kangra 1905 (M=8.6), Bihar-Nepal 1934 (M=8.4), Assam-Tibet 1950 (M=8.7), Uttarkashi 1991 (M=6.5), Latur 1993 (M=6.4) and Chamoli 1999 (M = 6.8) in the recent past.

The Bhuj earthquake of 2001 (M = 7.7), devastated many areas of State of Gujarat, causing extreme damage. Many areas in Rann of Kutchh had experienced liquefaction, sand and salt boils, and severe ground cracking. Delhi is having a typical geological set up, which can sustain large amplified shaking not only due to earthquakes in and around Delhi, but also due to strong earthquakes in Himalayas. This imposes a very high risk of an earthquake disaster in Delhi, resulting into high casualties and great damage to properties. The losses due to damaging earthquakes can be mitigated through a comprehensive assessment of seismic hazard. Damages caused by liquefaction of saturated soil showed that after liquefaction the ground failed, sand boiling occurred and the structure subsided unevenly causing tilting, cracking or even collapse. Therefore, conventional seismic measures of reinforcing the upper part of the structure in such situation are entirely in vain. Recognizing the potential hazard imposed by the liquefaction, a detailed study is undertaken to map the likelihood of liquefaction within Delhi region using measured shear wave velocities.

SOIL LIQUEFACTION

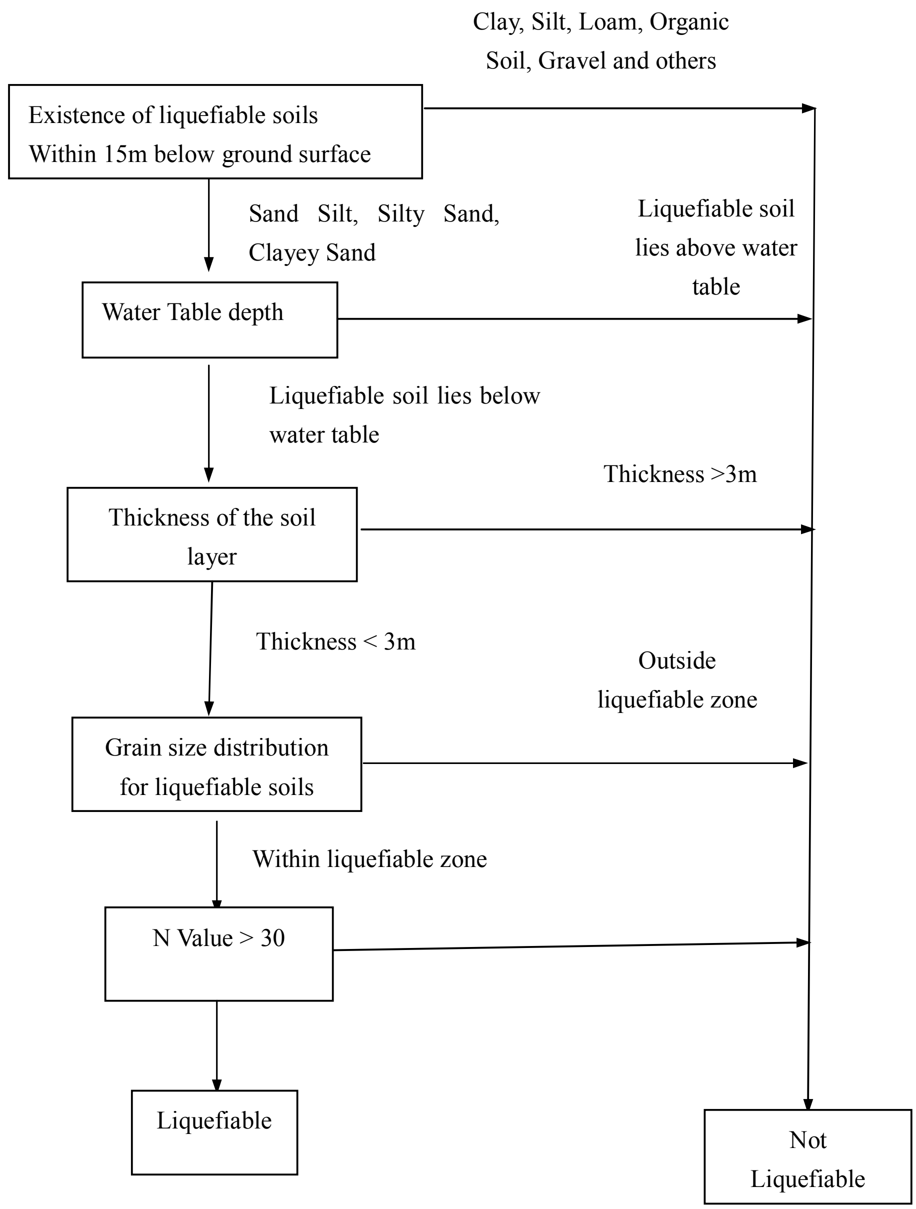
A large number of investigations have been made for understanding the phenomenon of soil liquefaction in the last four decades. From these investigations it was observed that a vast majority of liquefaction occurrences were associated with sandy soils and silty sands of low plasticity. It is necessary to understand the mechanism of soil liquefaction, where it occurs and why it occurs so often during earthquakes. Liquefaction of soil is a process by which sediments below water table temporarily lose shear strength and behave more as a viscous liquid than as a solid. The water in the soil voids exerts pressure upon the soil particles. If the pressure is low enough, the soil stays stable. However, once the water pressure exceeds a certain level, it forces the soil particles to move relative to each other, thus causing the strength of the soil to decrease and failure of the soil. The shear resistance of cohesion less soil is mainly proportional to the inter granular pressure and the co-efficient of friction between solid particles.

