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Liquefaction Behavior of Typical River Channel Deposit in Kolkata City

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ABSTRACT

Liquefaction susceptibility of river channel deposit in Kolkata city is studied using laboratory cyclic triaxial tests. River channel deposit, which supports a large part of rapidly growing urbanization of Kolkata city, mainly consists of sandy soil with little amount of silt. Cyclic triaxial tests have been performed on this soil sample with varying relative density, confining pressure, and cyclic strain amplitude. Results are presented to show how these parameters influence the pore water pressure generation within soil. Relative density, confining pressure and cyclic strain amplitude are found to affect the pore pressure generation characteristics in the soil, and the number of cycles required to reach liquefaction phenomena vary significantly. Finally, pore pressure generation characteristics are modeled using a hyperbolic model and a pore pressure generation equation is proposed for the typical river channel deposit soil. The model exhibits a certain threshold value of cyclic strain amplitude, up to which the initial rate of pore pressure generation decreases and then increases.

KEYWORDS

Confining Pressure, Cyclic Triaxial Tests, Liquefaction, Pore water pressure, River Channel Deposit, Sands

1. INTRODUCTION

Liquefaction is an exciting topic and active area of research in geotechnical earthquake engineering, although it is quite complex phenomena to be fully understood. The topic initially gained attention following the widespread damage due to liquefaction as a result of Alaska (1964) and Niigata earthquakes (Fukuoka, 1966; Seed, 1968). During liquefaction, soil experiences an increased deformation due to the reduction in effective confining stress when there is a build-up of high excess pore water pressure. Liquefaction generally occurs only in saturated clean sand. Fine grained soils do not generally liquefy (Krammer, 1996). Cohesionless soil deposit sometimes contains significant fine contents and some field observations also exhibit the liquefaction occurrence in sandy-silt/silty-sand type of soils after earthquake event (Ishihara et al., 1980; Boulanger et al., 1999; Orense et al., 2011; Cox et al., 2013). Since then, the study on the liquefaction characteristics of sandy-silt/ silty-sand type of soils has received much attention.

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Several methods of liquefaction potential evaluation are available and these methods mainly utilize different geotechnical data from field tests (Seed and Idriss, 1971; Youd et al., 2001; Idriss and Boulanger, 2006). In-situ shear wave velocity serves an alternative to penetration test in the liquefaction susceptibility evaluation (Andrus and Stokoe, 2000; Youd et al., 2001; Andrus et al., 2004). In order to study the liquefaction susceptibility of soil under controlled conditions in the laboratory, cyclic triaxial apparatus is used worldwide. It can be used to study the influence of different parameters on liquefaction susceptibility (Chien et al., 2000; Arab et al., 2002; Xenaki V.C. and Athanasopoulos G.A, 2003; Ravishankar et al. 2005; Paul et al., 2007; Stamatopoulos, 2010; Kumar et al., 2014; Kumar et al., 2020). Effect of presence of different percentage of silt content in sandy soils has also been studied by several researchers in laboratory using cyclic triaxial (Polito and Martin, 2001; Xenaki and Athanasopoulos, 2003; Stamatopoulos, 2010; Karim and Alam, 2014; Wei and Yang, 2019). Uniform clean sand deposits are quite hard to find as very often this deposit exists with certain percentage of silt content. Now as the behavior of a soil deposit under cyclic loading may significantly vary for different types of soil deposit depending on the nature, so, each of them needs to be characterized for cyclic loading in the laboratory under controlled condition.

In this study, an effort has been given to study the liquefaction characteristics of typical RCD in Kolkata city. The Kolkata city is extended up to an area of ~ 185 sq.km and the population as per the Census of India, 2011 is about 4.5 million. More than 80% of the city area is covered and congested with buildings, business areas, hospitals, and schools. Most of the constructions of the city is without any proper planning and quite old (Nandy 2007). With the expansion of urban habitation, it is now extremely important to study the liquefaction characteristics of a soil prior to any construction over it. The alluvial Gangetic deposit mainly forms the subsoil of Kolkata city. In the city, two different types of subsurface stratifications are observed: normal Kolkata deposit (NKD) and RCD. In NKD, a thick layer of silty clay/ clayey silt up to a depth of ~14m and after that a deposit of stiff/very stiff/ hard/very hard clay to a depth of 40-50m with intermediate sand layers is observed. On the other hand, along the course of Adiganga channel The RCD is observed. In this stratification, medium to dense sandy deposit is obtained up to a significant depth (Roy and Sahu, 2012).

Few studies have been carried out on the liquefaction behavior of Gangetic sand. Nilay and Chakrabortty (2018) studied the liquefaction behavior of Ganga River sand with the influence of non-plastic silt. The study concludes that with 10% silt content the rate of excess pore water pressure generation decreased initially, after that increased significantly with 30% silt content and then reduced for 100% silt content. Das and Chakrabortty (2021) conducted strain controlled cyclic triaxial tests on cohesionless soil collected from middle Ganga plain to study the influence of effective confining stress, shear strain amplitude and frequency of motion. The study concludes that the cyclic shear strain amplitude significantly affects the dynamic properties and liquefaction strength, whereas, effective confining stress and frequency of motion have minor influence at large strain. Naik et al. (2021) studied the efficacy of biochar in liquefaction mitigation of Ganga sand. The results pointed out the 30 to 50% increase in loading cycles for soils treated with biochar in comparison with clean Ganga sand. Das and Chakrabortty (2022) presented a study to model the large strain cyclic behavior of cohesionless soil from MGP using regression, statistical and neural network methods. The authors find neural network to be more precise in predicting cyclic behavior of soil. Sharika and Kumari (2023) also studied the liquefaction behavior of Ganga sand. The study reveals that the state of soil and effective confining stress are the major contributing factor in the liquefaction susceptibility.

The liquefaction potential at different locations of Kolkata city is studied by Chakraborty et al. (2004) using Artificial Neural Network (ANN) for different PGA levels, concludes that the RCDs are the most vulnerable to liquefaction. Now the need of a controlled laboratory study to analyze the cyclic behavior of Kolkata-RCD is essential in order to understand the soil behavior in case of an occurrence of actual future earthquake event. Soil sample which typically represents the RCD is collected from Industrial Training Institute (ITI) compound, Tollygunge, Kolkata. Now, the liquefaction characteristics of this typical RCD has been studied using controlled laboratory cyclic triaxial tests. An effort has

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