The liquefaction phenomena that results from this process can be divided into two main groups e.g. flow liquefaction and cyclic mobility (Youd, T.L. and Perkins, 1978). Flow liquefaction can occur when the static shear stress is greater than the shear strength of the soil in its liquefied state. The deformations produced by flow liquefaction are induced by static shear stress. It occurs less frequently than cyclic mobility but can cause more severe damage. Cyclic mobility occurs when the static shear stress is less than the shear strength of the liquefied soil. It can occur in broad range of soils and site conditions. Various laboratory and field methods have been developed to assess soil resistance to liquefaction.

The information regarding geomorphology, soil properties and its origin, water table depth, past seismic history is very essential in the liquefaction assessment of an area. Generally, the liquefaction process is associated with recent Holocene deposits and un compacted fills. However, there have been a few observed cases of liquefaction of Pleistocene and even pre-Pleistocene deposits.

LIQUEFACTION HAZARD ASSESSMENT

The first step in liquefaction hazard assessment is the evaluation of liquefaction susceptibility. Liquefaction susceptibility was first coined by Youd and Perkins (1978) as a measure of inherent resistance of soil to liquefaction, and can range from not susceptible, to highly susceptible. Susceptibility can be estimated by comparing the properties of a given deposit to other soil deposits where liquefaction has been observed in the past. The primary relevant soil properties include grain size, fines content (i.e., amount of silt and/or clay), density, degree of saturation, and age of the deposit. In order to assess the preliminary liquefaction potential assessment of soil deposits over a large area in a seismically active region, the following procedure outlined in Fig. 1 can be used. Liquefaction susceptibility maps are the most basic level of liquefaction hazard mapping.


Clay, Silt, Loam, Organic Soil, Gravel and others
Existence of liquefiable soils Within 15m below ground surface
Sand Silt, Silty Sand, Clayey Sand
Liquefiable soil lies above water table
Water Table depth
Liquefiable soil lies below water table
Thickness >3m
Thickness of the soil layer
Thickness < 3m
Outside liquefiable zone
Grain size distribution for liquefiable soils
Within liquefiable zone
N Value > 30
Liquefiable
Not Liquefiable

$$FA(M_0, f, R) = C \cdot S(M_0, f) \cdot G(R) \cdot D(R, f) \cdot A(f) \cdot P(f) \cdot I(f) \quad (1)$$

where,

.

.

Table 1. Regional parameter in Southeast of China

$\Delta\sigma$ (bars)	β_s (km/s)	ρ_s (g/cm^3)	Q
150	3.5	2.8	$200f^{0.2}$

.

.

Fig. 1. Comparison of the attenuation curves of horizontal PGA on bedrock

.

.

CONCLUSIONS

The strong ground motion attenuation estimation approach developed by the authors is realized by taking Southeast of China as an example. Regional source and crustal medium parameters are selected, and the source spectrum function and regional attenuation function form are determined.

.

.

ACKNOWLEDGES

This work was funded by National Key Project of Scientific and Technical Supporting Programs from the Ministry of Science & Technology of China under Contract No.2006BAC13B02, and National Nature Science Foundation of China under Contract No. 50538030.

REFERENCES

Atkinson, G.M. and Mereu, R.F. (1992), "The shape of ground motion attenuation curves in Sourtheastern Canada". *Bulletin of the Seismological Society of America*, Vol. **82**(5), 2014-2031.

Brune, J. N. (1971), "Correction". *Journal of Geophysical Research*, Vol. **76**(20), 5002.

Hanks, T. C. and Wyss, M. (1972), "The use of body-wave spectra in the determination of seismic-source parameters". *Bulletin of the Seismological Society of America*, Vol. **62**(2), 561-589.

Hanks, T. C. (1979), "b values and $\omega^{-\gamma}$ seismic source models: implications for tectonic stress variations along active crustal fault zones and the estimation of high-frequency strong ground motion". *Journal of Geophysical Research*, Vol. **84**(B5), 2235-2242.

Hanks, T. C. (1982), "fmax". *Bulletin of the Seismological Society of America*, Vol. **71**(5), 1867-1879.

Jin. Y.F., Fu, H., Qin, J.Z. et al. (2002), "Source parameters of moderate-strong earthquake sequence in 2001 in Yunnan". *Journal of Seismological Research*, Vol. 25, 116-123.

Liu, C. (2005), "Attenuation of strong ground motion from random vibration method", *Master Dissertation*, Harbin Institute of Technology, Harbin, China.

Tao, Z.R., Tao, X.X. and Liu, C. (2008), "Strong ground motion attenuation estimation from random vibration method". *Proc. of International Conference on Earthquake Engineering and Disaster Mitigation*, Indonesia.

The Institute of Crustal Dynamics. (2001), *The depth distribution of Moho-surface in China and around area*, Earthquake Press, Beijing.

Tian, Q.W., Liao, Z.P. and Sun, P.S. (1986), "Estimation of ground motion attenuation in China based on intensity data". *Earthquake Engineering and Engineering Vibration*, Vol. **6**(1), 21-35.

Wang, G.X. (2001), "Strong ground motion attenuation", *Doctor Thesis*, Institute of Engineering Mechanics, Harbin, China.